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BNQ 3019-190/2013

Reducing the Urban Heat Island Effect — Parking Lot Development — Design Guide

BUREAU DE NORMALISATION DU QUÉBEC

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Reducing the Urban Heat Island Effect — Parking Lot Development — Design Guide

Lutte aux ilots de chaleur urbains — Aménagement des aires de stationnement — Guide à l'intention des concepteurs

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The equivalent expressions **ought to** and **it is recommended that**, are used to indicate a useful, but not mandatory, suggestion or to indicate the most appropriate means of complying with this document.

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REDUCING THE URBAN HEAT ISLAND EFFECT — PARKING LOT DEVELOPMENT — DESIGN GUIDE

INTRODUCTION

Eleven of the last twelve years rank among the warmest years recorded since 1995 and can be attributed to rising levels of greenhouse gases (GHGs) in the atmosphere [61]. North American cities, "that currently experience heat waves, are expected to be further challenged by an increased number, intensity and duration of heat waves during the course of the century" [61]. In Québec, the warmest ten years of the 20th century were recorded starting in the 1980s [66]. Projections indicate that average temperatures will continue to rise in the coming decades [61], [14].

This constant rise in temperature, which has been observed and is still projected, will accentuate an issue that has now become familiar: the urban heat island effect. Urban heat islands occur in urban areas where the surface temperature or ambient air temperature is significantly higher than the average temperature of the overall city. In addition to the local climate - influenced by various meteorological parameters like temperature, relative humidity and wind - several anthropogenic causes promote the emergence and intensification of urban heat islands. These causes are the progressive loss of forests and vegetation cover, the impervious nature and low albedo of materials, the thermal properties of materials, the urban morphology, the size of cities and the heat production associated with human activity (air conditioning, vehicles, commercial and industrial activity and so forth). Moreover, intensified urbanization exacerbates this phenomenon in Québec's southern regions.

Urban heat islands present a risk to public health, particularly to certain vulnerable populations, including socially isolated people and the elderly. Summer heat waves, accentuated by urban heat islands, can cause discomfort, weakness, loss of consciousness, cramps, fainting, heat stroke and can further exacerbate existing chronic illnesses like diabetes, respiratory failure and cardiovascular, cerebrovascular, neurological and kidney diseases to the point of causing death [13], [52]. On the recommendation of the World Health Organization, health agencies from around the world, including those in Québec, have instituted various programs to mitigate the effects of intense heat and to reduce urban heat islands. The Institut national de santé publique du Québec, in conjunction with the Direction de santé publique de Montréal, produced a mapping tool to detect urban heat islands and locate certain vulnerable populations in Québec.

Large urban areas that have been paved, including road infrastructure, school yards, streets and parking lots, are covered in bitumen and other low albedo materials that absorb most of the solar radiation. During hot sunny days, these surfaces can reach temperatures as high as 50°C, creating urban heat islands [63]. However, an integrated development approach can counter the formation of

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urban heat islands and also help better manage stormwater runoff, two issues that could worsen in a context of climate change.

With public health protection in mind, this guide aims to counter the formation of urban heat islands in parking lots by proposing courses of action for more tailored and strategic development.

If the design objective is to limit the increase of a city's overall area covered by parking lots, there are several measures that can be implemented to this effect, including urban development methods that foster sustainable mobility, the use of public transit and car pooling or tightening urban perimeters.

However, these topics are not addressed here since they require other kinds of intervention, while this guide focuses on parking lot development techniques with the aim of reducing the urban heat island effect.

It should be noted that the organisation Vivre en ville proposes a broader approach that looks at those concepts.

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1 PURPOSE AND SCOPE

The purpose of this guide is to provide information, guidelines and recommendations to improve the thermal performance of parking lots in order to reduce the urban heat island effect.

The guide presents the properties of urban heat islands, urban heat island mitigation measures and reference documents on this topic.

This guide focuses on certain development practices like the use of natural green spaces, landscape techniques, road surfaces and infrastructure relating to stormwater runoff and other land uses. It provides examples and recommendations for developing parking lots.

This guide applies to the development and redevelopment of off-street parking lots, whether small or large. It applies to existing parking lots, projected parking lots or parking lots due to be renovated.

This guide is intended for designers, landscape architects, municipalities, agencies, government departments and parking lot owners.

2 REFERENCE DOCUMENTS

The reference numbers in square brackets indicate documents whose full reference is given in Annex H. The references to other documents that address the topic of this guide are given in the bibliography of Annex I.

3 DEFINITIONS

For the purpose of this document, the following definitions shall apply:

albedo, n. The ratio between the solar radiation reflected by a surface and the overall incident solar radiation upon it. French: ***albédo***.

> NOTE — Albedo values vary between 0 and 1. The higher the albedo of a surface, the more the surface reflects light and the less it heats the ground and, consequently, the atmosphere.

emissivity, n. The property of a body's surface to emit heat by radiation, expressed as the ratio between the radiation emitted by this surface and that emitted by a body that absorbs and transmits all the radiation reaching it (called a black body), when both bodies are at the same temperature. French: ***émissivité***.

> NOTE — The emissivity of an aluminium sheet is 0.09 and that of a brick 0.90. A material reflecting all the radiation reaching it will have no emissivity at all.

impervious surface, n. A parking lot surface that allows water to run off and reach an evacuation outlet without allowing the water to infiltrate into the ground. French: ***surface imperméable***.

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pervious surface, n. A parking lot surface that allows water to infiltrate into the ground. French: ***surface perméable***.

solar reflectance index, n. (abbrev.: **SRI**). A metric usually expressed by a number from 0 to 100 combining a body's ability to absorb and to re-emit heat (emissivity) and the fraction of the solar radiation (direct and diffuse) that is reflected by a surface (albedo). French: ***indice de réflectance solaire*** (abbrev.: ***IRS***).

thermal performance, n. The evaluation of precise parameters like the percentage of shade, the average SRI, water retention areas and other parameters that allow a parking lot to be assessed, on an arbitrary scale, for the extent of its cooling capacity. French: ***performance thermique***.

NOTE — A high thermal performance means that the heat island effect is low.

urban heat island, n. An area in an urban setting where the air temperature is higher than nearby areas leading to an increase in the heat effect felt locally. French: ***ilot de chaleur urbain***.

NOTE — Three types of urban heat islands are distinguished in literature:

- Surface heat islands: By measuring the infrared radiation emitted and reflected by surfaces, the locations in a city where the surfaces are hottest can be identified;
- Canopy layer heat islands: The canopy layer is the layer of air between the ground and the treetops or between the ground and the roofs of buildings, where most human activity takes place;
- Boundary layer heat islands: The boundary layer is located above the canopy layer. Canopy and boundary layer heat islands impact air temperature [59], [80].

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4 CHARACTERIZATION OF URBAN HEAT ISLANDS

4.1 THE URBAN HEAT ISLAND PHENOMENON

Environment Canada describes urban heat islands as *built-up areas whose summer temperatures are higher than nearby areas with differences that vary, according to the authors, from 5°C to 10°C.*

It has been shown by several authors [39], [44], [68], [69], [71], [77], [78], [81], [82] that land development practices have had a direct effect on the presence of heat islands, with an influence on the thermal comfort of citizens. “Different land uses or changes in land use cause various climatic reactions due to different albedos. Of course, the albedo is not the only factor responsible for climatic differences between two surfaces and identifying the other factors and their respective influences remains a challenge.” [77 (Translation)]

Nevertheless, it can be stated that the construction materials used to build urban infrastructure, such as bitumen-covered surfaces, promote the formation of urban heat islands. An American study conducted in four large cities showed that paved surfaces represent from 30% to 45% of the built-up area [34], which justifies the need to pay more attention to the development of these areas, parking lots in particular.

