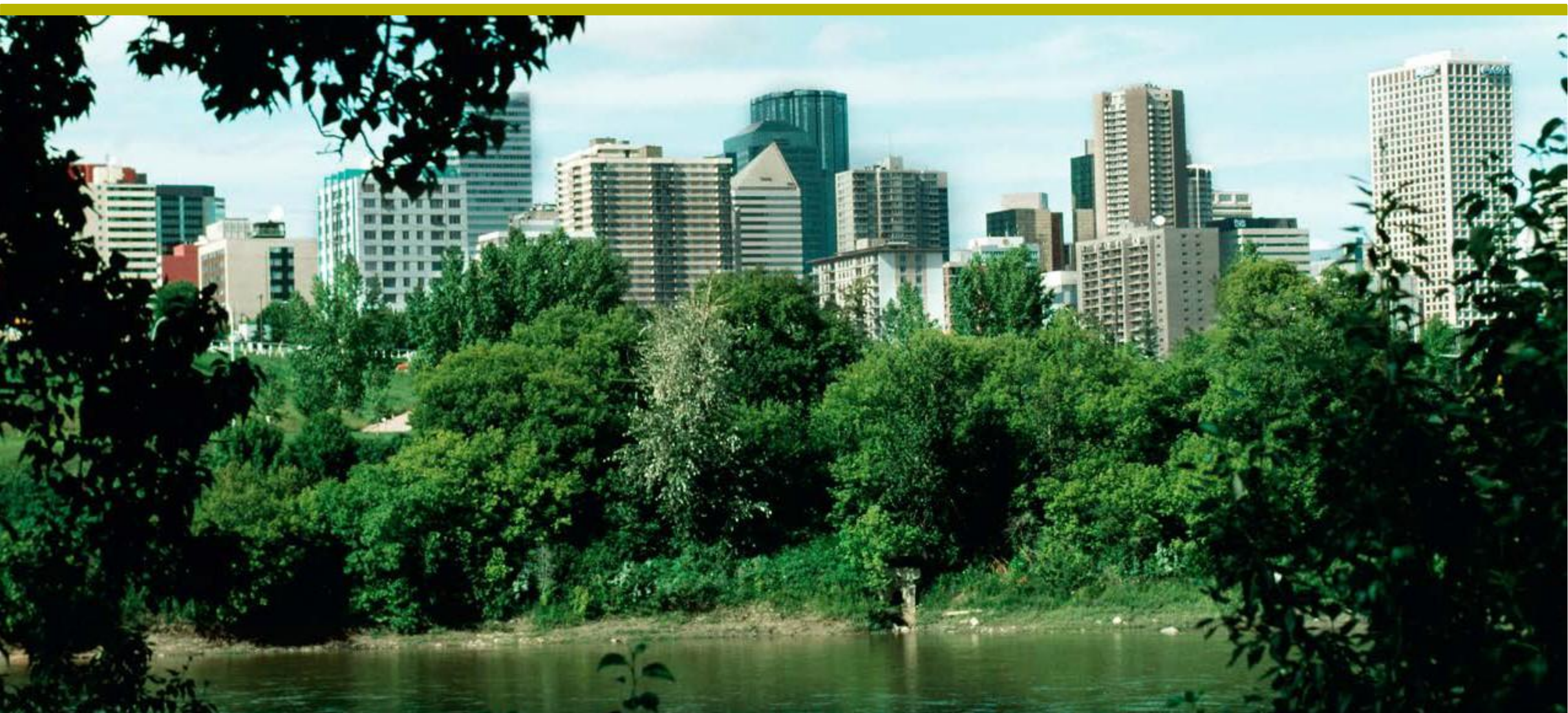
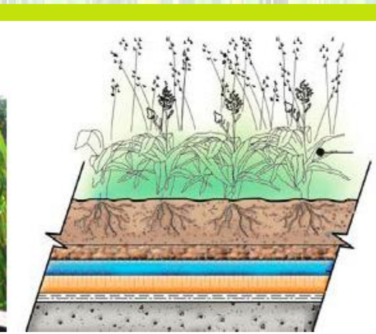
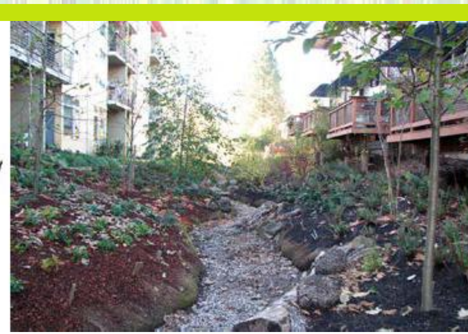


Low Impact Development Best Management Practices Design Guide

April 2025


PREFACE

This document – the *Low Impact Development - Best Management Practices Design Guide* (Design Guide) - was developed for the City of Edmonton (City) to provide guidance for the application of Low Impact Development Best Management Practices (LID-BMPs). It provides an overview of LID-BMPs and design guidelines that planners, engineers, developers, and designers can use to integrate LID-BMPs into land development, redevelopment, or retrofit projects. Development of the Design Guide supports the City's vision of sustainable growth and forwards the environmental goals laid out in The Way We Green, the City's environmental strategic plan. The Design Guide has been updated to reflect EPCOR's strategic direction, stormwater integrated resource plan, and changes to the LID design standards. The LID design standards are in the City of Edmonton Design and Construction (D&C) Standards Volume 3-02, Section 5.0 LID Facility Design. For further details, please reach out to LIDoutreach@epcor.com.

The Design Guide consists of multiple chapters about LID best management practices. As LID is an evolving field, this Design Guide is a living document and will be updated through continuing engineering experience and research studies in the City's local context. This Design Guide is not a design standard but rather provides high-level information about LID-BMPs to assist those interested in LID oriented development. Each site considered for development is unique. Consequently, the design of the LID-BMP facilities will also be unique and must be based on sound engineering principles that account for the soils, vegetation, topography, hydrology, and management requirements for the site. Qualified professionals should be consulted for advice specific to each development. In addition, the relevant requirements for stormwater management as set out in City drainage bylaws, the City of Edmonton's D&C Standards Volume 3 Drainage and other pertinent legislation remain applicable to LID. It is strongly recommended that discussions with applicable City of Edmonton departments be started early in the process to facilitate the design and approvals process and ensure mutual understanding of the development objectives and methodology.

The original document was drafted in June 2011 by AMEC Earth & Environmental with assistance from Armin A. Preiksaitis & Associates Ltd. and Progressive Engineering Ltd. Comments.

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TABLE OF MEASUREMENTS AND TECHNICAL ABBREVIATIONS

Abbreviation	Definition
cm	centimetre
g	gram
hr	hour
L	litre
m	metre
mg	milligram
mm	millimetre
Q_2	Edmonton's 2-year precipitation event (95% of storms)
Q_5	Edmonton's 5-year precipitation event
Q_{10}	Edmonton's 10-year precipitation event
Q_{25}	Edmonton's 25-year precipitation event
Q_{100}	Edmonton's 100-year precipitation event
WSE	water surface elevation

1.0 INTRODUCTION

***Stormwater** – water that runs off land and developed surfaces during a rainfall or snowmelt event.*

***Impervious area** – areas covered with surface material that prevents water from passing through or penetrating to the sub-soils.*

***Urban heat island** – an area, such as a city or industrial site, having consistently higher temperatures than surrounding areas because of a greater retention of heat, as by buildings, concrete, and asphalt.*

***Storm sewers** –* concrete or PVC pipes, buried below the frost line, designed to convey stormwater runoff from the surface to the receiving waterbody or an end-of-pipe facility such as a stormwater pond.

1.1 STORMWATER MANAGEMENT PRACTICES

1.1.1 IMPACT OF URBANIZATION

Increased land development alters the natural water cycle hydrology. As the City of Edmonton grows and more land is developed both within the city and in surrounding areas, hydrologic functions of the natural water cycle are altered. Urbanization creates impervious areas that negatively impact stormwater runoff characteristics. These changes to the natural hydrologic cycle result in:

- Potential for sanitary sewer releases to the environment through CSOs.
- Increased flooding;
- Decreased groundwater recharge;
- Decreased evaporation from soil to the atmosphere;
- Decreased transpiration from plants to the atmosphere; and
- Increased urban heat island effects.

1.1.2 CONVENTIONAL STORMWATER MANAGEMENT

Conventional stormwater management practices in Edmonton and other urban centers direct runoff from pervious and impervious areas either directly to the receiving water body or to stormwater ponds via storm sewers; or to the wastewater treatment plant via combined sewers. During extreme events, combined sewerage may overflow to natural water courses through combined sewer overflows (CSOs).

Stormwater ponds are used to reduce peak flows in the downstream system, thus reducing flows to the combined system and outfalls to natural water courses. Runoff reaching surface water bodies through the storm sewer system directly are characterized by increased volumes, durations and flow rates, especially during small storm events. Inputs to the receiving surface water body eventually result in:

- Erosion and sedimentation in receiving waters due to increased sediment loading and flow rates during small storm events;
- Water quality degradation due to increased sediment and pollutant loadings;
- Stream channel degradation due to erosion and sedimentation;
- Alterations to water temperature patterns within receiving waters due to the input of warmer runoff water;
- Degradation of quality of fish habitat due to erosion and sedimentation;
- Loss of recreation opportunities due to water quality degradation and bank erosion; and
- Potential for sanitary sewer releases to the environment through CSOs.

1.2 LOW IMPACT DEVELOPMENT

1.2.1 WHAT IS LID?

***Stormwater management facilities** – manage stormwater runoff to provide controlled release into receiving streams.*

***LID-BMP** – ecosystem-based approach to managing and treating stormwater runoff.*

The U.S. Environmental Protection Agency (USEPA) defines low impact development (LID) as *"an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible"* (US EPA, 2023). This approach focuses on maintaining or restoring the natural hydrological processes of a site, providing opportunities for natural processes to take place. Key principles in LID include:

- Preserving natural site features;
- Small scale, integrated stormwater management controls dispersed throughout the site;
- Minimizing and disconnecting impervious areas;
- Controlling stormwater as close to its source as possible;
- Prolonging stormwater runoff flow paths and times; and
- Creating multi-functional landscapes.

LID best management practices (BMPs) are techniques that rely on natural processes to manage water quantity and quality, including:

***Infiltration** – process by which water penetrates into soil from the surface or upper soil layers.*

***Interception** – the process of storing water above the ground surface, mostly in vegetation.*

- Absorption;
- Infiltration;
- Evaporation;
- Transpiration;
- Interception;
- Filtration through standing plant material and soil layers;
- Potential pollutant uptake by select vegetation; and
- Biodegradation of pollutants by soil microbial communities.

***Transpiration** – the process of absorption of water by plants, usually through the roots, the movement of water through the plants, and the release of water vapour through small openings on the underside of leaves.*

LID-BMPs promote maintenance of the hydrologic cycle, shown for a natural environment in **Figure 1.1**, where rainwater is able to provide soil moisture for plants, infiltrate to recharge groundwater aquifers, and allow for evaporation and transpiration of water back into the atmosphere. The properties of natural materials such as soil, gravel, vegetation and mulch reduce the volume and peak flow rate of runoff and enhance the quality of stormwater entering receiving water bodies. As a landscape develops, many of the functions of the hydrologic cycle shown in **Figure 1.1** are impaired. LID-BMPs seek to restore these natural processes to the urbanized landscape.

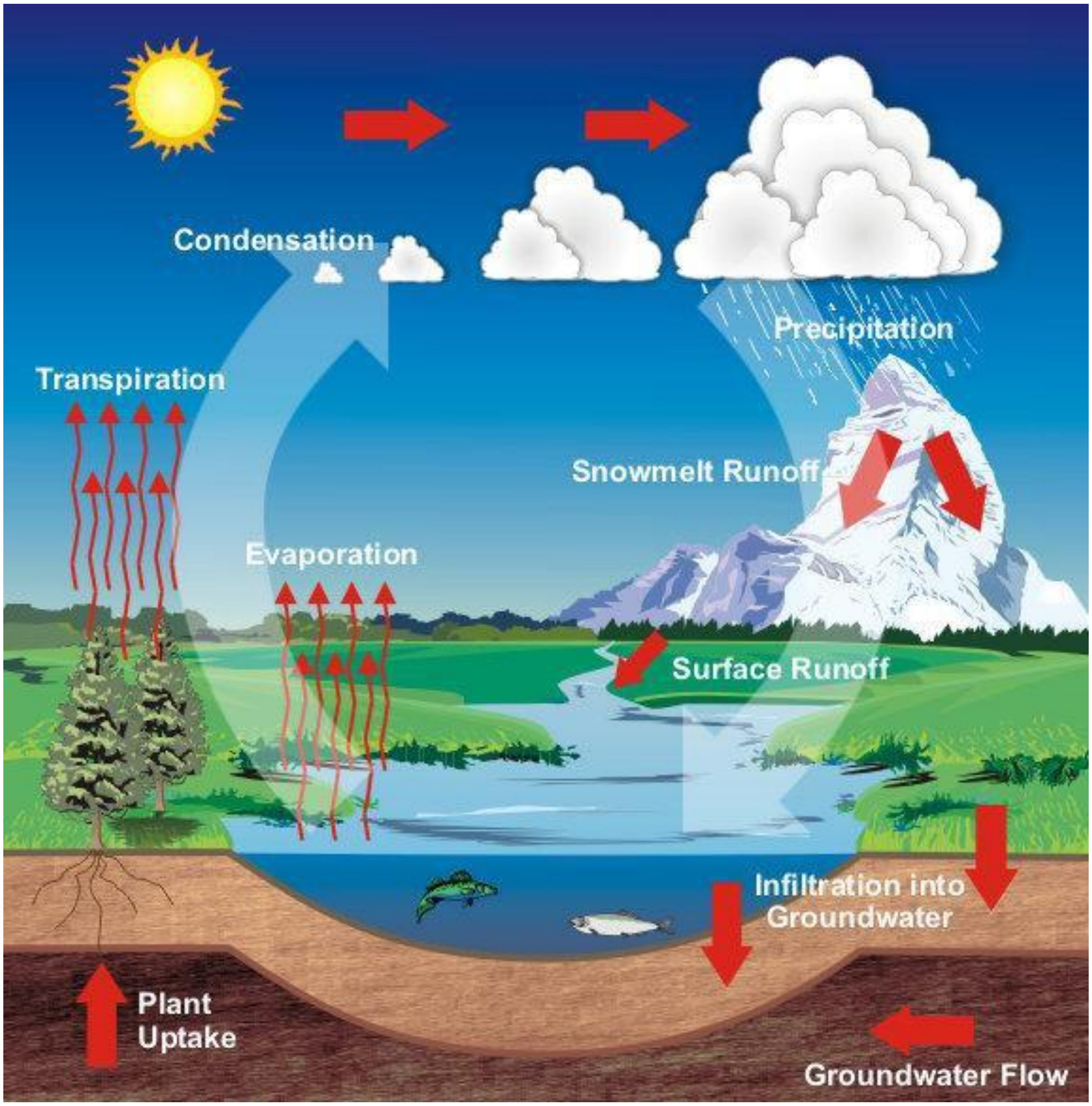


Figure 1.1: The natural hydrologic cycle

(www.solcomhouse.com/images/hydrowealth.jpg)

1.2.2 BENEFITS OF LID-BMP BASED DEVELOPMENT

There are three primary stormwater management objectives that typically drive LID-BMP applications:

- Stormwater volume control;
- Stormwater peak flow control; and
- Stormwater quality enhancement.

LID-BMP facilities often address all three of these stormwater management objectives at some level. Facilities may also be designed to work in series within a development to meet the regulatory requirements driving these objectives.

Applications of LID-BMPs provide many benefits to stormwater management, the environment and communities. Some of these benefits can be assigned monetary value while others are more intangible environmental or social benefits. These benefits are further discussed in **Section 4.4**.

1.3 LID-BMP DESIGN CONSIDERATIONS

Greywater *– untreated used domestic water that does not include sewage (e.g. laundry, dishwashing, bath waters).*

The application of LID-BMPs involves the use of existing natural systems, where feasible, and practical engineered systems that use natural materials. These systems are selected based on the individual requirements and design of the development or site. Application ranges from lot level to regional level, and facilities are often combined to meet the requirements of the site. Unique characteristics (site location, climate, vegetation, regulations) may affect the performance of LID-BMP facilities and must be accounted for in the design. These design considerations include:

- Tight soils;
- Frost depth;
- Local precipitation and hydrology;
- Suitability of vegetation to precipitation characteristics;
- Winter maintenance materials including sand, gravel and salt;
- Maintenance responsibilities and commitments;
- Regulatory conflicts or resistance;
- Regulation gaps (e.g. greywater re-use code); and
- Objectives or drivers for implementation.

Some sites may have unique challenges or constraints to the application of LID-BMPs that must be addressed by a qualified engineer/designer on a case-by-case basis. There is no universal prescriptive guide for LID-BMPs that applies to all sites. One unique challenge facing designers of LID-BMP facilities in the Edmonton area relates to cold climate considerations. These considerations are discussed in **Chapter 6**.

1.4 REGULATORY INVOLVEMENT AND APPROVALS

Regulations at all levels of government (federal, provincial and municipal) may have an impact on the implementation of LID-BMPs for stormwater management. Coordination between different parties at EPCOR EWS and the City may be required depending on the scope of the LID work. LID design and construction standards are located in the City of Edmonton's D&C Standards Volume 3-02, Section 5.0.

2.0 LOCAL CHARACTERISTICS

Since LID-BMPs are site specific, a full understanding of the characteristics of the local environment, such as climate, hydrology, soil and vegetation conditions, is instrumental in LID-BMP planning, design, construction and maintenance.

2.1 PHYSICAL AND CLIMATIC CONDITIONS

Edmonton is located in the Alberta Capital Region, at a latitude and longitude of 53°34′0″N, 113°31′0″W, respectively. The average elevation of the city is 686 metres above sea level.

Edmonton is in a semi-arid, continental climate region. The average maximum temperature is 24°C (July) and average minimum temperature is -15°C (January). There are about 140 frost free days in Edmonton, or a growing season of 138 days. **Table 2.1** shows climate data for the Edmonton region.

Ecologically, the City of Edmonton lies within the Central Parkland Natural Sub-region of Alberta (**Figure 2.1**), with prairie to the south and boreal forest to the north. Based on the fertility of the sub-region's soil, the area is dominated by cultivated land with only 5% native vegetation, primarily aspen and prairie mosaics, and 10% wetland (Natural Regions Committee, 2006). The soil survey of the Edmonton region (Alberta Soil Survey, 1962) is the main source of information regarding native soil types within the City of Edmonton (**Figure 2.2**). However, Edmonton city limits have grown nearly five times in aerial extent from 1959 to 2010, indicating that the majority of native soils in the area have been disturbed.

Bedrock underlying the City of Edmonton includes part of the Upper Cretaceous Wapiti Formation (Andriashek, 1988). This formation is composed of bentonitic sandstones, sandy shales, bentonitic clays, and coal seams. Within most of the area of the City of Edmonton, this is directly overlain by clay and silty clay deposits of Glacial Lake Edmonton. Quaternary sands, stratified deposits of the Empress Formation, and glacial till occur between the Wapiti Formation and the glacial clays in some places. Till of variable thickness makes up the surficial deposit in parts of east Edmonton.

Table 2.2 details some of the characteristics of soils native to the Edmonton region.

Table 2.1: Edmonton climate statistics

Climate parameter	Value
Average Annual Mean Temperature[1]	4.2 ºC
Average Daily Temperature, January[1]	-10.3 ºC
Average Daily Temperature, July	18.1 ºC
Frost Free Days[1]	141
Typical Frost Depth[2]	2.4 m
Average Annual Snowfall[1]	123.9 cm
Average Annual Precipitation[1]	422.5 mm

[1] Canadian Climate Normals 1991-2020, Edmonton (City) (Environment Canada, 2023)

[2] Edmonton Experience with Bottom Ask and Other Insulating Materials for Migration of Frost Have Induced Damage in Pavements (2011)

Table 2.2: Soil characteristics for the Edmonton region

Soil characteristics	
Map symbol	Mo.SiL; Mo.SiCL.
Water storage	> 12 cm of water per 30 cm of soil (High).
Topsoil (A horizon)	10 mm to 100 mm/hr saturated hydraulic conductivity (Medium).
Subsoil (B horizon)	3 mm to 10 mm/hr saturated hydraulic conductivity (Low to Medium).
Underlying soil (C horizon)	≤3 mm/hr saturated hydraulic conductivity (Low).
Topsoil thickness (cm)	Organic enriched topsoil horizon; commonly 15-25 cm, can be up to 50 cm or more in places; slightly acidic.
Natural drainage	Water is removed from the soil readily (Well).
Organic matter in topsoil	> 7% organic matter (High).
Salinity of subsoil	< 2% soluble salt (Low). > 8% soluble salt (Medium).
Stoniness	Relatively no stones.
Topography	Relatively level; very little non-arable land.

(Alberta Soil Information Centre, 2001).

2.2 HYDROLOGY

2.2.1 PRECIPITATION

***Precipitation** – any form of water that falls from the clouds including rain, snow, hail, sleet or mist.*

Average annual precipitation measured for Edmonton is 423 mm (1991 – 2020), of which 329 mm are rainfall and 124 mm are melt from snowfall (123.9 cm). On average, there are 133 days annually in which greater than 0.2 mm of precipitation (rain, sleet, snow or hail) occurs. The driest months are February and December, when on average 11.8 mm of precipitation occurs. The wettest month is July, with an average rainfall of 78.2 mm. **Table 2.3** shows monthly average precipitation as measured at Environment Canada's Edmonton City Centre Airport station.

2.2.2 EVAPORATION

***Evaporation** – process by which liquid water converts to water vapour by energy from heat or air movement.*

The average annual lake evaporation (the water that evaporates from water bodies) is 665 mm in Edmonton (Alberta Environment, 2010). 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.