The large paved surfaces found around shopping centres can influence air temperature even beyond the physical limits of the land occupied by the parking lot. The rise in temperature can be felt in neighbourhoods located near the urban heat islands. Examples of temperature profiles measured around shopping centres clearly demonstrate this (see Annex A). It should therefore be considered that a city’s overall temperature increase is the sum of all the temperature increases of its many heat islands.

Other infrastructure such as roads and roofs of buildings can also lead to urban heat islands. However, this document specifically addresses parking lots.

Grimmond’s table [44] presents some causes of thermal deterioration in a living environment.

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CAUSES OF THERMAL DETERIORATION ACCORDING TO GRIMMOND

Causes and Effects of Urban Heat Islands	
Characteristics	**Effects**
— Increased presence of mineralized surfaces — Large vertical structures — Reduced *sky view factor**	— Increased solar radiation absorption — Decreased loss of long wave (terrestrial) radiation — Decreased total turbulent heat transit — Reduced wind speeds
Thermal characteristics of surface materials (buildings and infrastructure)	— Higher heat capacity — Higher conductivity — Increased surface heat storage
Moisture characteristics	— Larger areas of impervious surfaces — Surfaces that shed stormwater runoff more rapidly – changes in the natural water cycle — Increased stormwater runoff with more rapid peaks — Decreased evapotranspiration

* Measure to quantify the openness of a site within an urban setting that has important climatic implications such as urban heat island, natural light and heat absorption.

{Source: [44] Grimmond, 2007 (part of the table).}

4.2 MAPPING OF URBAN HEAT ISLANDS IN QUÉBEC

Urban heat islands can be detected using satellites that measure surface temperatures. Small-scale maps (possible resolutions of 60 m to 120 m) can then be produced. The Institut national de santé publique du Québec used the data from this method, along with data from other sources, to develop an urban heat island mapping tool for Québec. This tool provides designers with an interactive map that can help locate urban heat islands across Québec in sectors with a density of at least 400 inhabitants per km^2. Designers can consult the map free-of-charge at the following Internet address: https://www.donneesquebec.ca/igo/apercu/?id=temperature.

To detect urban heat islands on an even smaller scale, aircraft can be equipped with a thermal camera to obtain images at a resolution of a few metres to even fifteen centimetres (e.g. Hansa Luftbild company). It is also feasible to take temperature measurements on a more one-off basis using a digital infrared radiation thermometer to measure temperatures at a specific point on the ground surface (e.g. VWR). There are also portable thermal cameras (e.g. Fluke, Ti55FT10/20/54 model; NEC company, R300Z model) with a resolution of 320 × 240 points.

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4.3 CHARACTERISTICS OF SURFACE MATERIALS IN PARKING LOTS

Urban heat islands are caused, in part, by the materials used on parking lot surfaces; it is therefore important to characterize these materials according to certain parameters to understand their behaviour and make informed choices for their use.

According to the Environmental Protection Agency (EPA), three basic parameters can be associated with surface materials and characterize their behaviour: albedo, emissivity and perviousness. In addition to these three parameters, a fourth increasingly used parameter should be considered – the solar reflectance index (SRI) – an index combining emissivity and albedo. The four parameters are defined in Chapter 3.

A material with a high solar reflectance index, such as new white concrete (SRI of 86), will stay cool regardless of the power of solar radiation to which it is exposed. As a guideline, the table below presents the SRI of various materials.

SRI VALUE FOR CERTAIN MATERIALS

Material	SRI	Source*
New asphalt	0	1
Aged asphalt	6	1
Concrete tile, red	17	2
Typical aged concrete, gray	19	1
Concrete paving stone, natural gray	32	3
New concrete, gray	35	1
Clay tile, red	36	2
Typical aged concrete, white	45	1
Concrete sand paving stone, gray	46	3
Limestone paving stone	62	2
New concrete, white	86	1
Concrete tile, white	90	2

*Source 1: [23] Canada Green Building Council, 2010.
*Source 2: [58] Natural Stone Council, 2009.
*Source 3: Manufacturer of concrete paving stones.

SRI values commonly found in the literature for fields and forests do not consider factors that reduce the heat island effect like shade, evaporation and evapotranspiration produced by vegetation. Neither are ground level and canopy level temperatures considered. SRI is a measurement that is commonly used to characterize inert materials.

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The standard ASTM E1980 [3] specifies how to calculate SRI, giving two calculation methods. Each of the calculation methods has its own approach.

NOTE — Calculating SRI according to the standard ASTM E1980 [3] gives results that vary from 0 to 100, but, depending on the context (albedo and emissivity), the values calculated can be negative or exceed 100. This can be directly attributed to the formulas, but, in practice, the scale of 0 to 100 is used.

Other parameters, not addressed here, can also influence a material's temperature. They include convection (velocity), thermal conductivity, heat storage capacity, the material's thickness and urban morphology (the size of buildings and the space between them, which often generate urban canyons, as well as the sky view factor) [41].

4.4 PARKING LOT THERMAL PERFORMANCE INDICATORS

4.4.1 General

To assess parking lots and make comparisons among them, this document uses the notion of "thermal performance." The aim of assessing a parking lot's thermal performance is to determine certain parameters that could be used to compare existing parking lots or to evaluate the improvement in an existing parking lot's thermal performance before and after construction. The higher a parking lot's thermal performance, the lower the urban heat island effect will be. The parameters assessed can also be used to establish the minimum thermal performance to target in a specific context.

To determine a parking lot's thermal performance, the following parameters can be evaluated: percentage of shade, average SRI and the proportion of pervious surfaces and impervious surfaces.

4.4.2 Shade

The objective of calculating shade is to determine the percentage of the parking lot surface that does not receive any solar radiation directly at the ground. Shade can be created by trees, neighbouring buildings or other means like solar panels, structures, sunshades and so forth.

Calculating the percentage of shade provides a means of comparing two parking lots. Eventually, the percentage of shade could also become a regulatory requirement. The calculation method should take into account several parameters for the most reliable results.

The City of Sacramento developed a calculation method for use by parking lot building permit applicants. The target criterion is 50% shade (time and period of the year not specified). This calculation method can be used by designers. It is simple to use, but does not take into account the sun's position and shaded surfaces [20].

The Canada Green Building Council's LEED program proposes, for its part, a different calculation method that considers the sun's position and shaded surfaces for determining the percentage of shade. It also takes into account the SRI of inert materials. In fact, the LEED Canada certification program proposes in its green building rating system a credit for measures aimed at reducing the urban heat island effect. The text relating to Credit 7.1 of the LEED program [23] is presented in Annex F. The requirements are for non-roof elements. Designers should read the LEED program analysis presented in Annex F.

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When calculating the percentage of shade, designers should clearly state the criteria and calculation method used (sun's position, time and date, age and dimension of the tree canopy, shade from other neighbouring infrastructure, simulation software). Designers should also present the data used to characterize the shade from trees.

4.4.3 Parking lot average SRI

Calculating a parking lot's average SRI is another parameter that can be used to measure or compare thermal performance of several parking lots.

A parking lot's average SRI can be evaluated with or without considering shade. When shade is not considered, the average weighted value of all surfaces at ground level should be calculated. When shade is considered, the average weighted value of all surfaces from above (bird's eye view) should be calculated.

When this calculation method is used, designers should specify which reference document they used to calculate the SRI value. A calculation sheet is provided in Annex B with an example of an SRI calculation (weighted average).

4.4.4 Pervious and impervious surfaces

The area covered by a pervious surface in relation to the total parking lot surface is a potential indicator of thermal performance, to the extent that the surface contributes to lowering the temperature through water evaporation.

This information can be expressed as a percentage. The higher the percentage, the more pervious the surfaces are in the parking lot, and the better the thermal performance.

4.4.5 Overall parking lot thermal performance

To draw a full portrait of a parking lot's thermal performance or to make a comparison between two parking lots, one or more of the above-mentioned performance indicators can be used. Each indicator provides an evaluation according to a specific approach and leads to a better understanding of the parking lot's physical characteristics.

To improve a parking lot's thermal performance, various methods can be used, including reducing the mineralized space, creating shade, using materials that reflect solar radiation and using all means that contribute to evaporation (see Chapter 5).

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5 REDUCING THE URBAN HEAT ISLAND EFFECT

5.1 MITIGATION MEASURES

Considering that global warming tends to intensify the urban heat island effect, several authors and research groups have focused on mitigation measures to reduce their impact both on health and on energy consumption [25], [32], [34], [44], [50], [83]. The World Health Organization [83] lists various examples; an increase in the number of trees allowed the heat index to be reduced from “extreme heat” to “high heat” in Munich (1985), depending on the size of the green space, the cooling influence was measured at distances of from 150 m to 900 m in Berlin and up to 250 m in Bonn (1985); in Tel-Aviv (2000), the presence of a small lake helped lower the air temperature and increase relative humidity.

5.2 STRATEGIES FOR IMPLEMENTING MITIGATION MEASURES

The ideas presented in the following paragraphs are provided to assist designers in selecting the mitigation measures they can implement to reduce the urban heat island effect.

Mineralized surfaces that are impervious and dark, like bitumen mixes, continuously exposed to the sun, are the primary cause of higher temperatures in parking lots. These commonly used surface covers are the traditional choice for developing a parking lot and are the first elements designers should address.

To effectively reduce the urban heat island effect, designers or regulatory authorities may consider the possibility of using the strategies below, which are currently available, in the proposed order:

- Reduce parking lot areas (regulatory approach to reduce a parking lot’s total area and the number or size of parking spaces [see Clause 5.4]);
- Green parking lots and their surroundings:
  - — Conserve natural and existing green spaces on the site;
  - — Plant various types of vegetation and particularly large canopy trees to create shade within the parking lot and lower the ambient heat; this also includes other methods like green roofs, vertical gardens, etc.
- Manage on-site stormwater runoff:
  - — Allow stormwater runoff to infiltrate through pervious surfaces; and into the ground;
  - — Create surface or underground stormwater runoff storage areas;
- Use surfaces with a high SRI or that are extremely pervious (especially in unshaded areas or for surfaces exposed to solar radiation for long periods such as traffic lanes).

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Using one or more of the above-mentioned mitigation measures may depend on several factors specific to each parking lot (see Clause 5.3.2).

An example of a parking lot development project where these recommendations were applied is given in Chapter 6.

5.3 PERFORMANCE OBJECTIVES AND DESIGN ELEMENTS

5.3.1 Parking lot performance objectives

There are many methods that can be used to reduce the urban heat island effect when developing parking lots.

Since parking lot configurations vary, with different-sized surfaces and various locations, a range of methods can be used and tailored to each situation to reduce the urban heat island effect.

The state of knowledge and development of recognized practices are not yet honed enough to accurately define the performance indicators a parking lot classification tool should target, if one were to be developed. Given this situation, designers should aim for the same level of performance for all parking lots while using various and appropriate methods to achieve the target level. The main goal should be to use any means that will help reduce the urban heat island effect.

5.3.2 Associated design elements to consider

In municipal regulations, parking lots are often identified by the type of use found in the zoning bylaw. The following parking lots are mentioned:

- Parking lot in a commercial area;
- Parking lot in an industrial area;
- Parking lot in a residential area;
- Street parking.

Parking lots can also be characterized by a typology associated with the form, the dimension or the relation to the built environment.

When designing a parking lot that contributes to reducing the heat island effect, several design parameters should be considered, including those associated with the adjacent building's use, how long and how often the parking spaces are used, who the parking lot users are, its physical (geographic) location and parking lot fees. Annex C presents elements for reflection on this topic.

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5.4 RECOMMENDATIONS OF THE MINISTÈRE DES AFFAIRES MUNICIPALES, DES RÉGIONS ET DE L'OCCUPATION DU TERRITOIRE TO REDUCE THE URBAN HEAT ISLAND EFFECT

Cities and municipalities have the power to regulate various aspects of urban development to establish a framework for parking vehicles. It is therefore conceivable that municipal bylaws could contribute to reducing the urban heat island effect caused by surface parking and promote development that will not add to this problem.

To this end, the Ministère des Affaires municipales, des Régions et de l'Occupation du territoire (MAMROT) has proposed various regulatory provisions that municipalities can adopt to reduce the urban heat island effect in parking lots.

These provisions are illustrated using examples presented in Annex E and involve the following topics:

- Number of parking spaces
  - — Reducing the number of parking spaces
  - — Imposing a maximum number of parking spaces
  - — Sharing parking lot use
  - — Providing incentives for shared parking
  - — Eliminating the obligation of providing parking spaces
- Dimensions of parking spaces
  - — Reducing the minimum dimensions of parking spaces
  - — Creating different-sized parking spaces
  - — Establishing maximum sizes for parking spaces
  - — Creating spaces for small-sized cars and bikes
- Indoor parking lots
  - — Reducing outdoor parking lot areas by developing underground or multi-storey parking garages
- Parking lot development
  - — Greening parking lots
  - — Sustainably managing runoff water
  - — Using appropriate surface materials

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5.5 GREENING OF SURFACE PARKING LOTS

5.5.1 General

Planting vegetation in a parking lot contributes to reducing air and surface temperatures due to the pervious surfaces used and the shading created. All available space should be considered for planting, including roofs and walls of buildings adjacent to parking lots. In all cases, designers should seek advice from a plant specialist to ensure that appropriate selections are made.

Annex D presents thermal images of two residential sectors where trees were planted. The images highlight the effect of vegetation on the thermal heating of the sectors.

Among plants, trees significantly contribute to reducing the heat island effect and should be given priority in any parking lot development project. For vegetation, and trees in particular, to develop and grow normally, the following vital needs should be met:

- Need of roots for oxygen;
- Need for appropriate quality water;
- Need for nutrients;
- Need for light;
- Need for space, both underground and above, for future growth.

In order for these needs to be met, designers should consider several factors that affect tree growth in parking lots:

- A tree root system is much more expansive than the projection of its branches from the surface of the ground, covering an area as much as 4 times greater (see Illustration 1).

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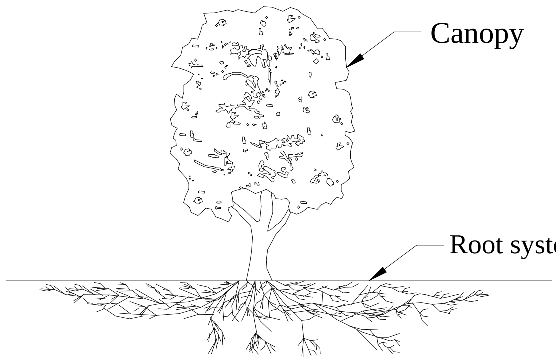
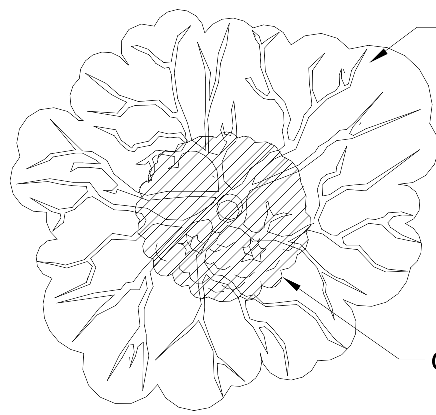


FRONT VIEW



TOP VIEW

ILLUSTRATION 1 — SHALLOW DEVELOPMENT OF A TREE ROOT SYSTEM

{Source: [56] Matheny and Clark, 1998 (adaptation).}

- Tree roots do not usually develop deep into the ground, but stay close to the surface. Over 80% of roots taking in air and water (rootlets) are found in the first 10 centimetres of the ground [54]. Certain roots can follow paths created by (for example) natural cracks or tunnels and descend deeper. In soils with a coarser texture, like sandy soils, air can penetrate more easily and more deeply, which may contribute to root development (see the example of a mulch cover versus a grass surface in Illustration 2).