Table 2.3: Monthly average maximum and minimum temperature and precipitation (1991-2020) for City of Edmonton region

Month	Maximum Daily Mean (ºC)	Minimum Daily Mean (ºC)	Precipitation (mm)
January	7.3	-34.4	19.6
February	8.7	-30.1	11.8
March	13.8	-29.0	16.8
April	17.8	-15.1	28.6
May	23.4	-2.1	44.2
June	26.8	6.0	69.9
July	26.7	7.4	82.7
August	25.9	4.1	60.7
September	23.0	-0.2	38.5
October	18.2	-15.0	20.5
November	11.5	-26.1	17.5
December	9.2	-33.1	11.8
Yearly Total			**422.5**

Canadian Climate Normals 1991-2020, Edmonton (City) (Environment Canada, 2023)

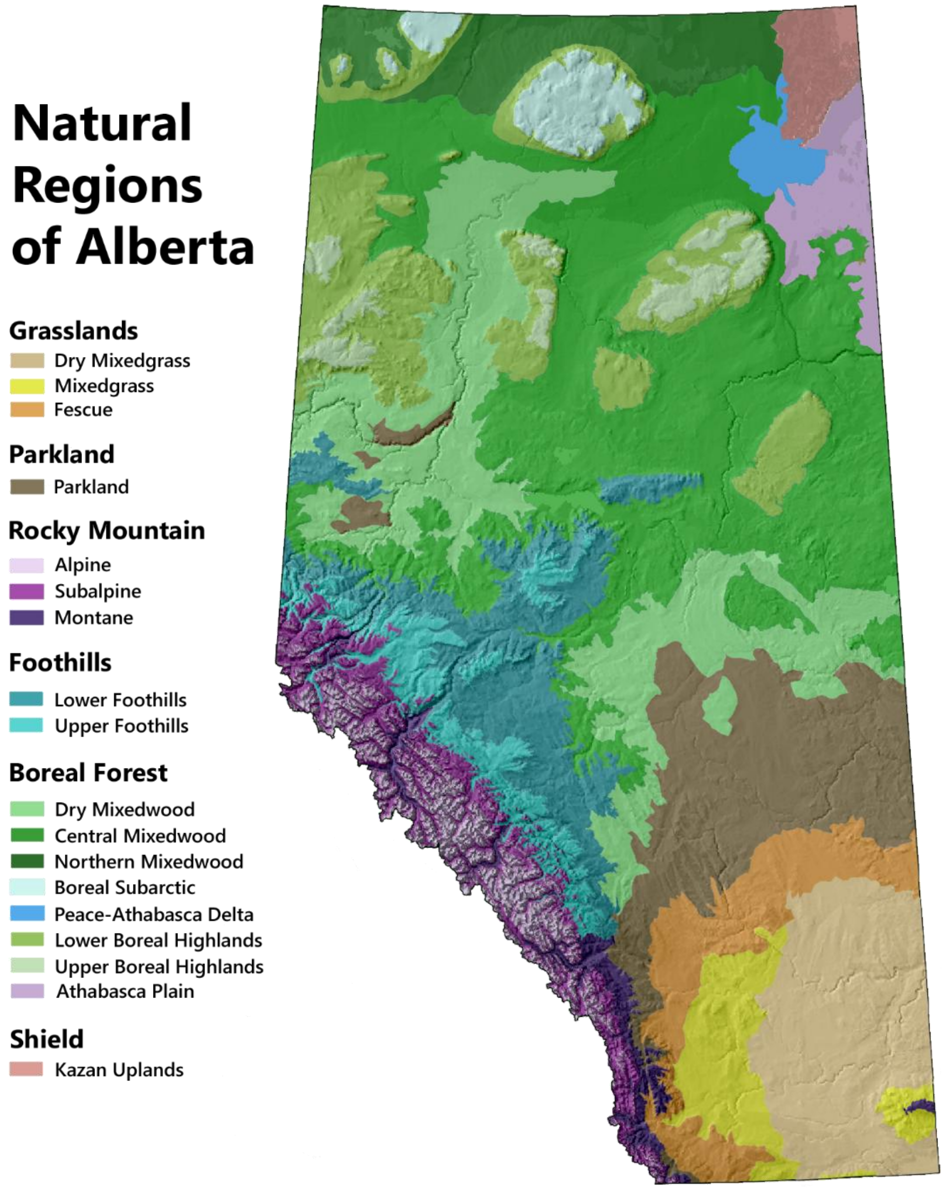


Figure 2.1: Natural regions and sub-regions of Alberta

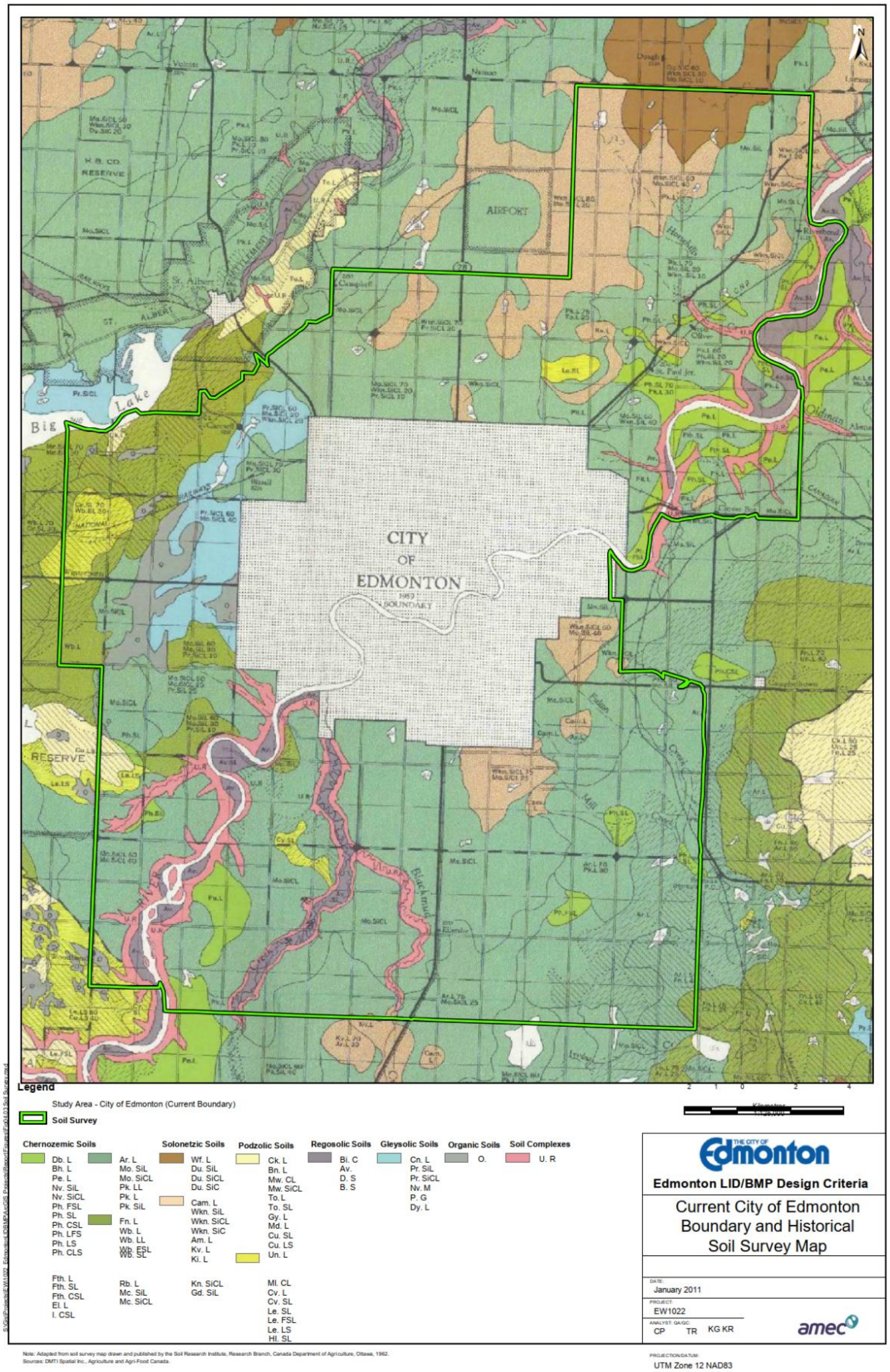


Figure 2.2: Historical soil survey map

3.0 LID SITE PLANNING AND DESIGN

Implementing LID allows Edmonton to manage runoff close to the source which builds capacity in the existing storm system, reduces peak flows during large events and builds green infrastructure. All of this supports infill and flood and climate change mitigation allowing Edmonton to move forward as a leader in sustainable city building. As part of supporting this shift LID is seen as an integral piece in the puzzle of greening and supporting resilience in Edmonton.

The benefits of LID are described in the following sections:

1.2.2 – Benefits of LID-BMP Based Development

4.3 – Performance of LID-BMPs

4.4.1 – LID Benefits

6.4 – LID Facility Design Process

Greenfield *– land that has not been previously developed.*

Brownfield *– abandoned or underused commercial or industrial land available for re-development.*

The focus of this chapter is primarily on larger site greenfield and brownfield development. However, LID retrofit opportunities at the lot level are abundant and may provide solutions for stormwater management, flooding and erosion issues in established communities. Strategic inclusion of LID at the site and neighbourhood scale, seeks to:

- Minimize land and vegetation disturbance;
- Capitalize on the natural hydrology of the site when locating roads, buildings and drainage features;
- Reduce the impacts of development by minimizing soil compaction and impervious area;
- Reduce or prevent stormwater runoff during small storm events;
- Reduce Urban Heat Island effects in localized areas;
- Provide treatment for stormwater runoff as close to the source as possible;
- Incorporate multi-purpose landscapes that treat water as a resource rather than a nuisance; and
- Integrate LID with other elements of the public and private realm to realize multiple goals, such as place making or traffic calming, in the same space.

3.1 LID DEVELOPMENT DESIGN

In addition to the standard development design process, a site that intends to include LID should try to achieve the following outcomes:

Table 3.1: LID development design

Outcomes	Design approaches
Include LID at every step of the development process from planning through to construction and maintenance.	
Complete a holistic site assessment prior to site delineation	▪ Identify natural vegetation and soil preservation zones ▪ Delineate development areas based on soil and hydrologic features
Reduce runoff	▪ Minimize impervious areas ▪ Shrink road lengths and widths ▪ Shorten driveways ▪ Decrease hard landscaping ▪ Prioritize treed boulevards ▪ Include naturalized landscapes ▪ Include green roofs ▪ Where naturalized landscapes are not possible, consider the use of permeable pavements
Preserve natural hydrologic processes	▪ Connect natural drainage corridors throughout the site allowing for capture and conveyance and the complimentary benefits of wildlife movement and pedestrian connections to destinations ▪ Direct runoff toward natural depressions and wetlands
Preserve existing drainage paths	▪ Minimize site grading ▪ Convey runoff through bioswales instead of gutters ▪ Locate roadways to avoid significant changes to the site topography ▪ Locate new open spaces to retain existing drainage paths and natural landscapes
Integrate LID into other elements of the design	▪ Capture rainwater for re-use ▪ Include parking lot bioretention areas ▪ Add LID to curb extensions or central medians ▪ As applicable, use LID to grow healthy urban trees faster ▪ Leverage LID as a focal point, such as an entry feature or landmark

3.2 LID SITE DESIGN PROCESS / SEQUENCE

The LID site design process builds on the conventional site design process with key modifications to capitalize on natural characteristics of the site. The LID site design process seeks to minimize detrimental hydrological impacts of development (**Figure 3.1**) by reducing impervious surfaces and using soil, vegetation and topography to maintain the hydrologic cycle.

The LID site planner has an extensive tool kit at their disposal to mitigate negative impacts on receiving waters by managing volume, discharge frequency, peak flow rates and water quality. Beginning at the assessment stage, involvement of a multidisciplinary LID design team, including qualified and experienced professionals in landscape architecture, vegetation ecology, geotechnical engineering, soil science and water resources engineering, is recommended to ensure long term success of LID site designs.

The comparison of LID Neighbourhood planning with Conventional Neighbourhood planning is referenced throughout this section for illustrative purposes.

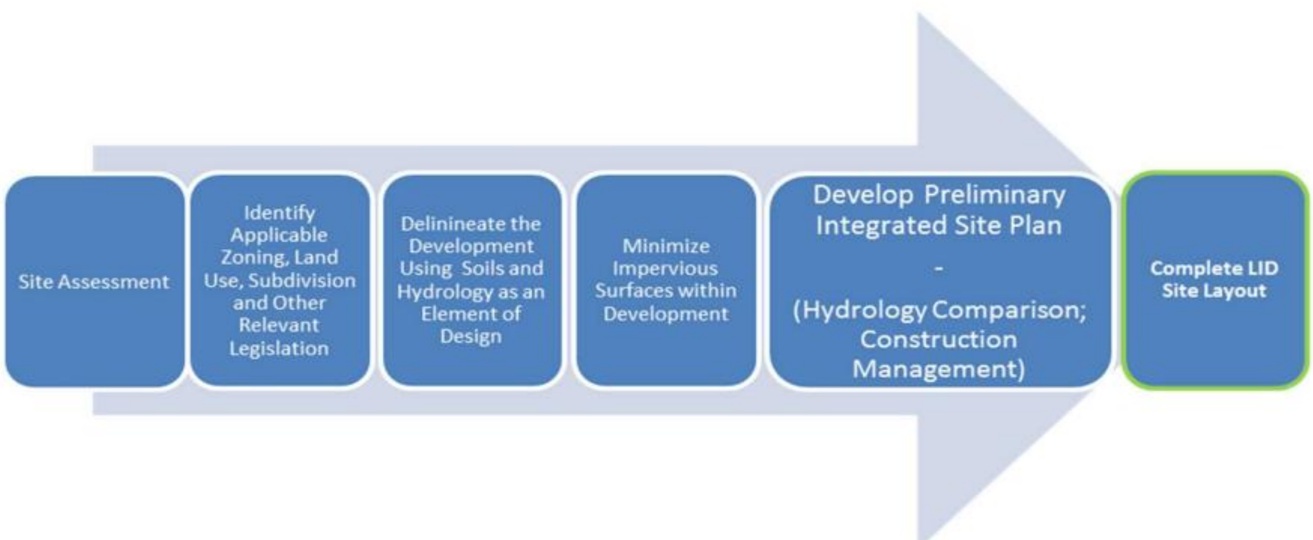


Figure 3.1: Steps to designing an LID site

3.2.1 SITE ASSESSMENT

A holistic approach can be taken for characterizing key aspects of the pre-development condition, including soils, geotechnical vegetation and hydrologic conditions. A thorough understanding of these aspects enables development of designs that work to preserve the natural hydrologic response of the developed watershed.

Site assessments provide the information needed to fully understand unique aspects of a potential development area. The City of Edmonton's D&C Standards can be consulted for more information.

3.2.1.1 SOILS AND GEOTECHNICAL ASSESSMENT

Soils and geotechnical assessments are recommended to determine pre-development soil and sub-surface conditions (PSAT, 2005). The following planning decisions are directly based on results of the soils and geotechnical assessment:

- Soil preservation zones in areas of more permeability;
- Suitable LID facility locations;
- Recommended soil amendments; and
- Required soil protection measures during construction.

Facility failures such as flooding, ponding and clogging can occur if infiltration-based LID facilities are located in tight soil zones caused by soil compaction or the presence of bedrock or clay sub-soils. High native soil permeability increases the potential for groundwater contamination in the presence of elevated pollutant concentrations. Slope stability may be compromised when infiltration-based LID facilities are located in an unsuitable area.

3.2.1.2 VEGETATION ASSESSMENT

A vegetation assessment is necessary to identify any areas requiring protection during the construction process (PSAT, 2005). These protected areas may be selected to:

__Riparian__ – related to or located on the banks of a natural water course.

- Maintain a contiguous riparian or wildlife corridor;
- Preserve rare plants;
- Maintain mature tree stands; or
- Maintain slope stability during construction.

The vegetation assessment may also provide a natural plant palate for the landscape designer.

3.2.2 HYDROLOGIC ASSESSMENT

Hydrology is a function of the vegetation, soils and topography of the site, as well as precipitation patterns. For many sites an assessment of precipitation and meteorological conditions of the site must be combined with a detailed survey to determine the hydrologic patterns of the site (**Figure 3.2**). Peak discharge rates from storm events depend on the hydrologic response of the site during precipitation events, and these rates are used to determine the impact of the site on the receiving stream or downstream stormwater management facilities. This assessment must be carried out by a qualified stormwater engineer.

3.2.3 IDENTIFICATION OF APPLICABLE ZONING, LAND USE, SUBDIVISION AND OTHER RELEVANT LEGISLATION

In most cases, developable land is subject to a hierarchy of overarching policies to which appropriate land uses must conform through the subdivision of land. The corresponding Area Structure Plan (ASP), Area Redevelopment Plan (ARP), or Neighbourhood Structure Plan (NSP) is the linkage between zoning and high-level statutory documents. The ASP / ARP / NSP provide a conceptual layout of major city sectors by locating roads and other servicing corridors, open spaces and general land uses.

The level of detail provided in planning documents for LID implementation should be consistent to what is required for other drainage infrastructure, as detailed in the City of Edmonton's D&C Standards, as well as in their Terms of Reference for Plans and Amendments that can be accessed here.

Intent to implement LID in a development should be incorporated into these planning documents. Proposed locations and types of LID techniques should be displayed on land use and transportation maps and incorporated into the drainage plans. The ASP should also include discussion on proposed LID techniques as an application of sustainable development principles. The Edmonton Zoning Bylaw controls the use and development of all land in the City of Edmonton and provides an essential link between policies and subdivision and development control.

Area Master Plans (AMPs) develop and propose drainage solutions to achieve stormwater management goals for an area. At this stage in the planning process, the type and locations of LID facilities should be considered and included as part of the conceptual design of the proposed drainage scheme.

The Neighbourhood Design Report (NDR) defines the basis of detailed design of the principal components of the sanitary sewer and storm drainage infrastructure. At this stage the feasibility of the LID facilities proposed in the AMP should be analyzed. Land required for the facilities and operation and maintenance requirements should be provided for the LID facilities in the NDR.

Passive recreation *- emphasizes the open space aspect of a park and involves a low level of development, including picnic areas and trails.*

3.2.4 DELINEATION OF THE DEVELOPMENT

Development delineation and subdivision design is the result of a series of comprehensive considerations based on hydrology, topography, soil variability, land and legal encumbrances, surrounding land uses, environmental contamination and impacts, and servicing constraints. Involvement of a multi-disciplinary design team is critical at this stage to account for unique site challenges and constraints impacting the implementation of LID designs.

The first step in both conventional and LID development planning is to identify 'primary' and 'secondary' conservation areas. Primary conservation areas typically consist of non-developable lands adjacent to water bodies and water courses, wetlands and steep slopes as identified by analysis of the site's topography and/or environmental and geotechnical studies. Depending on the context of the site, secondary conservation areas may include less significant natural areas such as existing tree stands, historically and culturally significant sites, sites with exceptional views of surrounding land, and high-quality agricultural lands. Development is designed to avoid primary conservation areas and preserve secondary conservation areas wherever feasible.

Remaining land is referred to as the potential development area. Careful preservation of primary conservation areas and minimized development on secondary conservation areas often yields higher lot value. In accordance with the Municipal Government Act, 10% of developable land, which includes secondary conservation areas, must be dedicated to municipal reserve (MR). No development may take place on land deemed environmental reserve (ER). However, passive recreation uses are permitted.

During the LID planning process, the following additional considerations will help to delineate the development area to protect hydrological and ecological features, and allow for incorporation of LID facilities:

- Identify protected areas (riparian habitat, stream buffers and wetlands, among others), easements, setbacks, existing drainage, topographic features, and natural drainage features;
- Locate development in areas with lower infiltration potential such as barren clayey soils and preserve higher infiltration soils for LID facilities, where practical;
- Delineate the development envelope so that it respects natural features and conforms to existing site topography and hydrology;
- Utilize slopes to naturally direct flows to bioswales;
- Keep building footprints small to minimize grading and clearing of land;
- Avoid soil compaction and preserve natural vegetation where possible;
- Situate roadways in parallel with existing topographic ridges to avoid unnecessary soil disturbance;
- Where feasible, apply zoning consistent with LID design objectives. For example, replacing RF1 Zoning (6 metre minimum front yard setbacks)

with a combination of Residential Small Lot Zones (RSL) and Planned Lot Residential Zones (RPL) (5.5 metre and 4.5 metre front yard setbacks, respectively) will reduce site imperviousness by permitting shorter driveways and more lot green space; and

- Continue or initiate dialogue with appropriate City departments to ensure that expectations of both parties are understood and incorporated.

3.2.5 REDUCTION OF IMPERVIOUS SURFACES WITHIN THE DEVELOPMENT

Edmonton's Subdivision Control and Servicing Agreements dictate the level of flexibility a site planner has when designing a neighbourhood layout. Widths of roads, sidewalks, alleyways and driveways are often fixed to accommodate municipal servicing and emergency services response. The increase in the total impervious area causes an increase in total runoff volumes and peak runoff rates. The layout of the road network has a bearing on the total impervious area, **Figure 3.2** provides a schematic comparing the length of paved surface for various layouts. Many of the more recent conventional neighbourhood plans in Edmonton are characterized by a warped parallel layout.

LID sites use a variety of methods to minimize impervious areas. These strategies include the use of:

- Narrower road widths that reduce site imperviousness while decreasing requirements for clearing and grading;
- Flat curbs and roadside bioswales in place of traditional curb and gutter, resulting in a substantial reduction in construction costs;
- Single sidewalks limited to one side of primary roads (where it will not negatively affect the social objectives of the neighbourhood);
- One sided on-street parking;
- 'Green' laneways using pervious materials and surfaces;
- Minimized building footprints may be achieved by building taller, narrower dwellings rather than sprawling ranch style homes;
- Green roofs on multi-family and commercial sites to reduce urban heat island effects;
- Limited width shared driveways and two track driveways to reduce impervious area;
- Zoning changes to reduce the overall length of driveways, due to reduced lot setbacks; and
- Alternate street layouts designed to maximize the number of lots with the minimum amount of pavement as shown in **Figure 3.2.**

After minimizing impervious areas, portions of the remaining impervious area may be routed to vegetated areas throughout the neighbourhood to derive further hydrologic benefits. This can be accomplished in an LID context by:

- Disconnecting roof drains from weeping tile or storm sewers and routing flows to vegetated areas;
- Preventing compaction of pervious areas during construction;
- Fostering sheet flow through vegetated areas. Concentrated runoff can be converted to sheet flow by incorporating level spreader stormwater outlets; and
- Locating impervious areas to drain to LID facilities.