- Highly compacted modern road infrastructure (gravel) impedes tree root development, making it impossible for trees to deploy a functional root system and create an enabling environment to reach their full growth potential.

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- Illustration 2 presents the difference between a root system developing under grass and one developing under a mulch cover. Mulch is an organic material made of leaves, wood chips, straw and harvesting residues that are crushed and spread on the ground's surface to conserve moisture, limit weed development and control erosion (stubble mulch, dust mulch).

- It should be noted that the input of organic nutrients necessary for tree survival several years after the tree has been planted has often been over-estimated; cases of mature trees that managed to develop without the input of fertilizers or organic conditioners are frequent (e.g. Grande Allée in Québec city). A tree's survival needs must be met when the tree is first planted. It is therefore essential to provide beforehand enough room for air and water in soil.

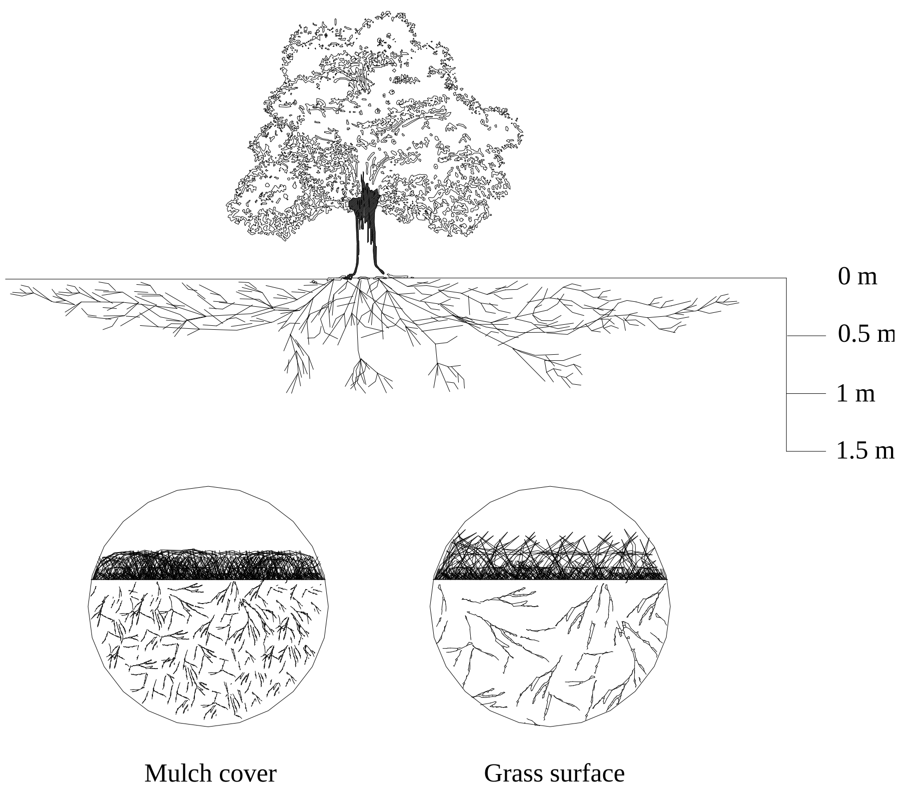

ILLUSTRATION 2 — DEPTH DEVELOPMENT OF A TREE ROOT SYSTEM
{Source: [46] Harris, Clark and Matheny, 2004 (adaptation).}

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5.5.2 Conservation and protection of existing trees

From project design to the construction work to develop or redevelop a parking lot, designers should take into account the following elements to protect existing trees:

- Minimize root loss or damage during excavation and compaction work;
- Avoid, where possible, raising and lowering the surrounding ground and, in cases where it must be done, ensure appropriate means for tree survival;
- Protect trees during work through appropriate methods to ensure the integrity of branches, leaves and trunk bark, and preserve the integrity of the root system by reducing areas for heavy vehicle traffic and for material storage;
- Prune trees so vehicles do not damage the lowest branches during work and pedestrians are not inconvenienced.

Designers should ensure that the requirements of Part IX of the standard NQ 0605-100 [1] are fulfilled to conserve trees and shrubs during development and construction work.

5.5.3 Tree planting

5.5.3.1 Appropriate planting space — It has been noted that trees planted in planting holes that are too small or surrounded by compacted gravel do not develop normally and die on average within 5 years of being planted in highly urbanized settings or cease to develop. Unable to develop their normal root system, these trees rapidly colonize all available soil for their roots, which are then subjected to drought, lack of air and sometimes salt from de-icing, and eventually wither and die over the short or long term.

The main challenge for parking lot designers using trees to provide shade consists of creating growth conditions favourable to trees in confined and inhospitable places, in particular by creating a sufficiently sized planting surface. With this aim, designers should strive to increase the surface and volume of soil available for trees, not only to ensure sufficient tree crown growth, but also to guarantee survival for many years. This is possible, for example, by designing planting areas in large continuous planting islands rather than small planting holes or individual spaces. Any other method to increase available surface and soil volume may also be used.

5.5.3.2 Planting holes — A tree root system should be able to develop easily and rapidly to ensure constant growth until it reaches maturity. Accordingly, an appropriate planting hole should be built.

In the case of planting holes intended for a single tree, designers should refer to the requirements of Part VIII of the standard NQ 0605-100 [1], which addresses this topic for trees and shrubs. Illustration 3, taken from this standard, shows an example of a planting hole typically used for planting one tree.

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Where possible, designers should use foundation materials that enable tree roots to develop. Soil-stone mixes, made by mixing clean stones, soil and sometimes binding agents, provide for an adequate environment allowing to achieve this result (see Clause 5.5.3.4 and Annex G).