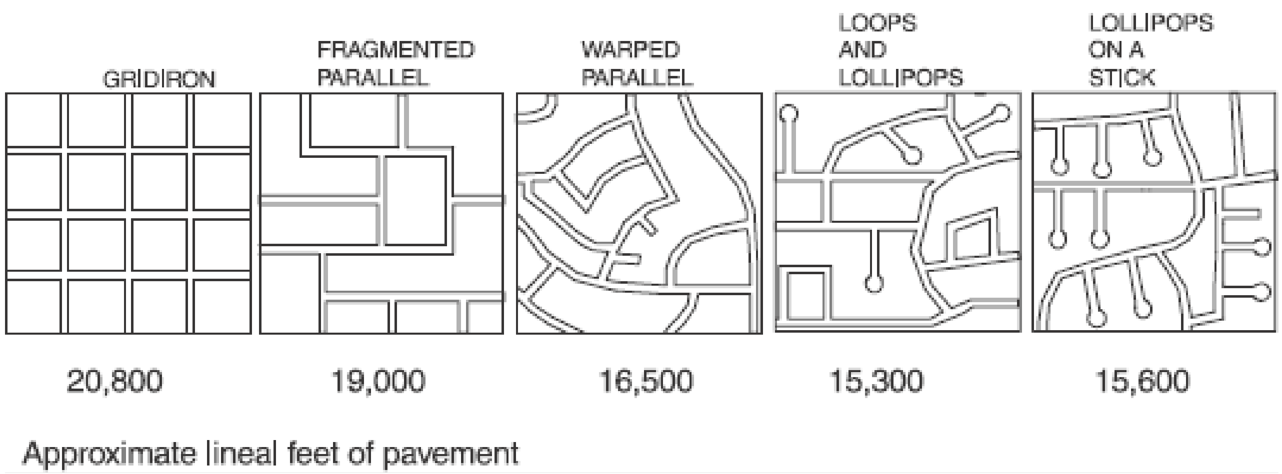


Figure 3.2: Street layout options according to pavement length

Table 3.2: Saturated hydraulic conductivity in relation to soil texture

Soil Texture	K_{sat} (mm/hr)
Coarse sand	>423
Sand	152 - 508
Sandy loam	51 - 152
Very fine sandy loam	15 - 51
Clay loam	5 - 15
Sandy clay	2 - 5

(USDA, 2014)

4.0 LID BMP OVERVIEW

4.1 LID BMP FACILITY FEATURES AND DESCRIPTION

LID Best Management Practices are intended for managing stormwater near or at its source in addition to efficiently conveying and discharging excess stormwater into a receiving water body. All LID BMP's follow the same principle of "*slowing it down, spreading it out, and soaking it in*" (EPA, 2011), aimed at encouraging the natural hydrological processes of absorption, infiltration, evaporation and evapotranspiration.

Through a literature review, LID-BMPs were assessed considering Edmonton's climate and physical characteristics. Six LID features were identified to be suitable for Edmonton's environment. The following LID BMPs are outlined below:

1) Rain gardens – ***Section 7.0***
2) Bioswales (bioretention) – ***Section 8.0***
3) Green roofs – ***Section 9.0***
4) Permeable pavement – ***Section 10.0***
5) Naturalized drainage ways – ***Section 11.0***
6) Rainwater harvesting for re-use – ***Section 12.0***

Five LID facilities were standardized; standards for bioretention gardens, bioretention basins (including bioswales), box planters, soil cells, and absorbent landscaping have been developed and are outlined in the City of Edmonton's D&C Standards Volume 3-02, Section 5.0.

4.1.1 RAIN GARDENS

Rain gardens are stormwater management and treatment facilities within a depression using vegetation and amended topsoil. The term "bioretention" and "rain garden" are often used interchangeably; however, this document specifies rain gardens as an LID without a storage layer or an underdrain, typically used on residential properties. They provide water quality treatment, reduce runoff, and allow for infiltration near where runoff originates, such as roofs, driveways and sidewalks.

Figure 4.1 shows examples of residential rain gardens installed in Edmonton.

Residential rain garden in Edmonton, AB.

Residential rain garden in Edmonton, AB.

Big Lake Trumpeter rain garden in Edmonton, AB.

Figure 4.1: Rain garden installations in Edmonton, Alberta

The fundamental differences between a rain garden and a conventional planting bed are that rain gardens use soils and vegetation to capture and treat rainwater typically at the low point of a landscape. Rainwater flows either naturally or through an inlet into the rain garden's concave surface. Rain gardens consist of two layers as shown in **Figure 4.2**.

Layer 1. Plantings and aged mulch

Layer 2. Amended topsoil

The City of Edmonton's D&C Standards Volume 3-02, Section 5.3, include bioretention gardens, which are similar to rain gardens, but include a storage layer.

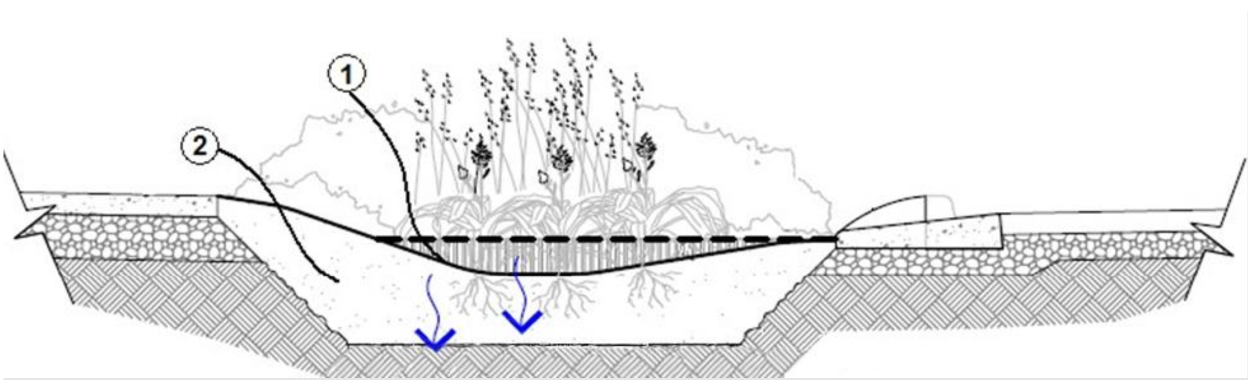


Figure 4.2: Layers of a rain garden

4.1.2 BIOSWALES (BIORETENTION)

In the City of Edmonton's D&C Standards Volume 3-02, Section 5.4, bioswales are standardized and included in as a subset of bioretention basins. Bioswales, also called vegetated swales, are swales with grass and other vegetation, enhanced topsoil, and an underlying infiltration layer (Claytor, 1996; TRCA, 2009; MDEP, 1997). They are designed to slow runoff velocities by increasing surface roughness. This results in increased surface contact time, allowing more infiltration, evaporation, transpiration and water quality enhancement prior to the runoff entering another stormwater management facility. Examples of bioswale applications are depicted in **Figure 4.3**.

The difference between bioswale and grass swale is grass swales have limited infiltration potential since they usually do not have an enhanced topsoil or infiltration underlayer, while layers of bioswale are similar to those of bioretention areas, as shown in **Figure 4.3**.

Allard Way, Edmonton, AB

Gateway Blvd (34 Ave), Edmonton, AB

Shamrock-Donan Park, Edmonton, AB

Figure 4.3: Local installation of bioswales

4.1.3 GREEN ROOFS

Green roofs consist of live vegetation established on top of buildings. There are two types of green roofs: extensive and intensive (see **Figure 4.4**) An extensive green roof consists of a relatively thin layer of growing medium (approximately 50 to 150 mm) and a ground cover type of plant that is hardy to the harsh conditions of a rooftop. An intensive green roof consists of soil depths of at least 300 mm and may include woody plants such as shrubs and trees. Intensive green roofs are often used as public green spaces. Both types of green roof consist of a series of layers as illustrated in **Figure 4.5.**

Downtown Building, Edmonton, AB

Victoria Golf Course, Edmonton, AB

Victoria Gold Course, Edmonton, AB

Figure 4.4: Intensive and extensive green roofs

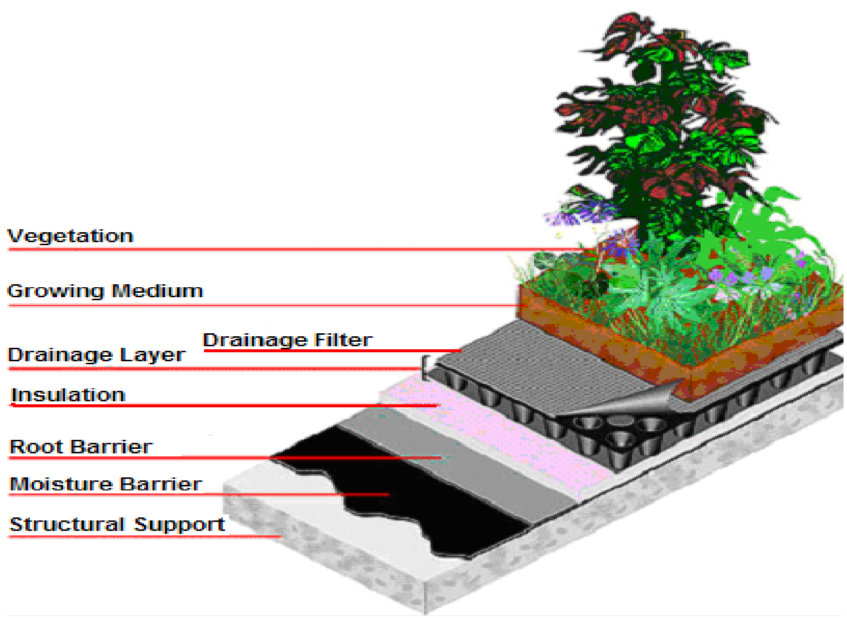


Figure 4.5: Layers of a green roof

(adapted from: greenwardliving.com/green.aspx)

4.1.4 PERMEABLE PAVEMENT AND GROUT

Porous asphalt, porous concrete, permeable unit pavers, open grid pavers and permeable grout (**Figure 4.6**) are all considered to be permeable/porous pavement. Incorporating permeable pavements into a development will reduce the effective impervious area of the development without losing its functionality. They are typically used in low traffic areas such as parking lots. In general, the structure of permeable pavement consists of four layers as illustrated in **Figure 4.6.**

1. Permeable pavement or pavers;

2. 'Choker course' or bedding layer or washed stone;

3. Reservoir layer consisting of clean washed uniformly graded aggregate or a tank consisting of a matrix of open weave boxes; and

4. Perforated underdrain incorporated into the reservoir layer as required.

As of 2023, permeable grout products were approved for trial in Edmonton. Approved products can be found on EPCOR's approved product list available online. Maintenance requirements for permeable paver products vary from manufacturer, and must be considered when including permeable pavers in project designs. For the products approved as of 2023, typical maintenance requirements include pressure washing twice a year and re-grouting if damaged.

University of Alberta, Edmonton, AB

University of Alberta, Edmonton, AB

Carter Crest, Edmonton, AB

Figure 4.6: Permeable pavement installation examples

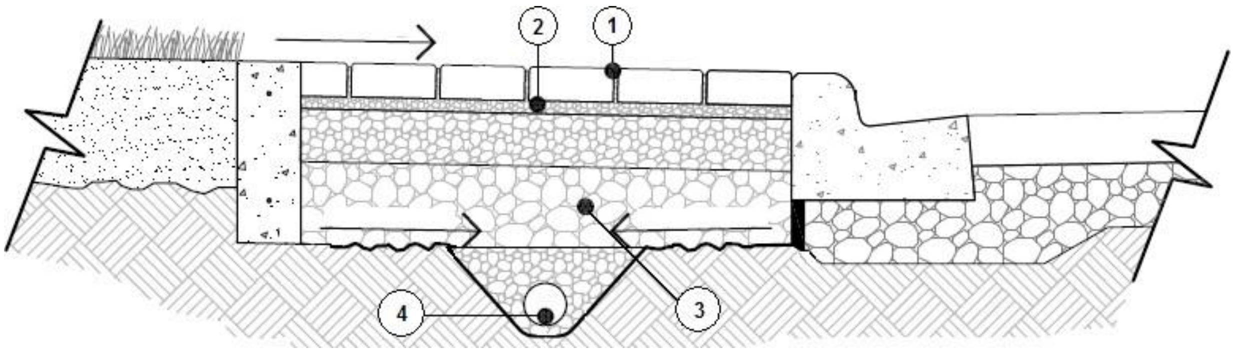


Figure 4.7: Components of permeable pavement facilities

4.1.5 NATURALIZED DRAINAGE WAYS

Naturalized drainage ways are surface stormwater conveyance features that use wetland zones, drop structures, natural materials and vegetation to replace storm sewer mains or prevent erosion of existing drainage ways (**Figure 4.8**). Naturalized drainage ways usually follow property lines and utility rights-of-way. These facilities are generally viewed as great amenities to surrounding communities and provide a refuge for birds and wildlife in the area.

Naturalized drainage ways are typically larger than grass swales and more engineered than natural wetlands. They generally have frequent or continuous runoff (base flow), even during periods of little or no precipitation resulting from residential irrigation and outdoor water use. Velocities of urban runoff and stormwater are slowed using natural vegetation, increased resistance along the flow path and drop structures (MDEP, 1997). Prolonged stormwater contact with natural materials promotes the hydrologic cycle through evaporation and transpiration. Infiltration is typically not a significant contributor to the hydrologic cycle due to saturated soils and/or direct connection with the groundwater table.

Naturalized drainage way and wetland

Filing 35, Denver, CO

The Preserve, Denver, CO

Figure 4.8: Naturalized drainage ways in medium and low density developments

4.1.6 RAINWATER HARVESTING FOR RE-USE

Rainwater harvesting gathers and accumulates rainwater falling on a rooftop and stores it for re-use in irrigation or other legislated uses. Rainwater harvesting may be as simple as collecting rainwater from roof downspouts in a rain barrel and using it to water planters and gardens. On a larger scale, rainwater may be collected in a large cistern located underground or in a garage or basement, and then re-used for irrigation with a direct hook-up to automatic sprinklers or an outdoor hose bib (**Figure 4.9**).

Residential Rain Barrel

Residential Rain Barrel

University of Alberta, Edmonton, AB

Figure 4.9: Types of rainwater storage tanks

4.2 PERFORMANCE OF LID-BMPS

LID-BMPs replicate natural hydrological processes to manage surface runoff due to urbanization. They reduce runoff volumes and rates and improve stormwater quality.

In general, treatment of stormwater begins with filtration of particulates as runoff flows over the surface and through vegetation, and again when it infiltrates through mulch and soil layers. Water is retained in the growing medium and contributed back to the hydrologic cycle through evapotranspiration. Soil microbes within the soils provide decomposition for pollutants such as hydrocarbons and nutrients. Soils also allow metals and chemicals to sorb to soil particles and compounds within the soil, preventing their release to receiving streams.

For permeable pavements, water quality benefits begin with filtration of stormwater through the porous asphalt / concrete or bedding course layer. Contaminants such as fine particulates, oil and grease and heavy metals will be trapped within the pore structure of the porous asphalt / concrete or bedding course layer.

Due to the site specific characteristics of LID features, performance varies from site to site. Performance also depends heavily on design objectives and quality of construction. **Table 4.1** summarizes overall performance of LID-BMPs for reduction of annual runoff and some key pollutants.

Table 4.1: Observed removal efficiencies (%) in LID-BMP facilities in the USA and Canada

	Rain Garden	Bioswale[1]	Green Roof[2]	Permeable Pavement[3]	Naturalized Drainage Way[4]
Annual Runoff Reduction (RR)	50~90	40~80	45~60	45~75	
Total Suspended Solids	59-90	65-81	86	85-89	80
Hydrocarbons		65			
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] based on monitoring results for grass swales
[2] filtering practices
[3] infiltration practices
[4] based on monitoring results for wet swales (CWP, 2007a; Claytor et al, 1996)

4.3 LID BENEFITS, COSTS, AND LIMITATIONS

4.3.1 LID BENEFITS

Table 4.2 provides a summary of the benefits that the six LID-BMPs and **Table 4.3** provides a summary of the benefits the five EPCOR standardized LIDs described in this guide. These benefits can be realized at various scales according to local and site-specific factors. Some of the benefits can be quantified with a monetary value while others are intangible. The *Value of Green Infrastructure*, developed by the Center for Neighborhood Technology, provides a reference to calculate the economic benefit of LID applications (CNT, 2010). Benefits that can be quantified with economic values include avoided runoff treatment, total suspended solids (TSS) reduction, air pollutant removal, and energy savings from green roofs.

Reduced stormwater runoff. LID is intended to intercept, infiltrate, filter, store, and detain stormwater runoff. For example, green roofs can store significant amounts of water in their growing media, while rain gardens can infiltrate and attenuate storm runoff.

Reduced flooding. LID applied throughout a watershed can reduce urban runoff volumes and thus has the potential to reduce subsequent flooding risk.

Reduced combined sewer overflow (CSO). Integrating LID into stormwater management practices can reduce overflow volumes, frequency, and impacts for both combined and separate systems through reducing peak flows and improving water quality. Some municipalities have found that the reduction of CSOs through LID-BMPs was more cost-effective than conventional practices of CSO storage and sewer separation (Riverkeeper, 2007).

Improved water quality. LID can improve water quality by effectively capturing and treating pollutants and sediments that typically wash into sewers and receiving water bodies. Pollutants are filtered, absorbed, or biodegraded while moving through infiltration media

Reduced salt application. Permeable pavement has been demonstrated to delay the formation of a frost layer in winter (Roseen, 2009; Houle, 2008), which can reduce salt application and reduce pollution to surface and groundwater resources. The economic benefit of salt reduction is a potential cost saving.

Reduced energy use. The presence of vegetation on LID facilities reduces the temperature of its surroundings. This can reduce requirements for heating and cooling systems, resulting in reduced energy use. For example, green roofs reduce roof surface temperatures through evaporative cooling from water retained in the growing medium and reduce a building's energy consumption by providing superior insulation. Rainwater harvesting saves energy by reducing use of potable water that needs energy for treatment and transport.

Improved air quality. Vegetated LID facilities (e.g. bioswale, rain garden) can improve air quality through uptake of air pollutants and deposition of particulate matter. Permeable pavement, rainwater harvesting, and vegetated LID facilities can indirectly improve air quality by reducing the amount of water/wastewater treatment needed, in turn reducing greenhouse gas production and air pollution from power plants.

***Albedo** – reflective power or fraction of solar radiation reflected by a surface or object.*

Reduced urban heat island. Permeable pavements help reduce the surrounding air temperature because they absorb less heat than conventional pavement. Vegetated LID facilities mitigate the urban heat island effect through evaporative cooling and reduction of surface albedo.

Improved aesthetics and property values. The vegetation cover of LID facilities can enhance aesthetic appeal of an area and increase adjacent proper values by increasing their proximity to an open space (ECONorthwest, 2007). Some permeable pavements help to reduce noise.

Improved habitat. LID supports biodiversity and provides valuable wildlife habitat in the urban setting by contributing green spaces and connections to ecological corridors. By introducing more nature to spaces mental and physical health of residents can be improved as well (NCBI, 2021).

Reduced cost of stormwater infrastructure. LID can help reduce the demand for conventional stormwater controls (e.g. curb-and- gutter) and reduce requirements to upgrade downstream storm sewer capacity with additional infrastructure. LID can potentially reduce the long-term cost of operation, maintenance and rehabilitation of stormwater management infrastructure through improved environmental performance.

Table 4.2: Benefits of LID-BMPs

Benefits	LID facilities					
	Rain garden	Bioswale	Green roof	Permeable pavement	Naturalized drainage way	Rainwater harvesting
Reduced storm runoff	+	+	+	+	+	+
Reduced flooding	+	+	+	+	+	+
Reduced CSO	+	+	+	+	+	+
Improved water quality	+	+	+	+	+	+
Increased groundwater recharge	+	+		+	+	
Reduced salt application				+		
Improved air quality	+	+	+		+	
Reduced urban heat island	+	+	+	+	+	
Reduced energy use	+	+	+	+	+	+
Improved aesthetics and property values	+	+	+	□	+	
Improved habitat	+	+	+		+	
Reduced traditional stormwater infrastructure expenditure	+	+	+	+	+	+

(CNT, 2010; ECONorthwest, 2007; USEPA, 2007)

+ Yes □ Possible

Table 4.3: Benefits of EPCOR standardized LID

Benefits	LID facilities				
	Box planter	Soil cell	Bioretention basin	Bioretention garden	Absorbent landscaping
Reduced storm runoff	+	+	+	+	+
Reduced flooding	+	+	+	+	+
Reduced CSO	+	+	+	+	+
Improved water quality	+	+	+	+	+
Increased groundwater recharge			+	+	+
Reduced salt application					
Improved air quality	+		+	+	+
Reduced urban heat island	+		+	+	+
Reduced energy use	+	+	+	+	+
Improved aesthetics and property values	+	+	+	+	+
Improved habitat			+	+	+
Reduced traditional stormwater infrastructure expenditure	+	+	+	+	+

+ Yes □ Possible

Traditional stormwater management practice – *The use of curb and gutter stormwater systems for handling stormwater opposed to using newer techniques such as LID, dry ponds, etc.*

4.3.2 LIFE CYCLE COSTS

There is considerable interest in comparing the development costs of sites designed using LID-BMPs to manage stormwater runoff and those designed using traditional stormwater management practices. Development of LID-BMP stormwater management systems costs less than comparable traditional systems in most cases. However, every development is unique and should be considered and assessed individually.