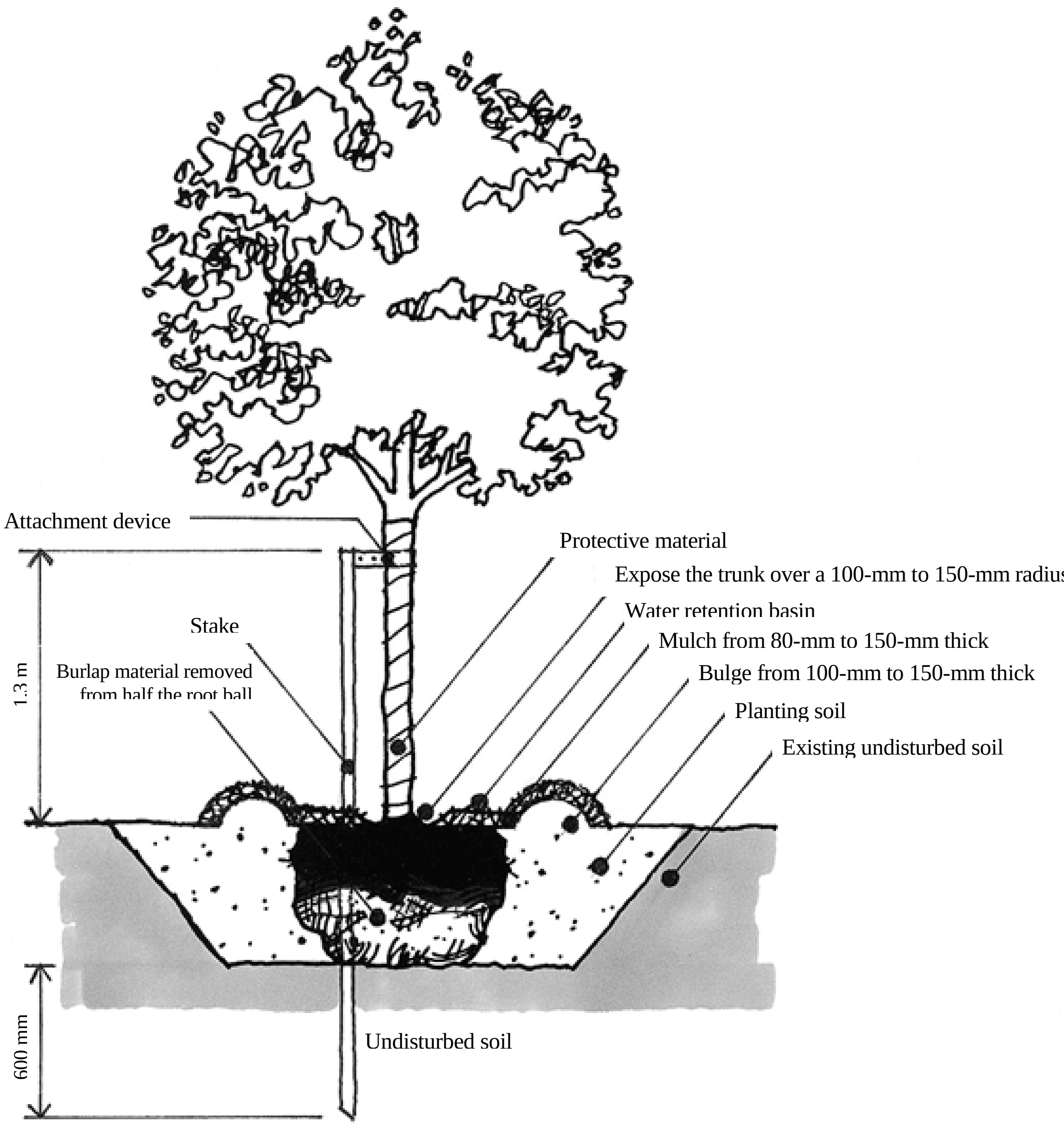

ILLUSTRATION 3 — PLANTING HOLE FOR ONE TREE

All planting holes should fulfill certain minimum requirements, whether for a single tree or for several trees and shrubs. Designers should take the following parameters into account:

- Establish the volume of the hole according to the tree planted.

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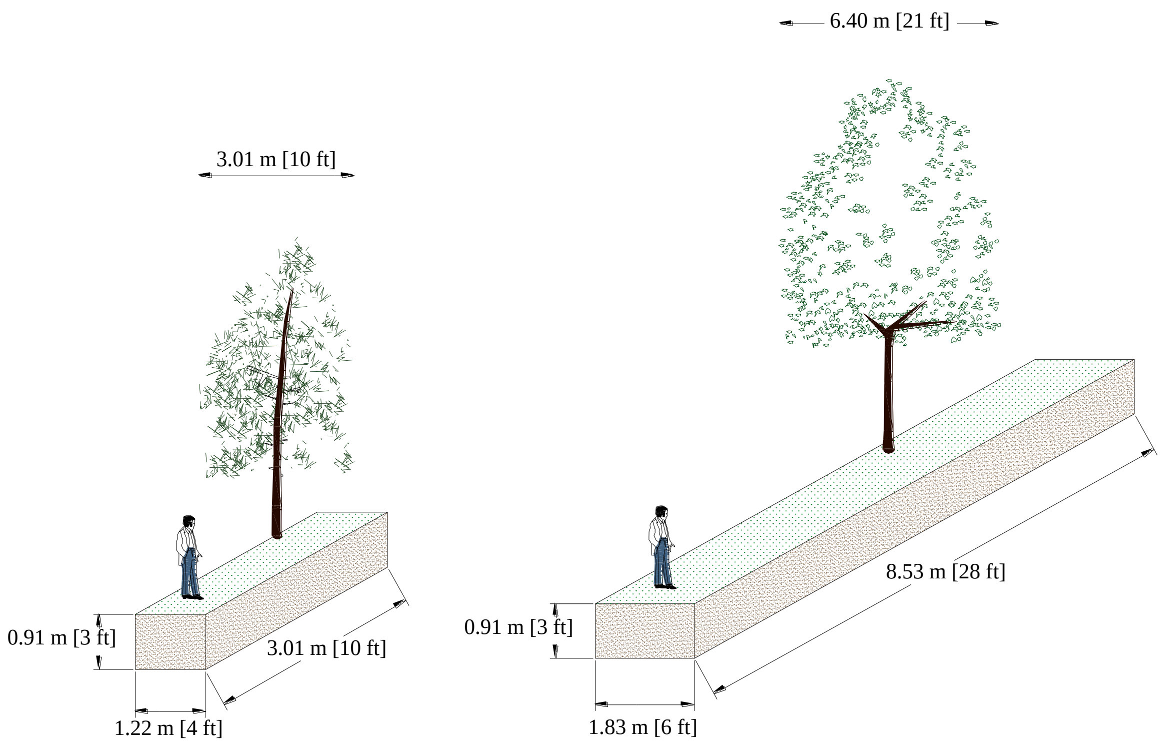
- Maintain the recommended minimum volume.
- Where several trees are planted, ensure continuous planting holes.
- Planting holes should have a pervious bottom.
- Where possible, ensure that planting holes are sufficiently wide (2.5 m to 3 m) to prevent vehicles from coming into contact with tree trunks.

The document *Tree Space Design — Growing the Tree Out of the Box* [18] gives soil volume examples, a few of which are reproduced in Illustration 4. This document also proposes examples of design methods for planting holes. Designers should refer to it for volume, depth and other technical parameters. The images of trees planted in tree pits seen in Illustration 4 show the maximum growth a tree can reach based on the dimensions of the planting hole.



Soil volume = 3.40 m^3 [120 ft^3] Soil volume = 14.16 m^3 [500 ft^3]