In the development of LID-BMP facilities, economies of scale apply when assessing costs. Sites designed with several similar features utilizing the same materials, or incorporating large facilities will have reduced costs per unit area compared to sites with a single LID-BMP feature. The costs of retrofit applications of LID-BMP in highly urbanized areas are likely to be higher than greenfield developments due to site preparation costs. Several additional factors will contribute to increased costs of LID-BMP facilities, including:

- Poor quality or contaminated site soils requiring extensive amendments or transport of soil;
- Requirement of geotextiles to prevent infiltration where groundwater contamination may occur or in tight soils where frost heave is a concern;
- Structural reinforcement requirements associated with retrofitting green roofs on existing buildings;
- Application of intensive green roofs utilizing higher soil volumes and more plant varieties than extensive green roofs;
- Plant selection variations for rain garden areas, bioswales and box planters depending on location, i.e., downtown planters may use species with higher initial costs or that require more maintenance;
- Higher labour costs associated with permeable paver installation compared to porous asphalt or concrete; and
- Small rainwater harvesting cisterns with higher costs per unit volume than large units.

Caution should be used when applying models developed for LID projects outside of the Edmonton region. Users should modify model parameters using local data if available for estimating LID costs applicable to the Edmonton region.

4.3.3 LIMITATIONS OF LID-BMPS

Although LID provides many tangible and intangible benefits environmentally and socially, it has some limitations. This section lists the limitations of each of the six LID-BMPs discussed in this Guide.

4.3.3.1 RAIN GARDENS

- Unlike stormwater ponds, rain gardens cannot treat large drainage areas;
- They are susceptible to clogging by sediment. Therefore, pre-treatment may be required, especially in locations where anti-skid material has been applied to the contributing catchment;
- They may consume considerable space, between 5% to 20%, of the catchment area;
- Incorporation into parking lot design may reduce the number of parking stalls available; and
- Depending on the location and development type, construction costs can be relatively high compared to some conventional stormwater treatment practices.

4.3.3.2 BIOSWALES (BIORETENTION)

- Improper installation will prevent removal of sediment and pollutants. Slopes and vegetation density are critical;
- Individual swales can treat only small areas;
- They are less feasible along roadsides with many driveway crossings;
- Phosphorus and bacteria removal capabilities are limited;
- Maintenance requirements are higher than curb and gutter systems;
- They may be subject to damage from off-street parking and snow removal when located along roadways; and
- In the City of Edmonton's D&C Standards Volume 3-02, Section 5.4, refer to bioretention for details on standardized practices for bioswales.

4.3.3.3 GREEN ROOFS

- Costs to build green roofs are high compared to traditional roof treatments;
- Only direct rainfall is treated;
- Control of maintenance and operation is often beyond municipal jurisdiction; and
- Design and construction experience is currently limited in Canada, though rapidly becoming less so.

4.3.3.4 PERMEABLE PAVEMENT

- Maintenance requirements are high compared to other LID-BMP stormwater management facilities;
- Costs to build permeable pavements are high compared to other stormwater management facilities;
- A small drainage area is treated;
- They are susceptible to clogging where anti-skid material is applied;
- Performance is reduced if freezing occurs while the surface is saturated;
- They are unsuitable for use in areas where heavy sediment loads are expected or in active construction or excavation areas that are not fully stabilized; and
- They are unsuitable for use in areas with heavy vehicle traffic, unless specifically designed for heavy loads.

4.3.3.5 NATURALIZED DRAINAGE WAYS

Flash Flood – *may occur when water levels in a drainage way rise very rapidly with little or no warning*

- They are impractical to implement in areas with very flat or very steep topography;
- They may be subject to some erosion during high flow velocities or volumes resulting from large storm events;
- They require considerable space for implementation, which may preclude their use in highly developed sites;
- Potential for high flow rates and/or flash floods must be assessed to ensure public safety where pedestrian access alongside naturalized drainage ways is encouraged; and
- Feasibility of application is reduced along roadsides with many driveway crossings.

4.3.3.6 RAINWATER HARVESTING FOR REUSE

- Systems have minimal water quality treatment capabilities;
- In Alberta, rainwater re-use systems often require potable water supplement since rainfall is not consistent enough to supply all irrigation or non-potable demands in a timely and economical matter;
- Installation MUST be done by experienced personnel to prevent any chance of cross contamination of the potable system; and
- Due to installation on private property, control of operation and maintenance is typically beyond the jurisdiction of municipalities.

5.0 EPCOR STANDARDIZED LID

There are five (5) standardized LID types whose design standards and specifications are outlined in Section 5.0 of the City of Edmonton's D&C Standards Volume 3-02. Design considerations and limitations can be discussed in the standards.

5.1 BIORETENTION GARDENS

Bioretention gardens appear similar to flower or shrub beds on the surface level, however, bioretention gardens use specialized LID soil to capture and treat storm water. Bioretention gardens do not contain an underdrain. Structural storage components are a necessary component of bioretention gardens.

Bioretention gardens differ from rain gardens as rain gardens do not contain a structural storage layer, whereas bioretention gardens do.

E.L. Smith bioretention garden, Edmonton, AB.

5.2 BIORETENTION BASINS (INCLUDING BIOSWALES)

Bioretention basins use vegetation, LID soil media, and storage layers to infiltrate, detain, and retain stormwater runoff. Bioretention basins differ from bioretention gardens as they contain underdrains connected to the city's drainage network. Bioretention basins consist of a flow inlet, ponding area, plant material, LID soil media, filter layer, storage layer, underdrain, and an outlet.

Bioswales are a subset of bioretention basins which utilize a shallow slope to convey and retain water.

Shamrock-Donnan Park bioretention basin, Edmonton, AB.

5.3 BOX PLANTERS

Box planters are similar to bioretention basins, however they are contained within a box structure, enabling smaller footprints and permitting installation closer to buildings. Box planters can be raised, level with the surroundings, or depressed below ground.

Box planters contain an underdrain and may or may not have a self-containing bottom.

Hugh J Bolton box planter, Edmonton, AB

5.4 SOIL CELLS

Soil cells provide structural support for sidewalks and roadways while allowing room for tree root growth and providing space for LID soil media to store runoff.

Backstreet soil cells, Strathcona, Edmonton, AB

5.5 ABSORBENT LANDSCAPING

Absorbent landscaping is an LID type that incorporates a shallow depression planted with both drought and saturation tolerant vegetation to collect surface flow. These facilities are graded to overflow directly into other LID facilities, or into the storm system. Unlike other LID facilities absorbent landscaping does not typically include underdrains. Plant selection is pivotal to the success of absorbent landscaping facilities and establishing a well-developed root system cannot be understated.

Carter Crest absorbent landscaping, Edmonton, AB.

6.0 LID-BMP FACILITY DESIGN

This chapter provides general considerations for design of LID-BMP facilities. Specific design recommendations for addressing local and climatic constraints will be described in later chapters.

All LID design parameters within this Design Guide are based on underlying assumptions that soils in Edmonton are tight and expansive, and that winter snow accumulates to a final frost depth and melts in the spring. Facility design details include cold climate adaptations and consideration of the City of Edmonton's sand / salt winter maintenance regime.

Each LID site is unique and has specific characteristics that require consideration during the planning and design stages to ensure successful implementation. A thorough investigation of each design parameter is required to ensure the design accounts for all local conditions surrounding the proposed application.

6.1 VEGETATION SELECTION AND PLANTING

Ornamental vegetation *– Vegetation typically grown for aesthetic (flowers, fruit, etc.) purposes.*

Vegetation selection and survival is an important facility feature as vegetation type, morphology, and structure influence hydraulics and pollutant settling or transport.

The use of native vegetation throughout the project site is recommended where appropriate. EPCOR has also developed a Low Impact Development (LID) Plant Maintenance Guide that recommends plants and outlines their requirements based on plants that have already been installed in LID facilities in Edmonton.

Regardless of the designation (native or ornamental), vegetation selection must meet weed and pest control requirements as outlined in the City of Edmonton Community Standards Bylaw, the Alberta Weed Control Act and Regulations, and the Agricultural Pests Act and Regulation, where applicable. Vegetation selections and planning should include the following considerations:

- Plan vertically to incorporate ground cover, understory shrubs, and trees. Plant in the spring or fall for quicker establishment. When planting trees, select species based on morphology (e.g., rooting zones, branching patterns, size at maturity, etc.). Note that deep rooting trees can improve soil structure with results similar to tilling. However, in areas where perforated weeping tile is used, deep rooting vegetation may damage buried infrastructure; and
- Select plant varieties that will thrive on the site conditions (climate, soil, and water availability) and that grow well together (e.g., group plants by water need). Plant selections on sizes and recommended planting distances as outlined in the City of Edmonton Guideline for Planting Trees on City Property (COE, 2008). Species selections should consider:
  - Maintenance needs, including mowing and pruning;

- Reduction of water and fertilizer needs after establishment;
- Resistance to pests;
- Climate resilience
- Tolerance of seasonal salt loadings, depending on facility location; and
- Pollutant uptake capacity.

6.2 SOIL MANAGEMENT AND AMENDMENT

6.2.1 SOIL MANAGEMENT

***Hydraulic conductivity** – the rate at which soil allows water to move through it.*

***Porosity** – a measure of the void space in a material, expressed as a ratio of the volume of void space to the total volume of the material.*

***Permeability** – the ability of a fluid to flow through a porous medium.*

The rate that water infiltrates is based on the soil's permeability (i.e., hydraulic conductivity). Saturated hydraulic conductivity refers to the rate of water movement through soil once void spaces within the soil are full of water and no more water can be retained within the soil structure. Although standard infiltration rates are difficult to determine, as both soil properties (chemical and physical) and vegetation cover influence water movement, unsaturated infiltration rates for native Edmonton soils are high regardless of soil type or vegetation cover (Verma and Toogood, 1969). A rapid decrease in infiltration rates following the first 30 minutes is attributed to the initial physical soil characteristics including moisture content, temperature, texture, structure, and porosity. Hydraulic conductivity is generally greater at the top of the soil profile due to the specific porosity, structure, and texture of the soil.

Compaction of soil particles is a factor in permeability. For example, materials consisting of strongly compacted clays, observed following construction with heavy machinery, have a hydraulic conductivity value of about 0.5 mm/hr (McKeague et al, 1986). After organic material is removed during site construction, sub-soils can become heavily compacted by construction activities. As well as reducing infiltration, this compaction due to construction traffic will impede root penetration, greatly reducing plant health and vigour. To increase plant survival and health:

- Loosen subsoil to a minimum depth of 150 mm in areas without compaction and 300 mm in areas with heavier compaction;
- Remove all subsoil material exceeding 50 mm in diameter (TRCA, 2009); and
- Cover loose and friable subsoil with 200 to 300 mm of topsoil for grass areas and 450 to 600 mm for shrub beds (Rosen 2009).

6.2.2 SOIL AMENDMENTS

Soil amendments, including mixed soil types, organic matter, fertilizers, and compost, are often required to ensure specific vegetation growth and to meet predetermined infiltration rates for the LID facility. Organic compost can be an excellent source of required nutrients for plant growth. However, selection of compost type and source is critically important.

The most common sources of compost include tree and vegetation prunings, construction waste, and animal manure. In LID facilities that promote surface infiltration through amended soils either for groundwater recharge or to an underdrain, it is not recommended that animal manure compost be used due to its high nutrient (nitrogen, N and phosphorus, P) concentrations. These nutrients may leach and contribute to elevated downstream loadings. Organic compost must be completely composted (i.e., no recognizable components) prior to use in LID facilities to prevent denitrification, weed growth, bacterial contamination and leaching of nutrients from amended soils.

Amendment additives may be used to meet specific hydrologic or pollutant mitigation needs of the site. Gypsum compost may be added to amended topsoil so that the calcium ions will reduce levels of exchangeable sodium in soils impacted by de-icing salts and help to regenerate water absorption qualities (Grieve et al, 2007). In addition to its mitigative effect for de-icing products, gypsum compost adds sulfur and calcium (necessary for plant growth) to the soil without changing its pH.

Compost amendments can assist in increased aeration, percolation, water holding capacity, and plant nutrient availability. The amount of compost required to be mixed into topsoil depends on both the type of topsoil and the type of subsoil it will overlay. For example, a sand-compost mix should only be used on well drained sub-soils, as it will form an impermeable layer when used in combination with clay subsoil. For the same reason, clay-laden topsoil should not be mixed with or placed over sand.

Each unique site must be thoroughly assessed for site specific characteristics that may have an impact on required soil amendments. The added compost must be balanced with the following factors:

- Surface run-off conditions;
- Sub-surface infiltration;
- Planting regimen;
- Storage requirements; and
- Cost effectiveness.

Amended topsoil characteristics are important factors in the success of vegetated LID facilities. A general list of desirable characteristics is provided in **Table 6.1**.

Table 6.1: Amended topsoil characteristics

Parameter	Values
Texture classification	Loamy Sand; Sandy Loam
Sand sized particles, larger than 0.05 mm diameter and smaller than 2 mm diameter	60% – 80%
Silt	10% – 25%
Clay	5% – 15%
Silt and clay combined	Maximum 40%
Organic matter	5% – 10%
pH value	6 – 8
Available Phosphorus	10 – 60 ppm

6.3 COLD CLIMATE CONSIDERATIONS

There are several cold climate design challenges that are always a design concern for implementation and operation of LID facilities (MSSC, 2005, Roseen et al, 2009). Similar to conventional stormwater management facilities, these challenges do not preclude implementation of LID facilities, but are listed here (**Table 6.2**) to inform the designer of the considerations that must be specifically addressed in the design of any LID facilities operating in cold climates.

Table 6.2: Challenges to design of LID-BMP facilities in cold climates

Cold climate characteristics	BMP design challenge
Cold temperature	▪ Pipe freezing. ▪ Reduced biological activity. ▪ Reduced settling velocities.
Deep frost line	▪ Frost heaving. ▪ Reduced soil infiltration. ▪ Pipe freezing.
Short growing season	▪ Short time period to establish vegetation. ▪ Different plant species appropriate to cold climates than moderate climates.
Significant snowfall	▪ High runoff volumes during snowmelt and rain-on-snow. ▪ High pollutant loads during spring melt. ▪ Other impacts of road salt / deicers. ▪ Snow management affecting BMP storage. ▪ Weight of snow piles causing soil compaction.

(Adapted from Caraco and Claytor, 1997)

6.3.1 MANAGING AND DESIGNING FOR ROAD SALT APPLICATIONS

Road salt used for winter de-icing can alter physical properties of soil and have an impact on vegetation growth and permeability. Detrimental impacts at high concentrations include increased soil swelling and crusting, increased erosion and soil dispersion, decreased structural stability, and increased electrical conductivity. Salts have also been shown to increase bio-availability of heavy metals by allowing them to become water soluble in soils (EC, 2001). Additionally, soil microbes, which are necessary for pollutant breakdown, soil structure, and permeability, can become inhibited with elevated salt concentrations (EC, 2001).

Vegetation injury is the most visible consequence of road salt application and spray. All species of vegetation are not equal when it comes to tolerance for road salt. **The City of Edmonton's** D&C Standards Volume 3-02, Section 5.0, contains some examples of salt-tolerant species.

Salt concentrations in soils are the highest in spring and decrease during warm weather rain events, as rainwater and road spray facilitate leaching of salts from soils. Based on impacts of road salt on roadside soil and vegetation, and on documented crop injury due to saline waters (Fipps, 2003; Bauder et al, 2007), the recommended maximum winter loading of chloride to a roadside LID facility planted with salt-tolerant grasses is 1000 mg/L (Texas Agricultural Extension Service, 1998).

LID facilities can be designed to accommodate road salt loadings. Soil amendments can be used to buffer some salt loading. Precipitation and irrigation will leach salt from soil. The amount of water required to reduce a damaging concentration of salt to an acceptable level is dependent on the depth and type of soil being treated (Boumans et al, 1977).

6.3.2 RECOMMENDATIONS FOR EDMONTON

Treatment train – *LID-BMPs placed in series to improve water quality treatment so that each successive cell receives cleaner water than the previous one.*

6.3.2.1 DESIGN ADAPTATIONS

Adaptations to frequently used LID-BMPs make application in cold climates feasible and introduce excellent opportunities to treat meltwater. Although biological pollutant removal may slow down in cold weather, standing vegetation still provides some filtering capabilities and soil microbes are alive and active (Roseen, 2009). By carefully evaluating the location and type of LID-BMP facility when designing a site, cold climate LID-BMP facilities can be a very effective and valuable part of a treatment train even during spring melt (Gunderson, 2008).

Adaptations for cold climates, including area where considerable anti-skid and de-icing materials are necessary, may include:

- **Careful site selection** for infiltration and filtration facilities to avoid implementation in zones where high concentrations of pollutants and sediments are unavoidable. Where space is available, implement pre-treatment (forebay) or straining features (vegetated filter strips) for

***Filter strips** – vegetated areas intended to act as an erosion and sediment control measure at the inlet of an LID. Filter strips by EPCOR's standards may vary from that of other jurisdictions.*

runoff prior to its entry to the filtration or infiltration facility;

- **Careful plant selection and placement** to use more salt-tolerant plants to buffer less salt-tolerant plants from the impacts of road salt and to minimize damage to LID facilities treating stormwater runoff from streets with heavy salt application;

- **Strategic application of sand and salt** to reduce impacts (clogging and elevated salinity) in snow storage zones and LID facilities receiving roadway runoff;

- **Placement of filter strips along roadways** to promote settling of sand and gravel prior to runoff entering an infiltration or filtration facility and to allow removal of anti-skid material from the filter strip during spring street sweeping. Filter strip widths vary depending on the type of roadway and the quantity of anti-skid material applied and may range from 5 m to 35 m depending on location and application rate;

- **Snow storage zones** for contaminated or gravel/sand-laden snow may be located on pervious surfaces or impervious surfaces where meltwater is directed to treatment facilities and contaminants are diluted prior to release;

- **Timely maintenance activities** to remove sand and gravel from streets and boulevards as soon as the spring melt has occurred;

- **Redirection of sand/salt laden flows** away from sensitive facilities during spring runoff. This may be through a bioswale or using traditional minor and major storm sewer systems;

- **Sizing of facilities** to accommodate snowmelt volumes where public safety may be compromised in the event that minor flooding occurs (such as near sidewalks and crosswalks);

- **Enlargement of curb cuts or employment of alternate curb types** to allow runoff to enter facilities during times when ice and snow may partially block inlets; and

- **Selection of facility location** away from crosswalks and sidewalks to prevent ice buildup on pedestrian routes during the spring melt period.

In residential and open space areas where high concentrations of chloride or soluble toxic pollutants are not present, infiltration (or filtration where sub-soils are tight) of meltwater is an effective way to remove many typical contaminants. Pre-treatment for particulates, including sand and gravel, are required to prevent clogging of facilities and may consist of filter strips, bioswales or settling basins.

6.3.2.2 OPERATION AND MAINTENANCE

Preventing contamination of receiving waters due to winter de-icing activities requires proactive operation and maintenance. The initial focus must be on keeping contaminants out of accumulated / dumped snow. Management approaches that aid in accomplishing these goals may include:

- Wise and strategic use of de-icing and anti-skid materials;
- Avoidance of salt additives (e.g., cyanide) which can be toxic at low doses;
- Storage and mixing of chemicals in covered areas and mixing only amounts required;
- Snow removal and/or meltwater routing to appropriate treatment facilities;
- A dilution system (may include irrigation) to reduce direct impact of high chloride concentrations;
- Rapid and regular street sweeping as soon as snow is gone from roadways;
- Litter control; and
- Erosion control.

Snow storage areas for relatively clean snow should be located on permeable surfaces to facilitate some level of filtering prior to meltwater entering receiving waters. If soil is highly impervious, the groundwater table is high or snow contains high concentrations of anti-skid or de-icing materials, storing the snow on an asphalt pad and directing meltwater to a treatment facility is recommended. LID filtration systems may be used to treat snow storage meltwater provided particulates are settled out prior to discharge into the filter.

6.4 LID FACILITY DESIGN PROCESS

LID facility design starts after the LID site design (described in section 3.2). Since each LID facility is site-specific, there is no universal design procedure applicable to all facilities. In general, design starts with the selection of facility types according to site suitability. The following factors should be considered when selecting LID features (O'Brien & Company, 2009).

Available space. Ensure there is sufficient functional open space to install LID facilities. Existing hydrological functional spaces should be preserved.

Soil performance. Infiltration and water bearing capacity of soils and sub-soils must be investigated and assessed. For tight soils that have limited infiltration capability, sub-drains should be installed.

Slopes. LID design must properly account for slope to ensure effective detention and infiltration performance. Small scale LID facilities perform well on gentle to moderate slopes.

Depth to groundwater table. For rain gardens, bioswales, and naturalized drainage ways, the facility base should be at minimum 0.6 m to 1 m above the seasonal high-water table.

Proximity to foundations and underground utilities. For rain gardens and bioswales, leave enough space between the LID facility and building foundations or other underground utilities to prevent saturation and uncontrolled moisture intrusion into these structures. The City of Edmonton's D&C Standards Volume 3-02 and geotechnical resources should be referenced for design geotechnical considerations and required setbacks.

Once facilities are selected, the next step is sizing of the selected facilities. Sizing of the LID facility is primarily influenced by runoff reduction and quality improvement requirements for the defined drainage area.

The LID facility design should also consider constructability and requirements for operation and maintenance.

6.4.1 FACILITY SELECTION

6.4.1.1 SITE CHARACTERISTICS

Selecting an appropriate LID facility to address requirements of the site is critical. A matrix (**Table 6.3**) has been developed to define capabilities of each of the six LID-BMP facilities identified in this Design Guide in meeting the three primary objectives of:

- Stormwater volume control;
- Stormwater peak flow control; and
- Stormwater water quality.

Also indicated in **Table 6.3** are types of urban land-uses where application of these LID facilities is most suitable and their relative land area requirements.

All selection criteria are based on the underlying assumptions that soils in Edmonton are tight and expansive and that winter snow accumulates to a final frost depth and spring melt. In areas where soils are more permeable, opportunities may exist to implement facilities that rely on infiltration in addition to evapotranspiration, detention, and filtration to manage runoff. Additionally, the sand / salt winter maintenance regime is incorporated and cold climate suitability of each facility is evaluated based on impacts of these activities on the LID facilities.