ILLUSTRATION 4 — EXAMPLES OF PLANTING HOLES

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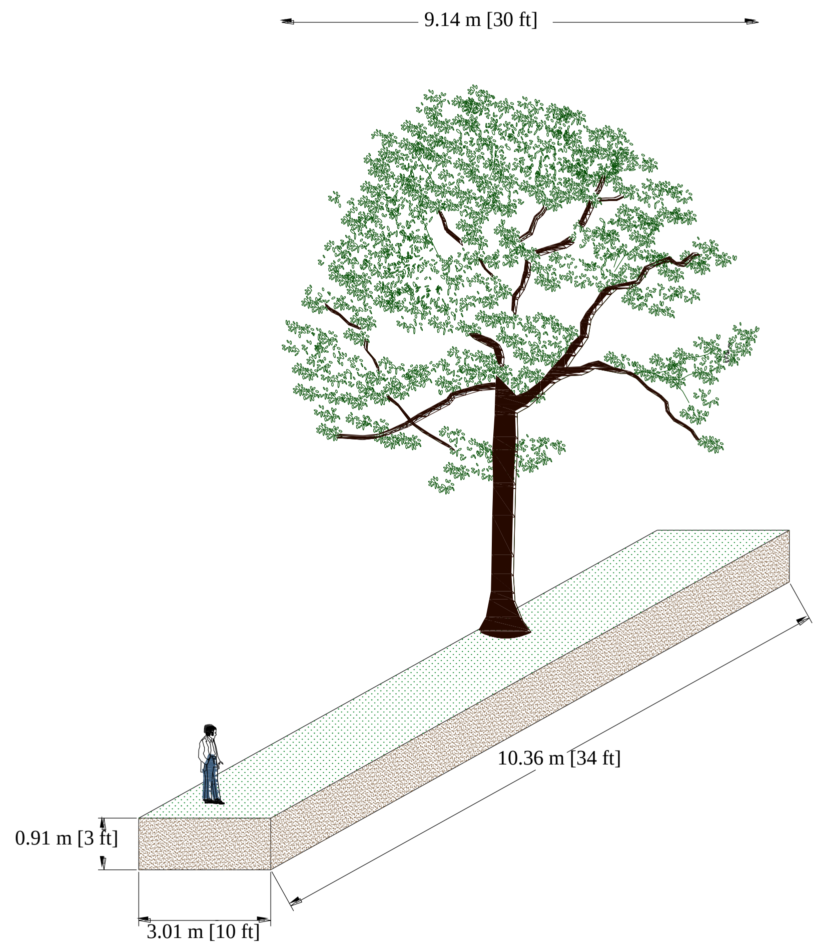

Soil volume = 28.32 m^3 [1000 ft^3]

ILLUSTRATION 4 — EXAMPLES OF PLANTING HOLES (concluded)

5.5.3.3 Root paths — In the case where a parking lot's classic granular base does not facilitate root development, and, accordingly, tree crown development, there is another technique that can be used, i.e. that of root paths (for example loam or soil-stone sandwiches, rigid tubes perforated with loam).

There are also modular soil cell systems that ensure sidewalk stability while allowing a large amount of soil to be added. Having been tested in certain Canadian cities, they seem promising since they may increase the growth and survival of trees planted in holes (see Clause 5.5.3.4 and Annex G). However, a parking lot remains a very inhospitable environment for vegetation survival, especially if it is not irrigated or watered during periods of intense heat.

To compensate for small-sized planting holes that would impede root system development, root paths can be created using tubing or other techniques. They can be installed in the pavement foundation to allow roots to develop, even creating a bridge for roots to richer soils in neighbouring planting spaces. Some examples of these techniques, taken from the document specified in

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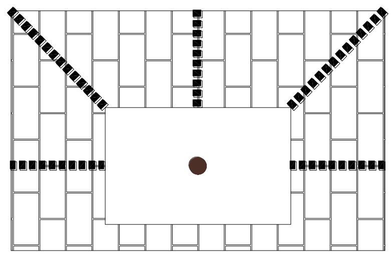
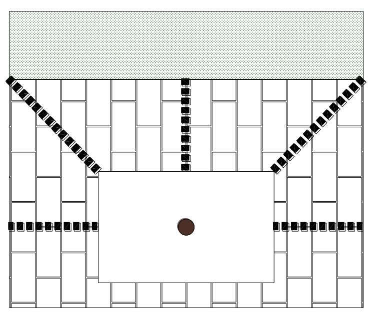
Clause 5.5.3.2 [18], are presented below (see Illustration 5). This technique may prove effective as long as surface water and air can reach the underground areas where roots are growing.

Designers should refer to that document for the design of planting holes.

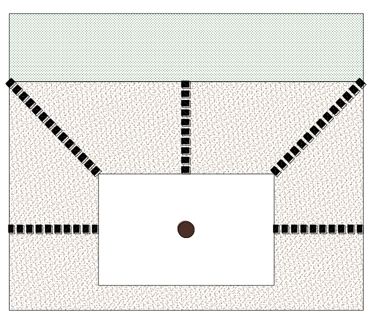
Note that no projects have been undertaken in Québec using this technique, but some projects have been completed in Ontario.



Root paths



Root paths connected to a green area under pervious ground



Root paths connected to a green area under impervious ground

ILLUSTRATION 5 — TECHNIQUES ENABLING THE DEVELOPMENT OF A ROOT SYSTEM UNDER PAVEMENT (TOP VIEW)

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5.5.3.4 Soil-stone mixes — Soil-stone mixes are composed of soil, stone and sometimes other substances or materials in variable proportions.

This type of mix has a structural capacity enabling it to be used under a road surface or a surface that could be subjected to compaction. This mix, which forms a solid network and drains through a prepared substrate of gravel and soil, enables the tree root system to develop among the stones. In order for the soil-stone mix to be effective for tree growth, it should enable air and water to penetrate. These mixes can be used under the parking lot road surface as a structure for the pavement or under a sidewalk or pedestrian area.

Other systems use rigid plastic structures that can hold a substrate enabling tree roots to develop. These systems are supposed to have a sufficient load-bearing capacity to support the loads associated with roads.

Information on these products and techniques is provided in Annex G.

5.5.3.5 Standard mixes — Designers should ensure that the mixes used to plant trees fulfil the requirements of Part III of the standard NQ 0605-100 [1], which addresses the soils to be used for this purpose.

5.5.4 Selection of tree species

5.5.4.1 General — Designers should call upon specialists to assist in the selection of tree species. Designers are also advised to analyse some of the parameters described in this clause in order to make a judicious selection of tree species.

In order for trees planted to resist weather-related factors, designers shall consider the hardiness of the species, annual temperature variations, the direction and force of wind and snow as well as how these parameters could evolve with climate change in the course of the tree’s life.

Designers should take edaphic factors into consideration, including the chemical, physical and biological components of soil having an influence on living organisms. Designers should also consider the fact that certain diseases and garden pests can hinder certain tree species.

Other parameters should be considered, including the underground and aerial space available.

In the context of climate change, designers may also consider the meteorological conditions that will prevail in the course of the coming years.

Aesthetic related factors are yet another element enabling designers to harmoniously integrate vegetation into the landscape design. Considerations concerning aesthetics and harmonious integration into the parking lot landscape are not addressed in this chapter, but other design elements that designers may consider are presented in Annex C.

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5.5.4.2 Selection of tree species — When selecting species and cultivars, designers should abide by the following criteria, which are specific to the environmental constraints of parking lots and take into account generally considered factors such as hardiness and resistance to pests and diseases:

- Resistance to stress caused by temperature variations;
- Resistance to hydric stress (flooding and periods of drought);
- Resistance to de-icing salt (in stormwater runoff and salt spray);
- Resistance to air pollution;
- Resistance to soil compaction;
- Application of vandalism protection measures;
- Attractiveness to rodents;
- Necessary maintenance (e.g. pruning).

These criteria should be considered in order to evaluate the potential effects on the useful life of vegetation after planting. Note that native tree species are not always the most viable choice in constrictive urban settings and many other choices could be more judicious. However, in several situations, it is still possible to use native species produced by nurseries.

Designers should also take into account the allelopathic properties of certain species (plants that suppress other plants) when designing green areas. Certain species can hinder the growth of other vegetation and therefore cause problems in cases of mixed or dense landscapes.

Designers should select various tree species to increase species diversity (biodiversity) and limit major problems due to pests often associated with monocultures.

To learn about certain characteristics of trees before making their selection, designers should consult the following documents:

- *Répertoire des essences arboricoles de la Ville de Québec* [65].
- *Guide des normes de plantation* [45].
- *Guide sur le verdissement — Pour les propriétaires institutionnels, commerciaux et industriels — Contrer les îlots de chaleur urbains* [26].
- *Répertoire des arbres et arbustes ornementaux* [28].

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- *Design Guidelines for "Greening" Surface Parking Lots* [73].
- *Parking Lot Tree Shading Design and Maintenance Guidelines* [20].
- *Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance* [10].