Table 6.4 summarizes site constraints associated with LID-BMP. The combination of information from **Table 6.3** and **Table 6.4** will facilitate appropriate LID selection based on site characteristics.

Table 6.3: LID facility selection matrix

Facility type	Management objective			Land use								Cold climate	Land area req.
	Vol.	Peak dis.	Water quality	School	Comm.	High density urban	Indust.	Single family res.	Multi-family res.	Parks / open space	Roads		
Rain Garden	+	+	+	+	+	■	□	+	+	+	+	+	■
Bioswale (Bioretention)	■	■	+	+	+	□	+	+	+	+	+	+	■
Green Roof	■	+	+	+	+	+	+	□	+			■	□
Permeable Pavers	+	+	■	+	+	+	■	+	+	+	□	□	□
Naturalized Drainage Ways	□	■	■	■	■	□	■	■	■	+	+	+	■
Rainwater Harvesting / Re-use	■	□	□	+	■	+	■	+	+	■	□	□	□

(Adapted from: AMEC, 2009; Alaska Department of Environmental Conservation, 2009; SEMCOG, 2008)

Symbol	Legend	Effectiveness in meeting objective	Land use / Cold climate suitability	Land area
+	High	One of the functions of the facility is to meet the management objective.	Well suited for land use application / cold climates.	High relative dedicated land area required.
■	Medium	Facility can partially meet management objective but should be combined with other facilities.	Average suitability for land use application / cold climates.	Moderate relative dedicated land area required.
□	Low	Facility contribution to management objective is the by-product of other functions and additional controls should be used in the treatment train if that objective is important.	Operational adaptations required for use in cold climates (see Section 6.0).	Low relative dedicated land area required.

Table 6.4: LID facility site constraint matrix

Facility type	Depth to water table or bedrock[1] (m)	Typical drainage area treated (m^2)	Native soil infiltration rate (mm/hr)	Head[2] (m)	Space[3] (%)	Slope[4] (%)	Setbacks[5]
Rain garden	1	5 to 1,000	Underdrain required if <13 mm/hr	1 to 2	5 to 10	0 to 2	B,U,W
Bioswale (bioretention)	1	≥50	Underdrain required in dry swales if <13 mm/hr	1 to 3	5 to 15	0.5 to 3	B,U,T,W
Green roof	N/A	≥20	N/A	0	0	0	None
Permeable pavement	1	≥5	Underdrain required if <13 mm/hr	0.5 to 1	0	1 to 5	B, U, W
Naturalized drainage ways	N/A[6]	≥50	N/A	>1	15 to 30	>2%	B,U,T,W
Rainwater harvesting / re-use	1	≥20	N/A	1 to 2	0 to 1	N/A	U, T

N/A = Not applicable
[1] Minimum depth between base of facility and elevation of seasonally high-water table, or bedrock
[2] Vertical distance between the inlet and outlet of the LID facility
[3] Percent of open pervious land on the site required for LID facility
[4] Slope at the location of the LID facility, effective slope of facility
[5] Setback Codes: B = building foundation; U = underground utilities; T = trees; W = drinking water wellhead protection area
[6] Naturalized drainage ways that incorporate wetland components must be kept moist and may be located within the groundwater table
(adapted from TRCA, 2009)

6.4.1.2 WATER QUALITY TREATMENT CAPABILITIES

The urban environment has many non-point sources of pollutants that are becoming more of a problem in receiving streams due to increased runoff from developed areas. The ideal method of reducing pollutants reaching these streams is by implementing source controls that prevent pollutants from entering stormwater. **Table 6.6** illustrates the sources of pollution in urban and industrial areas.

As it is often not possible for source controls to completely remove non-point source pollutants, strategically placed and specifically designed LID facilities may provide some removal capacity of pollutants commonly occurring in the urban environment (**Table 6.5**). Stormwater pollutant removal capabilities of LID occur through five primary removal mechanisms including:

- Sedimentation through reduced runoff velocities and extended detention;

- Filtering through soil and sand;
- Straining and settling of particulates passing through standing vegetation;
- Infiltration reducing pollutant loadings in runoff by allowing percolation into underlying soils; and
- Biological uptake of nutrients and contaminants by plants and soil microbes.

Table 6.5 shows pollutant removal efficiencies for five of the six LID-BMP facilities discussed in this Design Guide based on their ability to provide water quality enhancement in monitored LID facilities in Canada and the USA. The number of monitored LID-BMP facilities in Canada is currently limited and monitoring of LID pilot projects in Edmonton is recommended to determine more specific pollutant removal capabilities for this area.

Water quality treatment in rainwater harvesting systems (the sixth LID practice) is minimal without reuse. However, reuse for irrigation of other LID-BMP facilities will provide treatment at the levels indicated for those facilities (**Table 6.5**). Controlled irrigation through soil moisture monitoring can be designed to prevent runoff from irrigated areas, thereby removing 100% of pollutants occurring in the rainwater harvested for reuse.

Removal efficiencies can be misleading as high influent pollutant loads will tend to have higher removal efficiencies than low influent loads even though they have higher effluent loads than those with low influent loads (England, 2009). The best solution for reducing pollutants in stormwater runoff is to reduce pollutant loads at their source. This can be done through operation and management practices that prevent high pollutant loads from reaching the minor system or LID-BMP facilities. Selecting the appropriate LID-BMP facilities to manage pollutants coming from a particular site is vital to the success of both the LID-BMP facilities and the source control objectives of the site. **Table 6.5** is provided to facilitate this process.

Table 6.5: Observed removal efficiencies (%) in LID-BMP facilities in the USA and Canada

Pollutant	Rain garden	Bioswale	Green roof[2]	Permeable pavement[3]	Naturalized drainage way[4]
Annual runoff reduction (RR)	50~90	40~80	45~60	45~75	
Total suspended solids	59-90	65-81	86	85-89	80
Hydrocarbons		65			
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] Based on monitoring results for grass swales
[2] Filtering practices
[3] Infiltration practices
[4] Based on monitoring results for wet swales (CWP, 2007a; Claytor et al, 1996)

Table 6.6: Potential sources of pollution in developed areas

Constituents	Possible sources	Potential effects
Sediments – total suspended solids (TSS), turbidity, dissolved solids	Construction sites, urban / agricultural runoff, landfills, CSOs, septic fields, atmospheric deposition.	Habitat changes, stream turbidity, recreation and aesthetic loss, contaminant transport, bank erosion.
Nutrients – nitrogen and phosphorus (N and P)	Lawn / agricultural runoff, landfills, septic fields, atmospheric deposition, erosion.	Algae blooms, ammonia toxicity, nitrate toxicity.
Pathogens – total and fecal coliforms, E.Coli, viruses	Urban / agricultural runoff, septic systems, illicit sanitary connections, CSOs, domestic / wild animals.	Ear / intestinal infections, recreation / aesthetic loss.
Toxic pollutants – heavy metals, toxic organics	Urban / agricultural runoff, pesticides / herbicides, underground storage tanks, hazardous waste sites, landfills, illegal disposals, industrial discharges.	Toxicity to humans and aquatic life, bioaccumulation in the food chain.
Salts - NaCl, $MgCl_2$	Urban runoff, snowmelt.	Contamination of drinking water, harmful to salt intolerant plants.

(USEPA, 1993)

6.5 LID SITE MONITORING

6.5.1 FLOWS

***Non-point source** – Any source of water that is diffuse. Examples of stormwater non-point sources are land runoff, precipitation and seepage.*

Measurement of inflows to LID-BMP facilities may be difficult since flow inputs may be non-point source and numerous. However, inflow volumes and flows may be estimated based on precipitation at the site and the catchment area contributing to each individual facility.

Outflows can be measured by deploying a permanent or semi-permanent flow sensor (Doppler or ultrasonic are recommended) in the outlet pipe from a facility, treatment train, or the site. Outflow measurements can be used to provide a comparison with modelled estimates developed during the planning stage. If considerable topsoil amendments have been applied throughout the site and disconnection of impervious areas is a method used to reduce runoff, overestimation of runoff into a facility may occur when using standard modelling methods. Since all LID- BMP facilities within the treatment train are designed to reduce runoff, the resulting outflow reductions (compared with estimated values) can be attributed to the LID-BMP site plan and facilities.

6.5.2 WATER QUALITY

***Water quality sonde** – device in a logging assembly that senses and transmits water quality data.*

***Turbidity** – cloudiness or opacity in the appearance of water caused by suspended solids or particles.*

Monitoring of incoming and outgoing water quality in non-research based LID-BMP facilities can be difficult due to the fact that flow inputs to the facilities are often non-point source and may be numerous. This characteristic makes comparison of pollutant levels in inflows and outflows difficult but, with some planning upfront, it is not necessarily impossible.

Total Suspended Solids (TSS) is a frequently regulated pollutant and reduction of TSS in stormwater is commonly identified as an operational objective for stormwater management facilities. In addition to TSS, nutrients are becoming more of a problem in many receiving streams as algae and aquatic plant growth impacts oxygen levels and fish health during summer months.

Water quality sondes commonly measure turbidity (a substitute for TSS), nutrients, and water temperature with the option to add other parameters. Sondes are easily deployed for either spot samples or long-term monitoring in stormwater catch basins and outlet control vaults. Measurement of flows and water quality at the same locations may be desirable, and data loggers can be obtained to record all parameters for download at the same time.

6.5.3 OPTIONAL PARAMETERS

Other sensors or measurements that may provide additional information of interest include:

- Soil moisture sensors;
- Water depth sensors within the reservoir layers of infiltration facilities;
- A pump recorder for irrigation systems to measure pump rates and time of operation;
- A water quality autosampler triggered by storm events;
- A heated rain gauge to monitor snow water equivalents; and

Infiltration measurements conducted manually as spot checks to determine long-term soil capacity.

7.0 RAIN GARDENS

7.1 DESCRIPTION

Rain gardens are a stormwater management practice that use plants and soils to filter, retain, infiltrate, and distribute stormwater runoff. Rain gardens are different from bioretention gardens/basins as they do not have an engineered water storage layer and do not have an underdrain system. In general, a rain garden consists of pretreatment, flow entrance, ponding area, plant materials, a mulch cover, amended topsoil (a mixture of sand, fines and organic materials), and an overflow outlet.

7.2 APPLICATION

Rain gardens should be located close to where runoff is generated. Typical locations are near parking lots, in traffic islands, and near building roof leaders (**Figure 7.1**). Rain gardens can be incorporated into either new or retrofit sites based on the lot grading plan. Rain gardens may be used for snow storage provided that appropriate vegetation and soils are used, and that it will not impact the functionality of the LID, for example, soil compaction, salt, sediments, etc. Depending on the runoff volume to be controlled, site locations and soil conditions, enhanced infiltration may be required. **Figure 7.2** and **Figure 8.5** provide cross sectional details for an example cross section of a rain garden.

Rain gardens are not recommended in areas where slopes adjacent to the facility exceed 20% due to the risk of erosion (Winogradoff, 2002). Rain gardens should be planned to limit the removal of existing mature trees where possible.

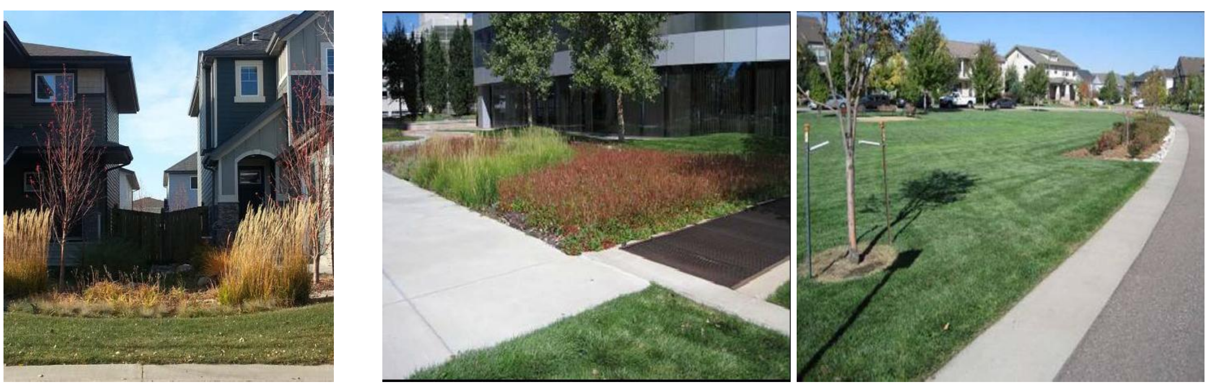


Figure 7.1: Rain garden installations in residential, commercial, and park settings

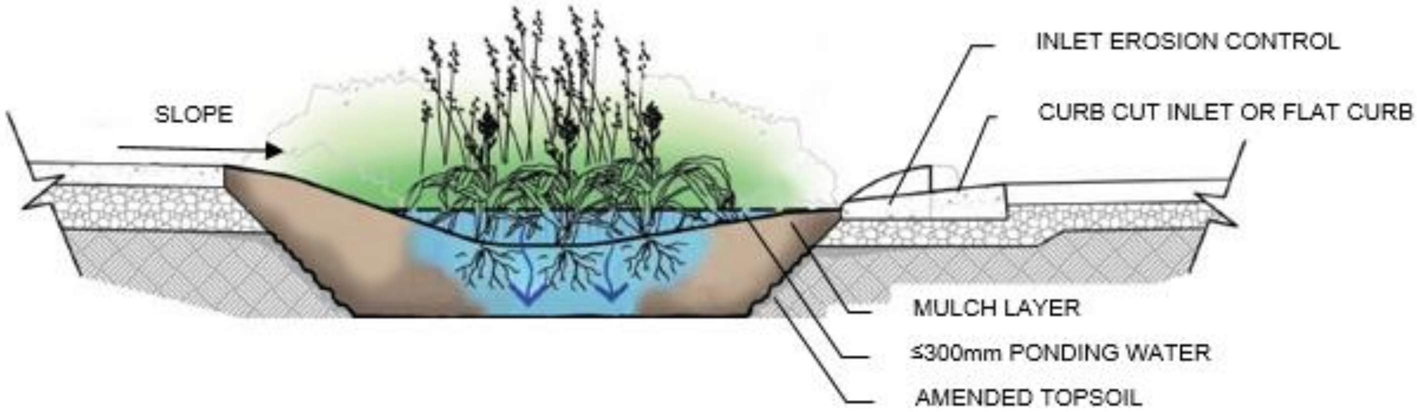


Figure 7.2: Cross section of a basic rain garden

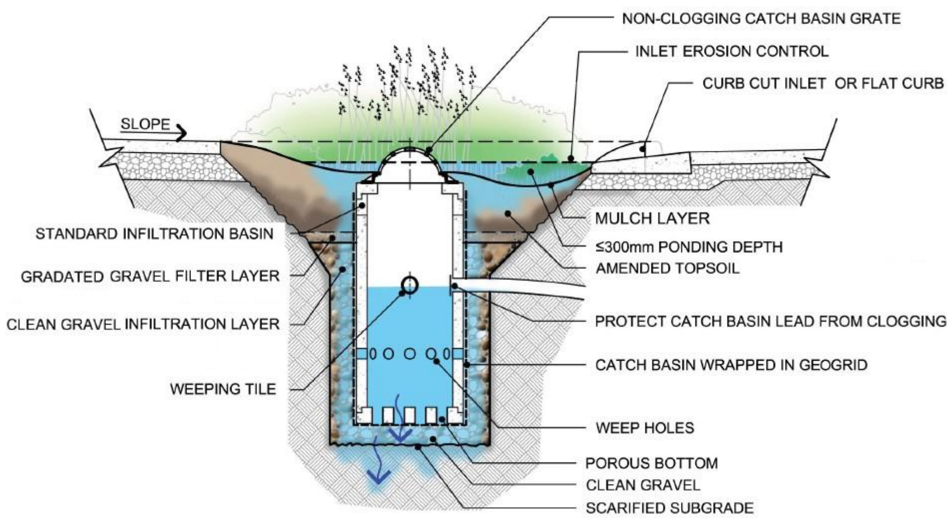


Figure 7.3: Cross section of a bioretention area with filtering infiltration gallery

7.3 DESIGN CONSIDERATIONS

Several key factors must be understood prior to facility design to ensure success, including:

- Sand and salt application methods and rates, and application variability throughout the site;
- Snow plowing methods and snow dump and storage locations;
- Sediment and salt concentrations resulting from road de-icing and snow storage; and
- Combined maximum volume of snow, ice and meltwater during spring thaw.

To ensure long-term viability of a rain garden, key components (i.e., the inlet, outlet, ponding depth, captured volume, media layers, buffers for ground water and structure) must meet the requirements listed in **Table 7.1**. The details of all rain gardens planned for the site must be included on design drawings as indicated in the City of Edmonton's D&C Standards Volume 3-02, Section 5.0.

Rain gardens that allow deep subsoil infiltration require sub-soils with hydraulic conductivity >13 mm/hr (USEPA, 1999a). In areas with lower hydraulic conductivities, the design of facilities to take advantage of deep infiltration to attenuate stormwater volumes is more challenging. Where sub-surface stability is not a concern and the ground water table is at least 1.8 m below the base of the facility (USEPA, 1999a), significant deep infiltration can occur in sub-soils with limited hydraulic conductivity if sufficient time is allowed. If additional time is required, it can be provided by increasing storage capacity in the facility to allow infiltration to occur between major storms while still managing the design storm. Other considerations are:

- Where necessary, to prevent icing of sidewalks and streets, size surface ponding volumes to accommodate the spring thaw volume of snow, ice and meltwater without considerable infiltration by topsoils;
- Provide filter strips (ranging from 3 to 5 m on collectors to 35 m wide at intersections along arterial roadways) between urban roads and the rain garden facility to allow sediments and particulate salts to settle prior to contact with the topsoils (EC, 2001);
- Plant salt tolerant plants as a buffer between the roadway and the less tolerant species (the City of Edmonton's D&C Standards Volume 3-02, Section 5.0);
- Plant species that grow later in the spring to avoid salt-spray damage to leaves and flowers as much as possible and to reduce the potential of repeated injury;

- Amend topsoil to mitigate the impact of de-icing compounds;

- Locate snow storage areas away from rain garden facilities unless vegetation and soil structure is specifically designed to accommodate snow storage (MSSC, 2005); and

- Place geotextile fabric along the sidewalls of the facility to help to direct the flow downward and reduce lateral flow under pavement when a rain garden is located in a media strip or parking lot.

Other design considerations besides those listed in the City of Edmonton's D&C Standards Volume 3-02, Section 5.0, include, but are not limited to:

- Locating LID facilities appropriately to minimize damage due to pollutants and de-icing and anti-skid materials, as well as snow plowing operations;

- Designing vertical profile of vegetation located along roadways or near intersections to prevent impedance of driver visibility;

- Sizing facilities receiving road runoff containing salts to prevent salt induced injury to plants and soils

- Designing soil type and structure and selecting vegetation to account for weight, added pollutants and melt volumes in facilities built with the intent to provide snow storage;

- Sizing curb cut inlets to prevent blockage by ice and snow during spring runoff; and

- Designing soil amendments in roadside facilities to buffer high salt loadings.

Table 7.1: Rain garden parameters and guidelines

Reported Parameters	Description
Sub-soil infiltration rate	≥15 mm/hr, underdrain is not required; underdrain required in tighter soils (<15 mm/hr); for design and modelling, use 50% of specified or measured rate.
Inlet design	0.5 m to 3 m grass filter buffer for non-point source inlet; erosion control at point source inlet; filter strips to buffer salt impacts are required as follows: 3-5 m width along collectors (may use sidewalk) and 5-35 m width along arterials.
Design discharge	Max overflow or underdrain flow rate in design events (2-year, 5-year, 10-year, 25-year and 100-year).
Surface area	3-30% of contributing impervious area, several small facilities provide better treatment than one large facility; facilities to be sized by designer based on snowmelt volumes and salt loadings, as required.
Contributing impervious area	<2 ha; pretreatment (grass filter with level spreader, etc.) to facility required if imperviousness <75%.
Facility flow velocity	<0.3 m/s in planted areas and <0.9 m/s in mulched zones, to prevent erosion.
Ponding depth	< 0.2 m during a 2-year design event; max. 0.35 m depth per the City of Edmonton's D&C Standards Volume 3-02, Section 5.0.
Soil depth	300 mm soil depth for 10 cm ponding depth; 450-600 mm soil depth for 15 cm ponding depth; 600 mm for 20 cm ponding depth.
WSE1 in design storms	Show that high water level 100-year, 4-hour design event does not compromise adjacent structures.
Captured volume	Volume of water retained through ponding and surface infiltration during the 2-year design event; additional volume captured during larger events if applicable.
Emptying time	Duration of ponded water following a 2-year design event is <48 hrs.
Media layers	Mulch: 70-80 mm depth (optional, site specific).
	Growing media: (amended topsoil with infiltration rate 25-50 mm/hr) 300-1000 mm depth.
	Filter layer: (14 mm washed rock <0.1% silt) 100 mm depth.
Geotextile fabric	Permeable filter fabric placed over drainage layer to control transport of sediments and direction of flow; permeability rate should be higher than that of soil or 75 gal/min/ft^2, whichever is greater.
Surface geometry	Flat bottom, recommended length / width = 2:1.
Side slopes	4:1 (H:V) preferred (max 3:1).
Groundwater buffer	Facility base must be 1 m above groundwater level (or 0.6 m if groundwater varies minimally throughout the year).
Structural buffer	Facility located at least 3 m from building foundations (or 1 m with the use of an impermeable membrane).
Vegetation	Species selected for contaminant removal, aesthetics and inundation / drought resistance (see the City of Edmonton's D&C Standards Volume 3-02, Section 5.0).