The first three documents were developed by agencies working in Québec and are therefore written for conditions found in Québec. The other three documents were written for conditions found in Toronto, California and New York State, respectively.

Tree selection should take into account the project's location. Other constraints like electrical wires, pylons, poles, right-of-ways and properties adjoining the parking lot could also limit the tree selection.

Designers should select trees adapted to sunlight conditions (full sun, semi-shaded, shaded). Other elements like the characteristics of the aerial structure, the characteristics of the root system and the planting distance also deserve consideration.

Where possible, selected trees should have good leaf density and wide horizontal deployment to ensure a sizeable shaded area. In confined spaces, when judiciously oriented, large-sized full-foliaged vegetation that is densely planted can provide sufficient shade.

Other factors, like fruit, can be considered a nuisance in certain tree species. Designers should take this into account and evaluate the impact on-site before selecting such a tree.

5.5.4.3 Selection of nursery-produced trees — Trees from nurseries can be cultivated and delivered in various ways. Where possible, designers should indicate in their specification that trees should be delivered with a complete root system and, if possible, with bare roots. Such trees are more viable, since they possess 100% of their root system. When trees are cultivated in containers, it is preferable to select trees grown in small containers. The nursery-produced trees recommended in this paragraph will give excellent results. Such trees are available at a lower cost and leave a smaller ecological footprint.

Using trees uprooted from fields and placed in metal baskets or containers should be avoided, since, under such production conditions, they will have lost over 80% of their root system. Trees need on average one year per every 25 mm of trunk diameter to recover from being uprooted from a field before beginning to develop their branch system. For example, after planting, a tree of 100 mm in diameter will take at least 4 years before rebuilding a root system comparable to the system it had when it was uprooted and, if conditions are favourable, aerial development will begin. Since parking lots remain inhospitable settings, hostile to tree growth and development, there is little hope of obtaining the shading sought in the medium and even long term, with vegetation planted in such conditions.

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5.5.4.4 Municipal bylaws regarding tree species — Designers should verify the municipal bylaws in effect to find out if any restrictions apply when selecting trees. It is possible that certain tree species may not be planted on a municipal territory due to phytosanitary risks (diseases, insects), inconveniences caused by the roots and other reasons.

5.5.5 Green areas and soil protection

It is beneficial to green areas not covered by pavement in a parking lot. First of all, when well maintained, they improve the appearance of the parking lot. In addition, as mentioned in the above clauses, vegetation can:

- provide cooler ground temperature through shade;
- cool the surrounding area through evapotranspiration;
- maintain soil perviousness for water and air;
- reduce soil erosion;
- improve air quality and reduce episodes of smog;
- in the case of taller plants, discourage foot traffic around trees and prevent soil compaction.

When adding vegetation between and beneath trees, vegetation covers and tree species should be mutually compatible. Accordingly, a species adapted to shade should be selected under a tree with dense foliage. A tree with a sparse crown should be placed over ground cover that requires more light. In all cases, designers should maintain a good-sized non-plant perimeter around the tree trunk and cover the surface with mulch [38], [40], [43], [74].

Four types of groundcover are commonly used in green areas: lawn, groundcover plants (low herbaceous and woody plants), wildflower mixes and shrubs [43].

The least costly lawn to purchase, seeded lawn, nevertheless requires more maintenance in the long term than other plant covers, including mowing, removal of debris and leaves, watering, fertilizing or conditioning. Lawns contribute to greening, but their aesthetic value is minimal compared to other plant covers that could be used. Designers should make certain that lawn mowing or grass trimming is not required near trees to protect the trunk from being damaged. All lawn maintenance (fertilization, weeding) should be reconcilable with the presence of trees [43], [74].

Designers should refer to the requirements of Part IV of the standard NQ 0605-100 [1] for sodding of lawns and Part V of the standard NQ 0605-100 [1] for seeding of lawns. Designers can also consult *Implantation et entretien d'une pelouse durable*, a guide on growing and maintaining a lawn, published by the Fédération interdisciplinaire de l'horticulture ornementale du Québec [36].

As for groundcover plants (herbaceous or woody), designers should install groundcover at the same time as trees are planted to avoid later damage to their root system. Using annual plants that need to be replanted every year is not advised for this reason [40]. In addition to the above-mentioned

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advantages, planting floral, fruit or coloured-foliage ground cover for autumn or winter survival adds seasonal interest to landscapes.

Wildflower mixes are sometimes seeded or planted between trees and beneath trees in an urban setting. Note that a sizeable surface, good ground preparation, steady watering and maintenance (weeding, cutting) and a good knowledge of vegetation are essential for the success of a wildflower mix [31]. Designers should consult suppliers of floral seed mixes, who can give many tips on this topic.

Shrubs have the added benefit of creating an effective barrier to circulation around trees [43]. According to the species, shrubs can add flowers, leaves, coloured fruit and volume throughout the year, which increases the aesthetic interest of landscapes. Designers should refer to the requirements of Part VIII of the standard NQ 0605-100 [1] for planting shrubs. Shrubs should be planted at the same time as trees are planted [43].

To reduce soil compaction due to trampling, designers should block potential pedestrian passages by planting saplings, shrubs or perennial plants to complete the vegetation in green areas. Such a practice is recommended to designers, because it also helps increase biodiversity, limiting the major pest or disease problems often associated with monocultures. For these same reasons, designers should vary the tree species planted.

Planting vegetation around trees reduces loss of soil moisture from the impact of direct sun on exposed roots. For this reason, designers should avoid using grass, which is recognized as appropriating air and water to the detriment of young trees that are less aggressive after planting. The same recommendation applies to the use of annual plants and overly aggressive perennial plants and shrubs [43], [74].

Designers should plan their development project so that air and runoff (exempt from de-icing salt) can infiltrate into the soil to reach the roots of trees and other vegetation. To do this, they can use pervious materials or materials with pervious joints or cracks designed into the cover. Various pervious materials can be used and are presented in Clause 5.6.7.

Designers should not use tiles or pavers with impervious joints, like joints filled with a sand-polymer mix, in areas where they want water and air to infiltrate into the ground.

5.5.6 Other considerations

5.5.6.1 Positioning of plants — When designers select tree locations with the aim of creating shade, their analysis should include the following elements:

- The tree’s position in relation to the surfaces where shade is needed;
- The tree’s geometry and its dimension at maturity and throughout its growth.

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Trees that are planted in locations that produce shade outside the parking lot or on surfaces with a high SRI (reflecting surfaces that absorb less heat) will not contribute to reducing the urban heat island effect. That is why trees should be positioned to maximize the shaded surfaces within the parking lot or to attenuate surface coverings that exacerbate the urban heat island effect (low SRI).

Moreover, since shade changes place throughout the day from west to east, passing by the north, it is important that trees are situated strategically between the sun and the surface to shade. Based on this principle, a tree planted in the northern section of a parking lot will, in large part, create shade outside the parking lot. To provide the most shade on the ground, designers should consider the fact that trees provide maximum shade that varies according to where the sun is shining and that shade is most often found on the north side of the trunk.

When analyzing tree positions, existing elements like adjacent buildings, existing plants and any other factor that could influence the parking lot's urban heat island effect should be considered.

5.5.6.2 Green Wall or Green facade — Climbing plants can be integrated into structures, like fences or building walls, to form green facades.

Green walls or green facades are an effective means to reduce the urban heat island effect in parking lots that are located near buildings.

Designers should consult the document *Climbing Plants: A Refreshing Solution* [12] to select the plants and support materials to use and find out how to plant and maintain the vegetation selected for green facades. Fact sheets on recommended vegetation are found with characteristics like hardiness, growth rate, type of support to use, exposure conditions and so forth.