(USEPA, 1999a, Stephens et al, 2002; GVRD, 2005; Caraco et al, 1997; COP, 2004b; MSSC, 2005; ACRAG, 2023), [1] *WSE is Water Surface Elevation*

Table 7.2: Suggested rain garden operation activities

Operation activities
Inspect for sedimentation, erosion, plant health and mulch condition.
Weed control.
Avoid using facility as snow storage facility unless specifically designed for this purpose.
Strategic application of de-icing and anti-skid material on roadways contributing to facility.
Street sweeping to prevent sedimentation.
Soil contamination testing in areas with high levels of contaminants.

8.0 BIOSWALES (BIORETENTION)

8.1 DESCRIPTION

Bioswales are open channels with dense vegetation specifically designed to attenuate, treat, and convey stormwater runoff. They are distinguished from rain gardens mainly by a linear shape and sloped bottom that facilitates water movement. Bioswales use amended topsoil, selected plantings, and may include an infiltration layer to provide enhanced water quality treatment and promote infiltration.

Used as a replacement for, or in conjunction with, curb and gutter, bioswales are designed to strain particulates from the water, reduce flow velocity, and reduce volumes through surface infiltration and evapotranspiration.

Directing stormwater through vegetation improves surface infiltration and soil moisture for evapotranspiration. Stormwater quality treatment in a bioswale is realized through straining and settling of particulates through vegetation, deep infiltration, biodegradation from soil microbes, and filtration through soil layers. Water quality treatment efficiency can be improved by increasing retention time through the use of check dams.

8.2 APPLICATION

Bioswales can be applied in most development situations, including residential areas, office complexes, along roadways, parking lots, parks, and other green spaces (**Figure 8.1**). Bioswales are well suited to treat roadway runoff because of their linear nature and ability for receiving sheet flows. They are often located within utility rights-of-way along property boundaries for serving one or multiple properties.

Using bioswales to replace existing drainage ditches is a common retrofit opportunity. Ditches are traditionally designed only to convey stormwater away from roads. In some cases, they can be retrofitted to bioswales to enhance infiltration and pollutant removal using check dams.

Bioswale at Mill Woods Parking Lot in Edmonton, AB

Bioswale at Big Lake Trumpeter neighbourhood in Edmonton, AB

Bioswale at Terwillegar Recreation Centre, Edmonton, AB

Figure 8.1: Local bioswale installations in residential and commercial settings

8.3 DESIGN CONSIDERATIONS

For more detailed design considerations, refer to bioretention basin standards in the City of Edmonton's D&C Standards Volume 3-02, Section 5.4. Bioswales must be designed to fit the unique characteristics of each site. The designer is responsible for ensuring the physical attributes of the site can accommodate a swale.

The slope of bioswales must not be greater than 3%. If the slope of the bioswale is 1% or greater, check dams must be used in the design to slow flow.

To ensure the long-term functionality of bioswales, the facility's physical and performance parameters listed in Table 7.1 should be considered during the preliminary design process. A bioswale cross section is shown in Figure 8.2 and accompanying longitudinal profile in Figure 8.3 shows a side view of a bioswale.

***Effective slope** – gradient governing flow velocity within a swale. If the slope of the surrounding terrain is too steep for a bioswale, the effective slope may be flattened by using check dams or drop structures.*

Bioswale designs must filter and convey Edmonton's 1-in-2-year storm event and be within the parameters listed in **Table 7.1**. The drainage area to a bioswale is based on the soil type, ponding depth, and surface area. Surface flow velocity within a swale at a given slope is determined by the roughness of the channel. Different types of vegetation and surface treatments applied in a bioswale will impact flow velocities. Modelling should be performed by designers to demonstrate the function of the bioswale.

The drawdown time of bioswales is based on soil type and ponding depth, and must be reported to ensure safety and aesthetics are maintained. Bioswales along roadways must be designed to prevent compromising the road structure with water infiltration. Ponding areas in bioswales are created by using check dams to retain water and reduce the effective slope (**Figure 8.3**). Effective slope can be determined using the following equation:

$$S_e = S_t - \frac{h}{L}$$

Where S_e is the effective slope;

S_t is the terrain slope;

h is the height of the check dam; and

L is the distance between check dams.

Other design considerations besides those listed in **Table 7.1** include, but are not limited to:

- Weaving swales around mature trees along boulevards and green spaces rather than removing the trees;
- Preventing icing of sidewalks and streets by sizing surface ponding capacity of the swales to accommodate the spring thaw volume of snow, ice and meltwater without considerable infiltration by topsoils (see **APPENDIX A**);
- Designing bioswales that will receive additional snow to account for the added weight because snow piles can cause topsoil compaction;
- Providing curb cuts designed to direct the rate of flow and volume of runoff stormwater into bioswales and protect bioswales from plow blades during snow removal;
- Amending topsoil to mitigate, as much as possible, the effects of de-icing compounds on soils and plants;
- Providing a buffer along arterial roads (5 to 35 m vegetated filter strip) and along collector roads (3 to 5 m filter strip or sidewalk) to protect swale vegetation from salt damage;
- Planting salt tolerant grasses and plants as a buffer between the roadway and less tolerant species (D&C Standards Volume 3-02, Section 5.0);
- Considering spring thaw volumes, soil compaction and salt damage to sensitive vegetation when the bioswale is designed specifically for snow storage;
- Equipping bioswales designed to receive high salt loadings with an underdrain to allow salt to leach from the swale.
- Selecting vegetation that will be able to structurally withstand moderate flow velocities and erosive forces of design events; and
- Providing a buffer between facilities with deep infiltration capability and roadways or building foundations to reduce the risk of heaving or foundation damage due to saturated soils.

The details of bioswales planned for the site must be included on design drawings as indicated in the City of Edmonton's D&C Standards Volume 3-02, Section 5.0.

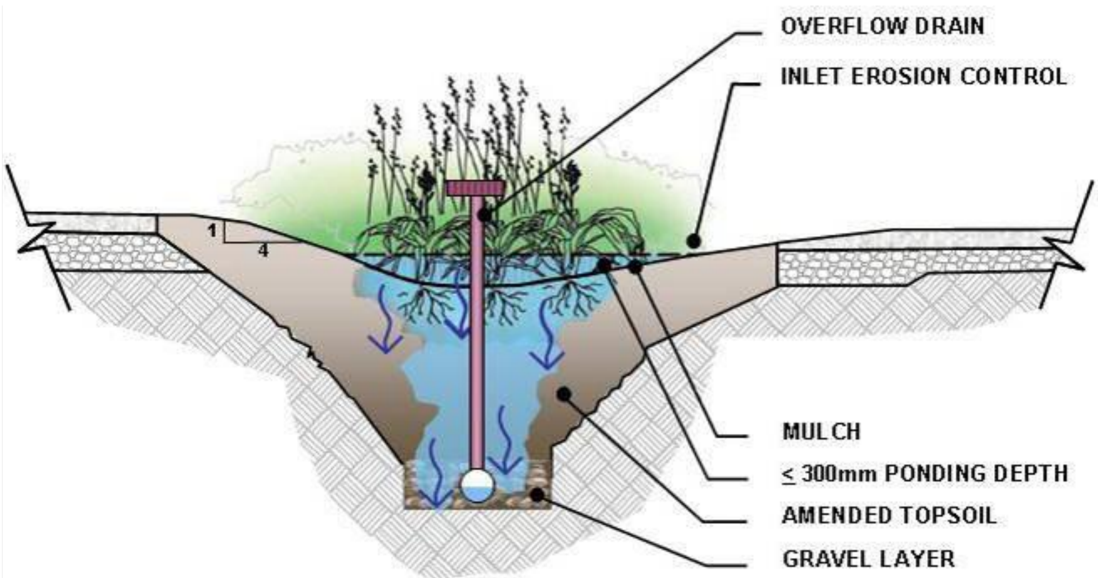


Figure 8.2: Example of bioswale cross section

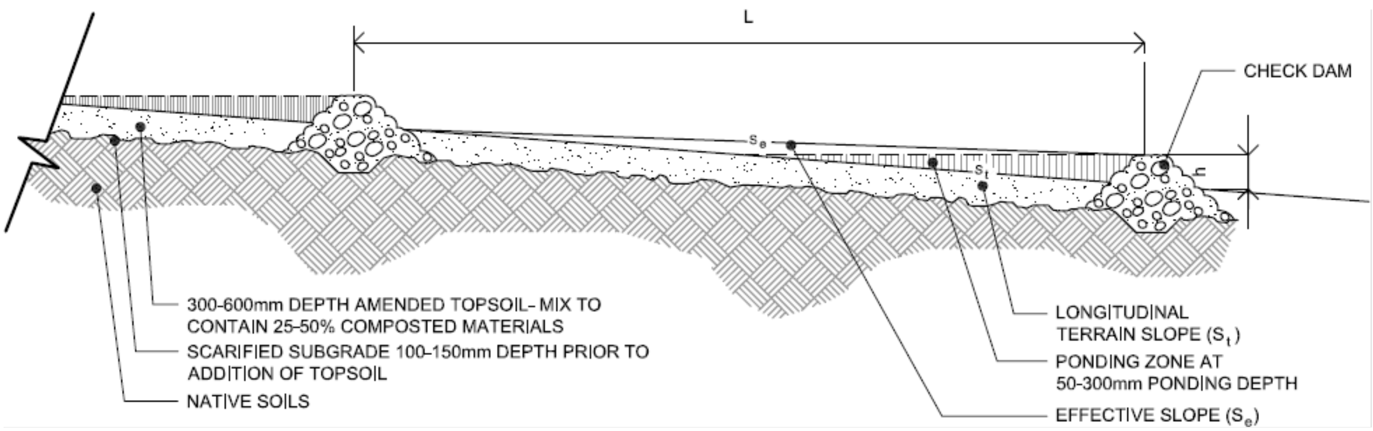


Figure 8.3: Example of bioswale longitudinal profile

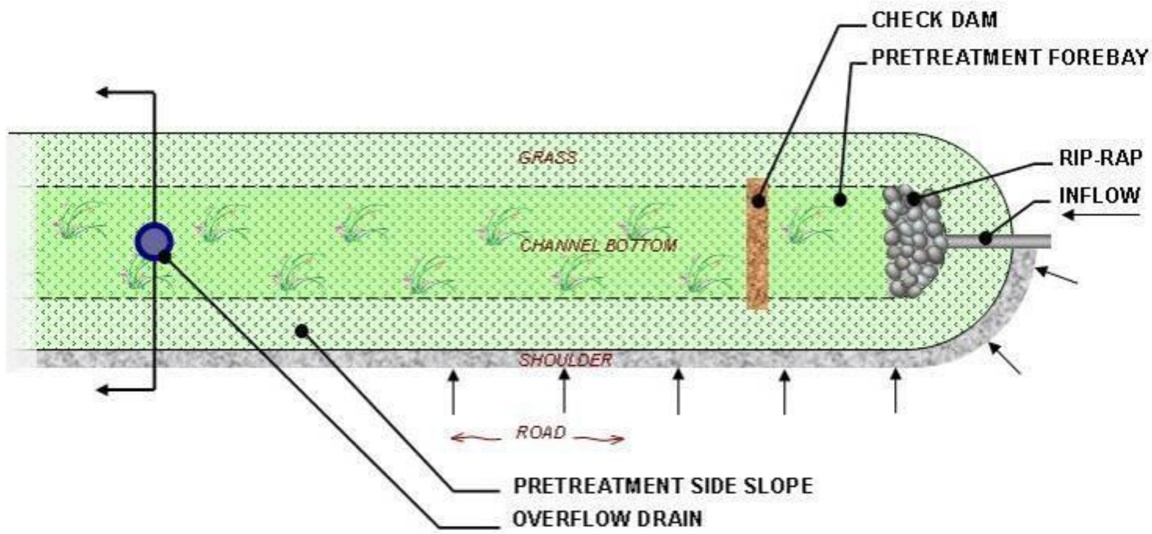


Figure 8.4: Plan view of a bioswale

9.0 GREEN ROOFS

9.1 DESCRIPTION

Green roofs are a stormwater management practice that uses vegetation overlaid on rooftops to delay and retain rainfall. They also offer shade and insulation benefits that result in reduced energy usage. While green roofs are experiencing a surge in popularity in recent years, they are a practice that actually dates back to 500 B.C. in Sumerian civilization (Collins, 2011).

A typical green roof consists of several layers overlying the roof structure. These layers are: vegetation, growing medium, drainage filter, drainage layer, root barrier, waterproof/roofing membrane, cover board, thermal insulation, vapour barrier, and roof and building support structure. These layers are illustrated in **Figure 9.1**. **Table 9.1** describes these layers and their function.

The amount of rainfall retained on a green roof depends on the depth of the growing medium and the roof slope, and it is reported that between 70% and 90% of the annual rainfall that lands on a green roof is retained (Perry, 2003). Green roofs provide shade to underlying surfaces, reducing heat transmission to the building and effectively reducing cooling costs by up to 25% (Goom, 2003). Winter heating costs may also be reduced (www.soprema.ca). Additionally, the process of evapotranspiration by vegetation lowers the temperature of the surrounding air, reducing the urban heat island effect (Peck et al., 2003). Green roofs also provide urban green space and habitat for birds and insects (Peck et al, 2003).

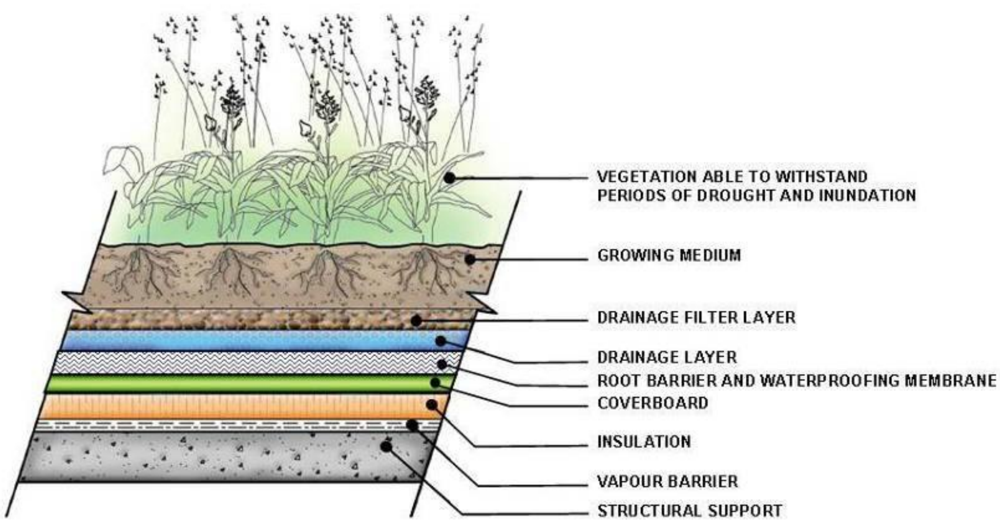


Figure 9.1: Example cross-section of typical green roof layers

Table 9.1: Function of green roof layers

Layer	Description and purpose
Vegetation	▪ Provides the biomass for evapotranspiration and insulation. ▪ Selection depends on the type of roof, building design, climate, sunlight, irrigation needs, intended roof use and similar considerations.
Growing medium	▪ Engineered for optimum support of vegetation, minimum weight and maximum water retention without water logging of plants.
Drainage filter	▪ Geotextile membrane to protect drainage layer. ▪ Prevents loss of growing medium and clogging of the drainage layer from migration of fines.
Drainage layer	▪ Removes excess water, prevents overloading of roof and provides good air-moisture balance in growing medium to prevent plant rot or water logging.
Root barrier	▪ Prevents plant roots from damaging roofing membrane and structural support of roof.
Waterproofing/ roofing membrane	▪ Protects structural support from moisture damage. ▪ Typically more durable in green roofs than in conventional roofs.
Cover board	▪ Thin semi-rigid board. ▪ Provides protection, separation and support for waterproofing membrane.
Insulation	▪ Usually required to meet thermal insulation requirements of the Alberta Building Code. ▪ Can be installed either above or below membrane of green roof.
Vapour barrier	▪ Resists passage of moisture through the ceiling.
Structural support	▪ Supports weight of saturated green roof, snow and wind loads, roof users, etc.

Adapted from USEPA, 2008.

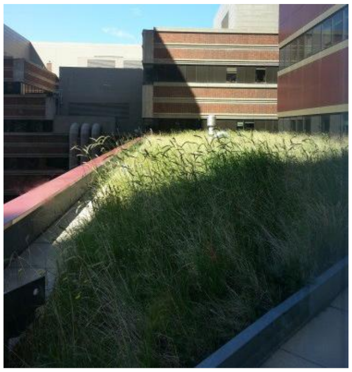
9.2 APPLICATION

Green roofs can be designed as part of new construction or installed as a retrofit following a structural assessment. They are suitable for installation on a wide range of buildings, including industrial, educational, and government facilities, offices, commercial properties, and residences. Generally, buildings with large roof areas are targeted for stormwater management.

Selection of intensive or extensive green roofs will depend on the location and desired function of the roof. Extensive green roofs are lighter weight, typically requiring little to no additional structural support, making them a more economical choice for retrofitting existing structures, whereas a new building may be specifically designed for the extra weight of an intensive green roof. Green roofs can be designed for many roof types. However, where the roof slope is more than 20 degrees, protection against slipping and slumping of the plant layer must be provided. Steeper roofs may retain less stormwater than an equivalent flatter roof.

In general, intensive green roofs are better suited to flatter roofs (5 degrees or less) and may be designed similar to a conventional garden or park space. They are often installed to reduce energy costs and provide an aesthetically pleasing park-like environment for building occupants or the general public to enjoy. Since intensive green roofs are heavier than extensive green roofs, they require more structural support to handle the weight of additional growing medium and public use, resulting in a higher initial investment. They may have greater maintenance requirements, including the need for irrigation systems. However, they are ideal candidates for dense, urbanized areas that have limited or no space available for planting at ground level.

Green roof at Fort Edmonton Park Pump Station, Edmonton, AB



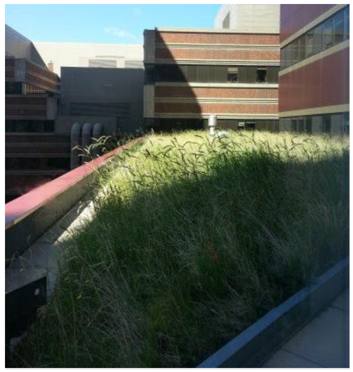
Green roof planted with grasses at the Mazankowski Heart Institute in Edmonton

Newly pl Terwillega showing Ed

Figure 9.2: Local installations of green roofs

Table 9.2 provides a comparison of the distinguishing features of intensive and extensive green roofs.

Green roof at Fort Edmonton Park Pump Station, Edmonton, AB



Green roof planted with grasses at the Mazankowski Heart Institute in Edmonton

Newly planted green roof at Terwillegar Recreation Centre showing perimeter drainage, Edmonton, AB

Figure 9.2: Local installations of green roofs

Table 9.2: Green roof characteristics – extensive and intensive

Green roof type	Growing medium depth (mm)	Growing medium saturated weight (kg/m^2)	Recommended vegetation
Extensive	100 to 150	129.1 to 169.4	Native grasses Sedums
Intensive	200 to 600	290 to 967.7	Native grasses Sedums Shrubs Trees

(City of Toronto, 2009)

9.3 DESIGN CONSIDERATIONS

Green roof designs must include a structural assessment completed by a professional engineer to ensure that the structural loading capacity of the building can support the green roof. To maximize the benefits of the green roof, heating and cooling implications for the building should be considered in the design. At a minimum, green roof designs must:

- Ensure structural stability of the roof to support the weight of both the green roof and snow loads based on continuous precipitation records;
- Confirm compliance of the roof with the Alberta Building Code;
- Consider meltwater runoff from the roof in the hydrologic model because water storage and detention benefits of green roofs will not be realized to the full extent during cold periods while the vegetation is dormant and infiltration through the soil layer is minimal;
- Select plants that can withstand the winter temperatures and snow pack with minimal or no injury; and
- Provide irrigation during the vegetation establishment period. This period may be extended due to Edmonton's limited growing season.

Established green roof at Stantec Consulting corporate office, Edmonton, AB

Green roof at Valley Zoo Arctic Shores in Edmonton, AB.

Entry Plaza in Edmonton, AB.

Intensive green roof at Lois Hole Alexandra Hospital Edmonton, AB.

Figure 9.3: Local installations of green roofs

The green roof design should also incorporate a drainage system to manage overflows from the green roof. The drainage system prevents damage to and erosion of the growth medium during heavy rains, maintaining optimum growing conditions. Adequate drainage also helps to preserve the roof structure.

The physical and performance parameters that are critical for long term operational success of green roofs are listed in **Table 9.3**. These parameters must be considered in the preliminary design process. Details of green roof layers, including material type, saturated weight, installation, maintenance and testing must be specified in the green roof design and are guided by consideration of these critical parameters. Pertinent details for green roof specification are listed in **Table 9.4**. Specifications that must be included on design drawings are identified in **Table 9.5**.

Irrigation of green roofs must be carefully considered during the design of the green roof to ensure that irrigation water will not take up available soil storage space that would then be unavailable during the next rainfall event. A continuous hydrologic model or one of many commercially available soil moisture or evapotranspiration based automatic sprinkler controllers may be warranted with the additional irrigation water input to ensure proper rainwater management is achieved. To reduce reliance on potable water supplies, water for green roof irrigation should be obtained from a cistern collecting excess rooftop runoff.

An electronic leak detection system may also be considered during the design process to help protect the roof from moisture damage. In addition, an electronic leak detection system may provide early warning of maintenance issues.

Table 9.3: Guidelines for green roof physical and performance parameters

Reported parameters	Description
Soil infiltration rate	Provide infiltration rate of growing medium.
Design discharge	Discharge rate through roof overflow during 2-year, 5-year, 10-year, 25-year and 100-year design events.
Captured volume	Volume of water retained within the growth media layer during the 2-year design event; additional volume captured during larger events if applicable.
Roof slope	<5% requires sloped underdrain; 5-20% gravity drainage; >20% lath grid to hold growing medium and drainage layer in place.
Material details	Layer specifications as per **Table 9.4**.
Saturated weight	Weight of layers when saturated and weight of retained rainwater not contained within facility.
Plant density	List of species and mature height, weight and density of vegetation (seeds $\geq$325/m^2; cuttings $\geq$12 kg/100m^2; plugs $\geq$11/m^2).

(City of Toronto, 2009)

Table 9.4: Details and considerations for green roof selection and design

Layer	Profile schematic requirements
Moisture barrier	▪ Material type and specifications ▪ Installation requirements ▪ Testing requirements
Root barrier	▪ Material type and specifications ▪ Installation requirements
Insulation	▪ Material type and specifications ▪ Material thickness
Drainage	▪ Material type and specifications ▪ Depth of layer ▪ Slope of layer ▪ Infiltration rate / hydraulic conductivity ▪ Percent void space
Filter	▪ Material type and specifications ▪ Installation requirements
Growing medium	▪ Material type and specifications ▪ Depth of layer ▪ Infiltration rate / hydraulic conductivity ▪ Percent void space
Planting	▪ Plant species ▪ Planting density ▪ Maximum height of highest species ▪ Weight of fully matured planting ▪ Transpiration rate (based on species or biomass density)

Table 9.5: Green roof drawing and reporting details

Parameter	Plan	Detail	Building Drawings	Description
Materials		x	x	Layer material type, specifications, depth.
Slope		x	x	Roof slope, illustrated to meet specifications.
Outlet		x	x	Roof scupper or downspout with erosion control; provide type, slope, diameter, height above membrane.
Surface area	x		x	Facility area outlined on drawings and stated in report.
Installation				Requirements for surface preparation and layer installation.
Testing				Leak testing, detection and maintenance requirements and schedule.

(City of Toronto, 2009)

9.4 OPERATION AND MAINTENANCE

A recommended schedule for operation, maintenance, and replacement activities for green roofs is contained in **Table 9.6**. This table is provided as a minimum recommendation as the schedule for these activities may vary depending on roof and vegetation type, climate and the level of maintenance acceptable to the owner. Facility designers must provide site specific schedules for operation, maintenance and replacement to ensure the long-term functionality of the green roof.

Facility inspections should be, at minimum, conducted monthly from April to September. Maintenance will include irrigating, fertilizing and weeding until plantings are established. After establishment, maintenance can be limited to two visits per year in the snow-free season for:

- Weeding;
- Debris removal;
- Safety inspection;
- Repair of moisture and root barrier membranes;
- Replacement of dead or dying plants; and
- Replacement of clogged or contaminated soils.

Table 9.6: Suggested green roof operation, maintenance, and replacement activities

Operation activities
Irrigation (5 mm per application).
Fertilizing (use slow release complete fertilizers).
Leak testing and safety inspection.
Inspection for plant health, soil erosion and layer deterioration.
Maintenance activities
Weeding.
Removal and replacement of unhealthy / dead vegetation.
Replacement of eroded soils.
Repair roof membranes and detected leaks.
Remove debris and ensure clear path through roof drainage outlet.
Replacement activities
Waterproof membrane

(Peck, 2003; COP, 2004b; GVRD, 2005, City of Toronto, 2009)

10.0 PERMEABLE PAVEMENTS

10.1 DESCRIPTION

Permeable pavements, also called porous pavement (pavers), include modular and cobble block pavers, structurally reinforced grass and gravel, porous asphalt, and porous concrete. In general, the structure of permeable pavement consists of pavement layer, angular rock filter course, angular rock sub-base, reservoirs course, underdrain (optional), insulations and barriers to protect adjacent buildings or roadway sub-base (**Figure 10.2**).

10.2 APPLICATION

Permeable pavements have been installed in cold climates with excellent results when designed, constructed, and maintained properly. The locations of permeable pavement systems must be carefully considered at the planning stage to ensure that traffic volume, de-icing activities, and operation and maintenance activities are suitable for the long-term functionality of the system. Permeable pavements can be used for low traffic roads, parking lots, driveways, pedestrian plazas and walkways. They are ideal for sites with limited space for other surface stormwater BMPs (TRCA, 2010).

The use of permeable pavements in sites with high levels of sedimentation and high pollution such as gas stations, handling areas for hazardous materials, and heavy industrial sites is not recommended (TRCA, 2010). Contaminated sites must be well understood and the impacts of infiltrated contaminants mitigated.

Properly designed, installed, and maintained permeable pavements have been shown to reduce frost heave, icing, pollutant loading and runoff, and to increase pavement longevity (Gunderson, 2008; Hun-Dorris, 2005).

ENK & Associates Parking Lot, DenverPhoto Credit: Kerri Robinson, AMEC

Porous Asphalt Parking Lot, Denver Photo Credit: AMEC Earth & Environment

Permeable pavers walkway at the University of Alberta East Campus Village, Edmonton, AB

Figure 10.1: Examples of permeable pavement installations

10.3 DESIGN CONSIDERATIONS

Unique site characteristics must be accounted for in the design based on professional knowledge and judgement. To reduce or eliminate potential for frost heaving, the structure and depth of the reservoir and drainage layer in a permeable pavement structure is vital. Appropriate design and construction for cold climates is possible and has been accomplished in other jurisdictions (SMRC, 2010). Consultation with an experienced professional is recommended during the design and construction process.

Figure 10.1 lists design requirements for the facility's physical and performance parameters, such as paver and sub-soil infiltration rate, layer material sizes and depth, under drain size, contributing area, and groundwater buffers.

Permeable pavements should be able to filter and convey the 1-in-2-year storm event. They may also be designed to provide some infiltration capacity within the sub-soils provided the infiltration rate of the underlying soils is $\geq$13 mm/hr.

Selection of pavement material is at the discretion of the designer, provided the infiltration rate and void requirements listed in **Table 10.1** are met. Porous asphalt and concrete must adhere to industry standards for gradation, mixing, and installation. Using contractors with experience installing porous asphalt and concrete is essential due to the sensitivity of the material to mixture and compaction requirements. Pavement materials must be inspected by the design engineer throughout the construction process to confirm consistency of the product, ensuring long-term success of the facility.

Other factors to be considered in permeable pavement design include:

- Alternate methods of discharge of excess stormwater (other than infiltration) if sub-soils have high clay content in order to reduce the risk of heaving during winter;
- Locate facilities appropriately to minimize damage due to anti-skid materials; and
- Provide adequate, rapid drainage for the base structure to minimize the likelihood of freezing while saturated.

Details of all permeable pavement areas planned for the site must be included on design drawings as indicated in

Table 10.2.

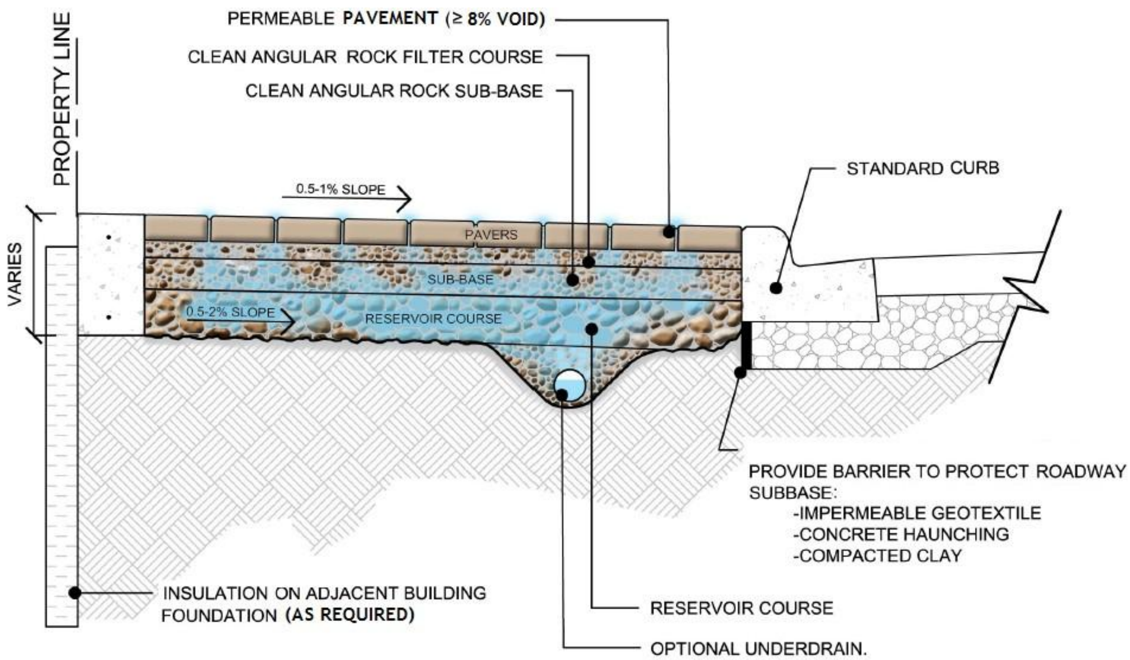


Figure 10.2: Example cross-section of permeable pavement installation

Table 10.1: Permeable pavement parameters and guidelines

Reported parameters	Description
Sub-soil infiltration rate	≥13 mm/hr, underdrain required in tighter soils; ≥26 mm/hr when contact with anti-skid material expected; ≥35 mm/hr when contributing area >4 hectares.
Pavement infiltration rate	Capable of maintaining 28 mm/hr over lifetime based on manufacturers tests and factor of safety of 10.
Open annular space	Cobble: min 8%; modular block / plastic grid: min 20%; asphalt / concrete: min 2%.
Layer materials	Filter course: (10-12 mm angular stone with <0.1% silt) 25-50 mm below base of pavers / pavement.
	Subbase: (25-40 mm angular stone with <0.1% silt) 100-250 mm depth below filter course.
	Stone reservoir: (>50 mm clean gravel with <0.1% silt) 150-500 mm depth below subbase.
Contributing area	Contributing impervious area up to three times the permeable pavement area.
Design discharge	Discharge rate through underdrain for 2-year, 5-year, 10-year, 25-year and 100-year design events.
Longitudinal slope	Subgrade slope 0.5-2%; surface slope 0.5-1%, ideally directed toward adjacent landscaped areas.
Captured volume	Volume of water retained within the pavement structure during the 2-year design event; additional volume captured during larger events if applicable.
Surface flow velocity	As per City of Edmonton specifications for overland flow.
Emptying time	Duration of water detention in reservoir layer <72 hrs.
Groundwater buffer	Bottom of reservoir layer located minimum 0.6 m to 1 m above groundwater elevation.

(USEPA, 1980; SMRC, 2010; GVRD, 2005)

Table 10.2: Permeable pavement drawing details

Parameter	Plan	Detail	Profile	Description
Location	x			Shown on plan view (driveways, parking stalls, pedestrian areas, emergency / delivery vehicle access).
Inlet	x	x	x	Shown on plan view, detail (if applicable), and in report.
Permeable pavement	x	x	x	Permeable surface (pavers, asphalt, concrete) with porosity and mix specifications.
Sub-surface materials		x		Layer order (filter, reservoir, geotextile) and specifications (gradation, hydraulic conductivity, void space).
Slope	x		x	Sub-base slope and surface slope.
Outlet	x	x	x	Underdrain diameter, material, slope & outlet, overflow spill elevation.
Catchment	x			Delineated catchment area directed to swale, report imperviousness ratio.
Summary	x			Summary table that includes LID type, location, catchment area (m^2), imperviousness (%), runoff volume for design storm (m^3), LID capacity (m^3) and surface area (m^2).
Depth	x		x	Depth of each layer, reservoir retention depth (if applicable), surface ponding depth (if applicable), extent of inundation during design storms (if applicable).
Flow arrows	x			From contributing area, within pavement structure and overflow route.
Erosion control	x	x		Located at inlet (until site stabilized), outlet if erosion potential exists.

10.4 OPERATION AND MAINTENANCE

Operations and maintenance requirements will vary depending on the specific type of permeable pavement used. Refer to supplier documentation in developing and operations and maintenance plan for the selected permeable paver product.

Over time, sediments will accumulate in the pores of permeable pavement, reducing the infiltration rate. To mitigate this, regular (annual) vacuuming of the permeable pavement surface is required. Some studies recommend designing the facility so that the installed pavement can maintain a minimum infiltration rate of 28 mm/hr with an applied factor of safety of 10 (initial rate: >280 mm/hr) to account for this reduction in efficiency (GVRD, 2005).

Facility designers must provide site-specific schedules for operation, maintenance, and replacement to ensure long-term functionality of the LID-BMP facility. The schedule for operation, maintenance and replacement activities for permeable pavement is contained in **Table 10.3**. The recommended timeline for these activities may vary depending on location and contributing area characteristics.

Damage to permeable pavements and pavers during winter plowing activities can be avoided by careful installation and maintenance and by using rubber spacers to buffer the plow blade from the surface, if required. Past experience has shown that permeable pavement is not subject to the level of ice build-up that occurs on traditional impervious materials since meltwater can infiltrate immediately. This characteristic should reduce or eliminate the need for de-icing chemicals. If anti-skid materials are required, it is recommended that clean gravel (2 to 5 mm) be used instead of sand, since it is resistant to breakdown and will not clog the permeable pavement pores.

For the permeable grout products approved by EPCOR typical maintenance requirements include pressure washing twice a year and re-grouting if damaged.

Table 10.3: Suggested permeable pavement operation, maintenance and replacement activities

Operation activities
Inspect for broken pavers, loose asphalt / concrete, clogged areas.
Do not apply sand for anti-skid.
Use salt sparingly, in spot applications, for de-icing.
Raise plow 10-25 mm to avoid damage to pavement surface while clearing snow.
Stabilize contributing catchment to prevent sedimentation and erosion.
Street sweeping in contributing catchment to prevent sedimentation.
Surface infiltration testing.
Maintenance activities
Immediately clean chemical or granular spills with vacuum and pressure washer.
Mow (length >100 mm) and remove clippings from structural vegetated surfaces.
Weeding of invasive species.
Litter, leaves, debris and weed removal.
Prune nearby vegetation to avoid debris accumulation.
Repair broken / loose surface material.
Underdrain flush.
Site vacuuming / gravel replacement to remove sedimentation.
Replacement activities
Pavers, asphalt or concrete.
Grass / plants in structural vegetated surfaces (unhealthy or dead >10%).
Gravel drainage layer.
Underdrain.

(Diniz, 1980; COP, 2004b; Gunderson, 2008)

11.0 NATURALIZED DRAINAGE WAYS

11.1 DESCRIPTIONS

Naturalized drainage ways are surface stormwater conveyance features that use wetland zones, drop structures, and natural materials and vegetation to replace storm sewer mains or prevent erosion of existing drainage ways. Naturalized drainage ways generally have frequent or continual runoff (base flow). They are typically larger than grass swales, more engineered than natural wetlands, and, in some cases, may appear similar to a small creek. Velocities of urban runoff and stormwater are slowed using natural vegetation, increased resistance along the flow path, and drop structures (MDEP, 1997). Additionally, prolonged stormwater contact with natural materials promotes the hydrologic cycle through infiltration, evaporation, and transpiration. **Figure 11.1** provides cross sectional details for a naturalized drainage way, with an outlet into a constructed wetland prior to entry into the storm sewer or receiving water body.

11.2 APPLICATIONS

Naturalized drainage ways are typically located near the downstream outlet of a developed basin as they require continuous base flow to maintain the health of wetland and riparian vegetation and prevent occurrence of stagnant pools. They can be implemented as retrofits to replace overloaded storm trunks or small eroded streams, or as part of new developments with long term growth in mind to prevent the occurrence of such situations.

As is indicated by their name, naturalized drainage ways must be designed to fit the unique drainage, topographic, and development characteristics of each site. Natural drainage ways should not be implemented in areas with very flat or very steep topography. The designer is responsible for ensuring that physical attributes of the site can accommodate a drainage way and that the naturalized drainage way will enhance treatment and aesthetics of stormwater management in the area.

Photo Credit: Dr.Robert McGregor, AMEC

11.3 DESIGN CONSIDERATIONS

Naturalized drainage ways require continuous base flow to meet all losses due to evaporation, transpiration, and seepage. The design may incorporate existing natural features such as wetlands, drainage paths, and recharge zones so long as care is taken to maintain natural patterns and avoid sedimentation or pollutant deposition. When incorporating wetlands, discussions with Alberta Environment will be required to approve the design.

Soils must be able to sustain vegetation growth and with vegetation present, withstand storm flows. Loamy soil is recommended for the channel and amended soils must be based on constructed wetland requirements.

The physical and performance parameters listed in **Table 11.1** must be considered during the preliminary design process. The parameters listed in **Table 11.1** are for the naturalized drainage way and its outlet to a wetland, receiving water, or storm sewer.

Naturalized drainage way designs must convey at least the 1-in-2-year storm event with non-erosive velocities (Claytor et al, 1996) and be within the parameters listed in **Table 11.1**. Where longitudinal slopes exceed 1%, drop structures should be used to reduce flow velocities and maintain flat grades. Water quality treatment through filtration by vegetation may be possible in some instances and is dependent on the site. Modelling of each individual site must be completed by designers to demonstrate function of the facility.

Other considerations for design and adaptation of naturalized drainage ways to ensure safety and long term functionality in the Edmonton climate and soils are as follows:

- Design and locate facilities for pedestrian access and provide safety measures appropriate for expected flow depths and velocities;
- Design vertical profile of vegetation located along roadways or near intersections to prevent impedance of driver visibility;
- Select vegetation to be able to withstand moderate flow velocities, erosive forces of design events and cycles of drought and inundation;
- Select salt tolerant species for plantings along roadways (the City of Edmonton's D&C Standards Volume 3-02, Section 5.0);
- Size facilities receiving road runoff containing salts to prevent salt induced injury to plants and soils as per **APPENDIX A**; and
- Design soil amendments in roadside facilities to buffer high salt loadings.

The plan view, details and profiles of any naturalized drainage ways must be included on design drawings as indicated in **Table 11.2**.

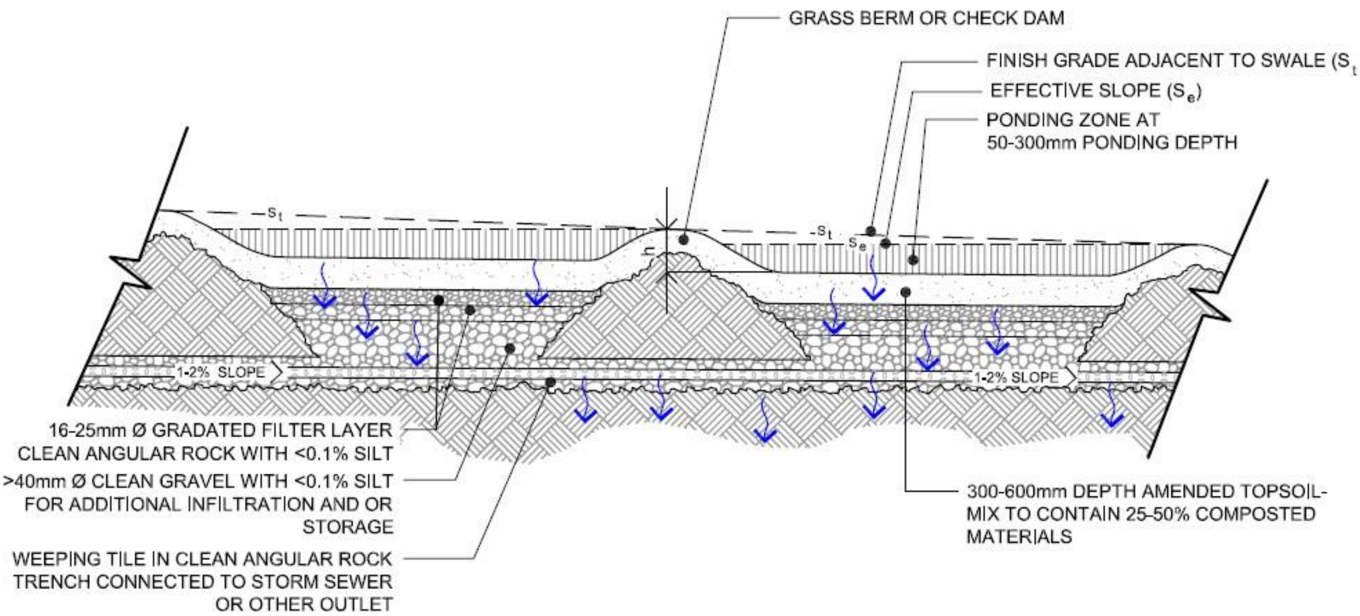


Figure 11.1: Example longitudinal view of naturalized drainage way with check dams

11.4 OPERATIONAL MAINTENANCE

Operational requirements to keep maintenance of naturalized drainage ways to a minimum include street sweeping, soil testing in high pollution areas, and removal of organic matter and sediment. Similar to grass swales, naturalized drainage ways should be inspected quarterly during establishment (first 2 years) and semi-annually thereafter, with spot inspections conducted after severe storm events. Visual inspection during spring break-up is important to mitigate flooding due to ice blockage.

EPCOR

Table 11.1: Naturalized drainage way parameters and guidelines

Reported parameters	Description and recommendation
Contributing area	≥1 ha.
Baseflow	Near continual baseflows resulting from return flows from residential or commercial water uses in contributing catchments, or proximity to water table.
Design discharge	Safely convey Q_2 event with non-erosive velocity (0.6 m/s to 1.5 m/s, depending on vegetation and soil type); Q_{10} and Q_{100} not to exceed rates defined in Master Stormwater Drainage Plan.
Flow-through velocity	Determine flow through capacity (maximum flow without re-suspending and flushing trapped pollutants) using hydraulic modelling; non-erosive velocities 2-year, 5-year, 10-year, 25-year and 100-year design events.
Flow depth	0.6 m to 1.2 m during a 2-year design event.
Ponding depth	0.15 m during a 2-year design event.
Media layers	Growing media: (amended soil) 300 mm to 650 mm depth able to support dense vegetation.
Vegetation	Grasses and dense vegetation (100% coverage at establishment – 2-years) on drainage way slopes and within wetland zones along drainage way.
WSE in design storms	Show that high water level in 100-year return period storm events do not compromise adjacent structures.
Captured volume	Volume of water retained through ponding and surface infiltration during the 2-year design event; additional volume captured during larger events, if applicable.
Emptying time	Duration of water quality volume ponding following design events is 24 hrs; however, baseflow ponding may extend beyond this time period and designs requiring this characteristic must be made accordingly.
Geometry	Site specific to take advantage of existing topography and natural water features; typically, trapezoidal or parabolic; provide cross-section details with dimensions labelled.
Side slopes	3:1 (H:V) or flatter preferred (max 2:1).
Longitudinal slope	Determine effective slope (>0.1%) for the 2-year design event using Manning's equation with initial n=0.035 and at maturity n=0.08; slopes >1% require grade control structures to flatten longitudinal slopes to less than 0.5% between grade control structures.
Groundwater buffer	Where appropriate, groundwater table may be in continual or intermittent contact with facility to sustain wetland vegetation.
Structural buffer	Facility located ≥3 m from building foundations.
Planting plan	Velocity tolerance for the 2-year design event flow; emergent plantings to be resistant to intermittent inundation and prolonged drought; wetland plantings appropriate where bottom is expected to receive continual baseflows.

(UDFCD, 2008; MSSC, 2005; COP, 2004b; Claytor et al, 1996; Caraco et al, 1997)

Table 11.2: Naturalized drainage way drawing details

Parameter	Plan	Detail	Profile	Description
Inlet	x	x	x	Shown on plan view and typical detail provided (pipe daylight, curb cut, flow spreader, ribbon curb, OGS): inverts; sizes; slopes; and, materials.
Materials	x	x	x	Material specifications (soil, drainage material, drainpipes, geotextile), depth and hydraulic conductivity.
Slope	x		x	Side slopes, longitudinal slope, effective slope, check dams or drop structures and flow disconnection curtains.
Outlets	x	x	x	Spill elevation, catch basin type and grate, weir and inlet control device (ICD).
Catchment	x			Delineated catchment area directed to naturalized drainage way, including daylighted pipe catchment.
Summary	x			Summary table that includes LID type, location, catchment area (m^2), imperviousness (%), runoff volume for design storm (m^3), LID capacity (m^3) and surface area (m^2).
Depth	x		x	Ponding depth, extent of inundation, and water surface elevation during design storm and maximum prior to spill.
Flow arrows	x			From contributing area; within drainage way and wetland zones; overland spill route.
Erosion control	x	x		Located at all inlets until site stabilized; outlets if overland spill.
Landscaping	x	x		Detailed planting plan and succession plan if required, for drainage ways and wetland zones.

(COP, 2004b; Claytor et al, 1996)

12.0 RAINWATER HARVESTING FOR RE-USE

12.1 DESCRIPTION

Rainwater is drops of freshwater that fall as precipitation from clouds. Rainwater harvesting is the collection and conveyance of rainwater from a building roof to storage in a rain barrel or a cistern for re-use in irrigation or approved non-potable uses. **Figure 12.2** shows a schematic of a rainwater harvesting system with a buried cistern. Key components of such a system include the roof surface, gutters and downspouts, roof washer to remove contaminants, cistern, and pumping and piping system. **Table 12.2** lists and details these components.

Above ground cisterns may include:

- Rain barrels that receive unfiltered runoff from downspouts and are not connected to automatic irrigation systems;
- Rooftop capture cisterns which provide irrigation pressure through gravity;
- Above grade bladders which may be located in tight spaces and an external pump to provide irrigation pressure; or
- Cisterns incorporated into a heated building allowing year-round water use for non-potable purposes.

Above ground cisterns are easily implemented. However, care must be taken to prevent damage and leakage due to winter freeze/thaw cycles. These cisterns require both an overflow and a drain to allow for winterization and for facility cleaning. Underground cisterns require cleanout ports or maintenance hole access, depending on the cistern design. Concrete cisterns must be winterized to prevent cracking and subsequent leaking due to the winter freeze/thaw cycle. Buried cisterns may also be made of plastic void crates able to withstand freeze/thaw cycling but requiring periodic vacuum cleanout as part of maintenance activities.

Residential rain barrel to harvest roof runoff for irrigating plants.

Residential rain barrel to harvest roof runoff for irrigating plants. Edmonton, AB

Residential rain barrel to harvest roof runoff for irrigating plants. Edmonton, AB

Figure 12.1: Installation of rainwater harvesting systems

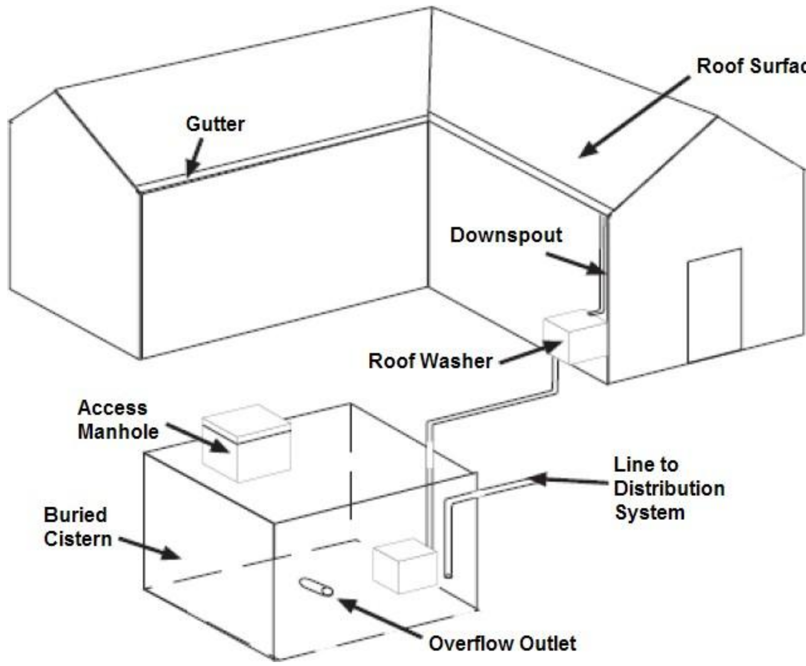


Figure 12.2: Example rainwater harvesting system schematics

(adapted from Rupp, 1998)

12.2 APPLICATION

Depending on the jurisdiction, rainwater can be used for outdoor irrigation, toilet flushing, and washing clothes. Re-use sources and applications are governed by federal and provincial legislation. In Alberta, rainwater re-use for irrigation is widely accepted and re-use for toilet flushing is becoming more common.

Topography, land use, and location all have impacts on rainwater harvesting system design and performance. Rainwater harvesting using a rain barrel typically does not require anything more than directing a downspout into a water storage container and then manually drawing water for irrigation.

Rooftop cisterns are likely to capture less rainwater due to structural limitations; however, gravity-based distribution to a re-use site is possible. Buried cisterns require pumping but store more water (TRCA, 2009) and should be located in native soils. If installation in a fill slope is necessary, both geotechnical and structural engineering design are required. Buried cistern overflows should be located with consideration for the foundation location. Lot grading, both adjacent to and downstream of the buried cistern overflow, should be designed to avoid flooding, ponding or soil saturation. Tanks should be water tight and installed at least 3 m from building foundations (TRCA, 2009). The location of utilities and services must be considered when placing buried cisterns to avoid conflicts.

Rainwater should only be harvested from roof surfaces. Avoid harvesting rainwater from vehicular or pedestrian areas, surface water runoff, or standing water to prevent introduction of contaminants such as salts, bacteria and metals (COP, 2004a). Due to the minimal water quality treatment available with rainwater harvesting, it is best paired with additional LID-BMP facilities when pollutant loading targets must be met.

12.3 DESIGN CONSIDERATIONS

Unique site characteristics must be considered in the rainwater harvesting system design based on professional knowledge and judgement. Cisterns must be designed and installed by qualified professionals, according to the manufacturer's instructions.

The following recommendations and criteria are provided to aid in the design of rainwater harvesting and re-use installations:

- The volume of rainwater that may be collected from a roof surface must be determined for each unique application based on the roof footprint or exterior roof area (ft^2 or m^2). A roof surface is generally about 75% efficient in collecting rainwater due to evaporation, abstraction and leakage, so the volume available for capture from a roof surface can be calculated using the following formula:

$$V_{rw} = \frac{0.75 * RA * D_{rw}}{1000}$$

Where:

V_{rw} = Volume of available rainwater for capture (m^3)

RA = Roof area (m^2)

D_{rw} = Average annual rainfall depth (mm)

- The volume available for capture from a rooftop may exceed, meet, or fall short of seasonal demand requirements based on bi-weekly rainfall patterns, size of the cistern, and other water uses. Careful sizing of the cistern is required, by a qualified irrigation or engineering professional, to ensure the size and costs of installation are appropriate for the capture volume and non-potable demands;

- A cistern may be connected to a potable water source, such as municipal water, for top-up in the event that demand exceeds captured volumes. The potable water top-up must have backflow prevention measures in place;

- Cistern overflows must be directed away from building foundations to avoid flooding or damage to the foundation during large events;

- The roof washer (first flush diverter) should be designed to divert the first 0.5 mm of runoff during an event away from the storage facility to avoid clogging or contamination. As a result, treatment of the diverted water does not occur unless the diverted water is directed to another LID-BMP facility in a treatment train approach;

- Account for frost depth and freeze / thaw cycles when specifying depth and type of outdoor cisterns;

- Confirm compliance with the Alberta Building Code; and

- Consider timing of seasonal water availability and demands using continuous precipitation modelling for determining the optimal cistern size.

Cisterns located within a building envelope must be included on drawings submitted for the building permit. Buried cisterns should be installed in native soils whenever possible to ensure subsurface stability (TRCA, 2009). Due to the capture and retention function of rainwater harvesting systems, natural soil testing is required only for buried systems. Other inspection and testing activities recommended to be completed during and following construction include:

1) A plumbing inspection to ensure its compliance with CSA B128 and

City of Edmonton bylaws; and

2) Leak testing of cistern and irrigation piping before commissioning.

Rainwater and greywater have different sources and therefore different requirements and limitations for re-use in Canada.

To ensure long term operational success of these installations, the facility's physical and performance parameters as listed in **Table 12.2** must be considered and included in the design.

12.4 OPERATION AND MAINTENANCE

Operational requirements include inspecting gutters and leaf screens, roof washers, filters, pumping and piping systems, and the cistern itself for leaks and sedimentation. The schedule for operation, maintenance, and replacement activities for cisterns is in **Table 12.3**. Filter and screen inspections are recommended monthly from April to September, and after a severe storm event. This table is provided as a minimum recommendation, as the schedule for these activities may vary depending on cistern type, location, and the manufacturer's recommendations.

Table 12.1: Rainwater harvesting system components

Components	Description
Gutter screen (leaf screen)	Prevents large debris and leaves from entering roof gutters.
Rainwater conveyance	System of gutters, downspouts and pipes (generally plastic) to carry water from roof to cistern.
Roof washer (first flush diverter)	Directs first 0.5 mm of rainwater volume, containing higher pollutant loads, away from cistern.
Filter	Removes smaller debris, particulates and bacteria from rainwater prior to entry into cistern; often included in roof washer.
Cistern	Watertight tank or void space connected to roof downspouts and re-use outlets.
Cistern overflow	Outlet pipe to surface or subsurface drain for use when cistern volume is exceeded.
Pump	Submersible or surface pump to pressurize irrigation or plumbing.
Delivery conveyance	Irrigation and non-potable water pipes, marked in purple as per CSA B128, with appropriate signage ("Warning: Non-Potable Water - Do Not Drink") at hose bibs or faucets.
Potable water top up	Pipes connected as per CSA B128, with backflow prevention to prevent contamination of potable water source.
Level indicator	Level indicator (float or other sensor) to trigger potable system top up when cistern volume drawn down.

(Kloss, 2008; CRDWS, 2007)

Table 12.2: Rainwater harvesting system design parameters and guidelines

Design parameters	Description
Gutter screen	Maximum screen size: 10 mm.
First flush diversion	Volume: 0.5 mm * roof area; spill directed away from building foundation.
Filter	Materials (type and depth of layer); treatment capacity (particle size and pollutants removed); maintenance schedule.
Cistern	Location: protected from direct sunlight, (sub)surface; volume, material specifications, overflow elevation; access port or maintenance hole.
Expected demand	Automatic or manual withdrawal, expected rate of withdrawal, expected purpose for re-used water.
Potable connection	(Optional) expected volumes and pattern of use; method of initiating top-up (manual / automatic).
Pump	Specification, type, and location (submerged or external).

(Kloss, 2008; CRDWS, 2007)

Table 12.3: Suggested cistern operation, maintenance, and replacement activities

Operation Activities
Inspect cistern, pipes and pump for leaks and clogs
Inspect filters.
Inspect roof gutter screens.
Irrigation hook-up.
Irrigation winterization and empty outdoor rain barrel/cistern.
Maintenance Activities
Litter, leaves and debris removal.
Prune nearby vegetation to avoid debris accumulation.
Repair leaks and cracks.
Filter cleaning.
Flush inlet and outlet pipes.
Vacuum / flush cistern to remove sedimentation.
Replacement Activities
Large shrub / tree removal.
Filter.
Cistern.
Pipes.

(COP, 2004a; City of Tucson, 2005)

GLOSSARY

Term	Definition
A Horizon	Surface mineral (topsoil) horizon.
Absorption	The physical uptake of water or dissolved chemicals by soils or organisms such as microbes or plant roots.
B Horizon	Enriched mineral horizon.
Biodegradation	Decomposition of any material by microorganisms.
Brownfield	Abandoned or under used commercial or industrial land available for re-development.
C Horizon	Undisturbed mineral horizon.
De-Icing activities	Salt and sand application to roadways during the winter to prevent ice build-up and provide traction.
Depression storage	Water retained in puddles and other surface depressions of the ground.
Detention (stormwater)	Water volume contained in a facility and released to the storm sewer network at a slower rate than the event runoff rate.
Disconnected impervious areas	Impervious surfaces, such as roofs, driveways, parking lots, that are designed to drain to vegetated surfaces or LID-BMP facilities.
Ecology	Study of organisms, their habitat and their interactions with the environment.
Erosion	The mechanical process of wearing or grinding something down (as by particles washing over it).
Evaporation	Process by which liquid water converts to water vapour by energy from heat or air movement.
Expansive soils	Soils that contain water-absorbing minerals and expand as they take on water.
First flush	During a rain event, the initial surface runoff from impervious surfaces which contains elevated pollutant loads accumulated during the preceding dry period.
Greenfield	Land that has not been previously developed.
Groundwater recharge	Replenishment of existing natural groundwater aquifers from surface water or precipitation.

Term	Definition
Holistic	Considering the importance of the whole system and the interdependence of its parts, including ecology, biology, hydrology, environment, sustainability, economics, growth, etc.
Hydraulic conductivity	The rate at which soil allows water to move through it.
Hydrologic cycle	Natural cycle of water from the atmosphere, to precipitation, to runoff, infiltration and groundwater recharge, to evaporation and transpiration back into the atmosphere.
Hydrology	Study of the movement, distribution and quality of water throughout the Earth and its atmosphere.
Impervious surfaces	Prevent water from passing through or penetrating into the sub-soils.
Indigenous vegetation	Plants that are native to a specific locale.
Infiltration	Process by which water penetrates into soil from the surface or upper layers.
Interception	Rainwater held by plants as the water falls onto leaves, stems and branches.
Invasive species	Non-indigenous species, or non-native plants or animals that adversely affect the habitats and bioregions they invade economically, environmentally, and/or ecologically.
Level spreader	Stormwater outlet designed to convert concentrated runoff to sheet flow.
Minor system	Stormwater sewers designed to accommodate 1-in-5-year storm event flows.
Non-point source	Pollutants or stormwater flows entering a facility or waterbody through overland sheet flow rather than through a specific discharge location (point source).
Ornamental vegetation	Vegetation typically grown in for aesthetic (flowers, fruit, etc.) purposes.
Passive recreation	Emphasizes the open-space aspect of a park and involves a low level of development, including picnic areas and trails.
pH	Degree of acidity.
Pre-development hydrology	Amount of water contributing to runoff and other stages of the hydrologic cycle prior to incorporation of impervious area (development) on the site.
Rainwater	Drops of fresh water that fall as precipitation from clouds.

Term	Definition
Retention (stormwater)	Water volume captured in a facility and released to groundwater or the atmosphere through the hydrologic cycle instead of to the storm sewer network.
Retrofit	Installation of new technology or features (i.e. LID-BMPs) to existing developments.
Riparian	On, of, or relating to the banks of a natural course of water.
Runoff	The portion of rainfall that is not abstracted by interception, infiltration, or depression storage.
Sedimentation	The act or process of depositing sediment.
Sheet flow	Slow, shallow stormwater runoff over the land surface.
Source control	Facilities distributed throughout a site to capture and treat stormwater runoff from small catchment areas.
Stormwater	Precipitation during a storm event that does not absorb into the soil and runs off into surface water bodies or stormwater management facilities.
Subdivision of land	The division of a lot, tract, or parcel of land into two or more lots, plots, sites, or other divisions of land for the purpose, whether immediate or future, of sale or of building development.
Tight soils	Soils resistant to infiltration.
Transpiration	The process of releasing water vapour through surface pores; typically refers to vegetation.
Treatment train	LID-BMPs placed in series to improve water quality treatment so that each successive cell receives cleaner water than the previous one.
Turbidity	Cloudiness or opacity in the appearance of water caused by suspended solids or particles.
Urban heat island	An area, such as a city or industrial site, having consistently higher temperatures than surrounding areas because of a greater retention of heat, as by buildings, concrete, and asphalt.
Urbanization	Physical growth of an urban area resulting in the conversion of pervious surfaces with impervious ones.
Water quality capture volume	The storage needed to capture and treat the runoff from 90% of Edmonton's average annual rainfall.
Water quality sonde	Device in the logging assembly that senses and transmits water quality data.

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APPENDIX A - COLD CLIMATE FACILITY SIZING EXAMPLE

Facility Sizing Examples Example 1: Sizing a LID-BMP facility for cold climate conditions assumptions:

Watershed area	0.5 ha
Impervious area fraction	100%
Average annual snowfall	123.5 cm
Average daily max January temp	-7.3 degrees Celsius
Average annual precipitation	365.7 mm
% of snow hauled from site	0%
Sublimation	insignificant
Pre-winter soil conditions	moderate moisture

$M = 10\%*S - L_H - L_S - L_{WM}$

where M = moisture in snowpack (mm)
S = annual snowfall (cm)
L_H, L_S, L_{WM} = losses to hauling, sublimation and winter melt, respectively (mm).

STEP 1 Determine if oversizing is necessary.

Average annual precipitation is less than 1/2 of average annual snowfall and snowfall is greater than 900 mm, oversizing is required.

STEP 2 Determine the annual losses from sublimation and snow plowing.

Loss from snow hauling based on 20% removal from site:

$L_H = 20\% * 10\% * (S*10\ mm/cm)$

where L_H = water equivalent lost to hauling snow offsite
S = annual snowfall (cm)
10% = factor to convert snowfall to water equivalent
0 mm = 0%*0.1*(123.5*10)

Sublimation is negligible: LS = 0

In Edmonton, sublimation may be significant and should be accounted for.

STEP 3 Determine the annual water equivalent loss from winter melt events.

Using information in Step 2, moisture equivalent in snowpack remaining after hauling is:

S*10 mm/cm * 10% - LH = 123.5 cm*10*0.1 - 24.7 mm = 98.8 mm

Substituting into Table C. 1, using column 2, and interpolating, the volume lost to winter melt L_{WM}, is:

L_{WM} = 49.4 mm

Table C. 1: Winter snowmelt

(adapted from Caraco et al., 1997)

Adjusted snowfall moisture equivalent	Winter snowmelt (January maximum temperature < -3.9°C)	Winter snowmelt (January maximum temperature < 1.7°C)
50.8 mm	25.4 mm	33.0 mm
101.6 mm	50.8 mm	68.6 mm
152.4 mm	76.2 mm	101.6 mm
203.2 mm	101.6 mm	134.6 mm
254 mm	127 mm	170.2 mm
304.8 mm	152.4 mm	203.2 mm

STEP 4 Calculate final snowpack water equivalent, M.

$M = 10\%*S - L_H - L_S - L_{WM}$

M = 0.1*123.5 cm*10 mm/cm – 0 mm – 0 mm - 49.4 m

M = 74.1 mm

STEP 5 Calculate the snowmelt runoff volume, R_S.

$R_S = (100\%-I)*(M-Inf)+I*M$

where I = percent impervious area contributing

Inf = infiltration (mm), assuming average moisture (20 mm) Rs = (100%-100%)*(74.1 mm -20 mm)+100%*74.1 mm

R_s = 74.1 mm

STEP 6 Determine the annual runoff volume, R.

Use the Simple Method (Schueler, 1987) to calculate rainfall runoff:

$R = 0.9*R_V*P$

where P = annual rainfall (mm)
$R_V = 0.05+0.9*I$, where I is the imperviousness % R = 0.9*(0.05+0.9*1)*365.7 mm
R = 312.7 mm

*Simple Method based on 25.4 mm rainfall which is close to the 1-in-2 year event of 26.6 mm so the simplifying assumptions of the original analysis (Schueler 1987) were used. http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm

STEP 7 Determine the runoff volume to be treated, T.

T = (Rs - 0.05*R)*A*10

where A = contributing area, ha
T = (74.1 mm - 0.05*312.7 mm)*0.5ha*10 T = 292 m3

STEP 8 Size the BMP.

The volume treated by the base criteria would be the larger of:

- Water Quality Volume:

$WQ_v = R_V*P_{WQ}*A*10$

where R_V = volumetric runoff coefficient P_{WQ} = water quality depth, mm A = contributing area, ha
$WQ_v = (0.05+0.9*1)*26.6$ mm*0.5 ha*10 $WQ_v = 126.4$ m^3

- Cold Climate Volume:

$V_{cc} = 0.5*T$ therefore this is the volume used to size the BMP

$V_{cc} = 146$ m^3

Sites required to accommodate the full snowpack melt volume on the surface will require dedication of a significant portion of the land to LID facilities. Cold climate sizing should only be used for sites where overflow from LID facilities cannot be accommodated safely in the minor and major storm systems and where overflow from the facilities will cause property damage or become a danger to public safety.