5.5.6.3 Vegetation maintenance — Vegetation maintenance is an important practice to implement following planting, and should be kept up over time, which means that an appropriate budget should be allocated for this from the start of the project.

Maintenance includes, among other things, watering, pruning, winter protection, addition of hoops or other physical barriers, cleaning and weeding of surfaces.

Designers can consult the standard NQ 0605-200 [2] to obtain details on arboricultural and horticultural maintenance.

5.5.6.4 Planting — Designers should plant trees or other vegetation before buds break in spring to obtain favourable outcomes at the lowest cost.

After planting seedlings, watering and proper support with stakes or trellises should be ensured. It is also necessary to use biostimulants (see Part VIII of the standard NQ 0605-100 [1]). Note that it is important to maintain an appropriate mulch cover at the foot of the tree after planting (see Illustration 3).

Designers should request that trees be planted according to the requirements of Part VIII of the standard NQ 0605-100 [1].

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5.5.6.5 De-icing salts — Sodium chloride used in parking lots can jeopardize vegetation survival if salt-laden water reaches planting holes. Overly saline water can lead to a reduction in water absorption by roots, and therefore to drying out of the plant. In addition, water containing sodium chloride is toxic to vegetation in varying degrees. Finally, the increase in sodium content in the ground can increase soil compaction problems in the case of more clay-type soils. The use of de-icing salts should therefore be kept to a minimum in areas that drain into planting holes and vegetation that can resist these conditions should be selected [4], [17], [22], [27].

A series of mitigation measures to reduce the effects of de-icing salts are available in several publications listed in the reference [27] in Annex H. Designers should not plant trees in areas planned for snow disposal.

5.6 ON-SITE STORMWATER MANAGEMENT

5.6.1 General

As mentioned at the beginning of this chapter, reducing the urban heat island effect involves using several strategies, such as:

- Reduce impervious surfaces and replace them with pervious surfaces;
- Increase green surfaces;
- Manage rainwater.

These three strategies produce positive outcomes in reducing the urban heat island effect, and can also contribute to reducing the volume and flow of runoff when it rains. Replacing impervious surfaces and other urban materials with green spaces and adopting best practices for managing rainwater runoff (see Clause 5.6.7) will create temperate microclimates that improve the wellbeing of users and neighbouring residents.

Several studies establish a correlation between the ground's moisture rate and the attenuation of the urban heat island effect. Indeed, water contributes to cooling air through the process of water phase change (water changing from liquid to vapour) at evaporation and transpiration, since water consumes a part of the atmosphere's thermal energy, thus lowering air temperature. Accordingly, moist ground, even without any vegetation, will have a cooling effect compared to dry or impervious ground [30], [37], [47], [49], [62].

Consequently, best practices, which also include measures to intercept, infiltrate, treat or retain stormwater runoff onsite — whether or not vegetation is added — can prove to be effective methods in reducing the urban heat island effect. The following paragraphs describe the basic principles of these systems and provide several details on the various best practices applicable for parking lots.

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The Ministère du Développement durable, de l'Environnement et des Parcs (MDDEP) [6], in partnership with the Ministère des Affaires municipales, des Régions et de l'Occupation du territoire, published a rainwater management guide entitled *Guide de gestion des eaux pluviales — Stratégies d'aménagement, principes de conception et pratiques de gestion pour les réseaux de drainage en milieu urbain*. This document is available on the MDDEP website, and designers should refer to it for the topics addressed in this chapter.

5.6.2 Perviousness of soils

Water dispersion, either downward or horizontally, through various layers of soil, constitutes what is commonly called "infiltration." Perviousness is the ability of a porous substance (layer of soil) to allow a liquid or gas to flow through it, i.e. infiltrate into it. In soil, this corresponds to the ease with which air or water can flow through a given soil horizon, based on the soil's texture[1] and structure[2]. The perviousness also depends on the soil's stratigraphy, compaction and degree of saturation.

The perviousness coefficient describes the perviousness of a soil and designates the relation between the soil's perviousness and the viscosity of a fluid flowing through the soil. The more pervious a medium is, the faster water will flow through it. The most pervious soils are gravel pavers and the least pervious are homogenous clays. Perviousness can be qualified as high, medium or low.

The term most commonly used in urban hydrology to represent a soil's perviousness is the infiltration rate. It designates the flow of water penetrating into the surface soil. The infiltration rate is the speed with which water penetrates into the soil. It is generally measured by the depth (in mm) of a layer of water that can penetrate into the soil in one hour. For example, an infiltration rate of 20 mm/h signifies that 20 mm of water on the soil surface will take an hour to infiltrate. The infiltration rate depends primarily on the feed source (irrigation, rain), the state of moisture, and the properties of the soil under study. The perviousness coefficient and the soil's infiltration rate are important data for designers to consider to reach one of the objectives in reducing urban heat islands, which is to enable the presence and accumulation of water in the soil.

The presence of vegetation increases soil perviousness, and in more than one way. On one hand, large pores are produced by roots and the passage of organisms such as earthworms in the soil; on the other hand, vegetation and the organic matter they produce contribute to maintaining a granular structure in the soil, guaranteeing appropriate porosity and, therefore, perviousness to air and water. Finally, the interception of rain by vegetation reduces the raindrops' impact on the soil, protecting it from compaction and thus maintaining perviousness [15], [33], [55].

1. Relative proportions of different soil fractions or granulosity.

2. Combination or disposition of primary soil particles into secondary soil particles, units or aggregates, called peds, that are graded according to size, shape and appearance into types, classes and grades of aggregation (organization and thickness of successive layers of soil).

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5.6.3 Surface stormwater runoff

Contrary to infiltration, surface stormwater runoff (runoff) designates the ground's capacity, at any given time, to facilitate water running over its surface. It is the runoff coefficient that characterizes this phenomenon. It expresses the fraction of the rain running over the area of a given site, taking into account, among other things, the nature of the site's surface, the average slope of the surface, the intensity of the rain, the percentage of water stored in the lowest points of the site, the atmospheric conditions prior to the rain (for example, if it rained in the course of the previous days), etc. [16]. The following table gives an overview of several values this parameter could have based on the type of surface.

RUNOFF COEFFICIENT ACCORDING TO SURFACE TYPE

Surface Type	Runoff Coefficient*
Pavement	0.70 to 0.95
Roofs	0.70 to 0.95
Lawns, sandy soils	
Slight slope (2%)	0.05 to 0.10
Average slope (2% to 7%)	0.10 to 0.15
Steep slope (7% and over)	0.15 to 0.20
* Typical values for return periods of 2 to 10 years. Higher values are appropriate for rarer events.	

(Source: [6] MDDEP, 2011, Chapter 6, extract from Table 6.19.)

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The following table presents the runoff coefficient values based on the type of land use. The higher the runoff coefficient, the more surface runoff there will be and, consequently, the less infiltration into the ground. Illustration 6 shows the effect of progressive urbanization on runoff and the infiltration ranging from vegetation cover to dense urbanization.

RUNOFF COEFFICIENT ACCORDING TO THE TYPE OF LAND USE

Type of Land Use	Runoff Coefficient*
Commercial	
Downtown	0.70 to 0.95
Suburb	0.50 to 0.70
Residential	
Houses in suburb	0.25 to 0.40
Detached houses	0.30 to 0.50
Duplexes	0.40 to 0.60
Townhouses	0.60 to 0.75
Apartment buildings	0.50 to 0.70
Industrial	
Light	0.50 to 0.80
Heavy	0.60 to 0.90
Parks, cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Fields	0.10 to 0.30

* Typical values for return periods of 2 to 10 years. Higher values are appropriate for rarer events.

(Source: [6] MDDEP, 2011, Chapter 6, Table 6.20.)

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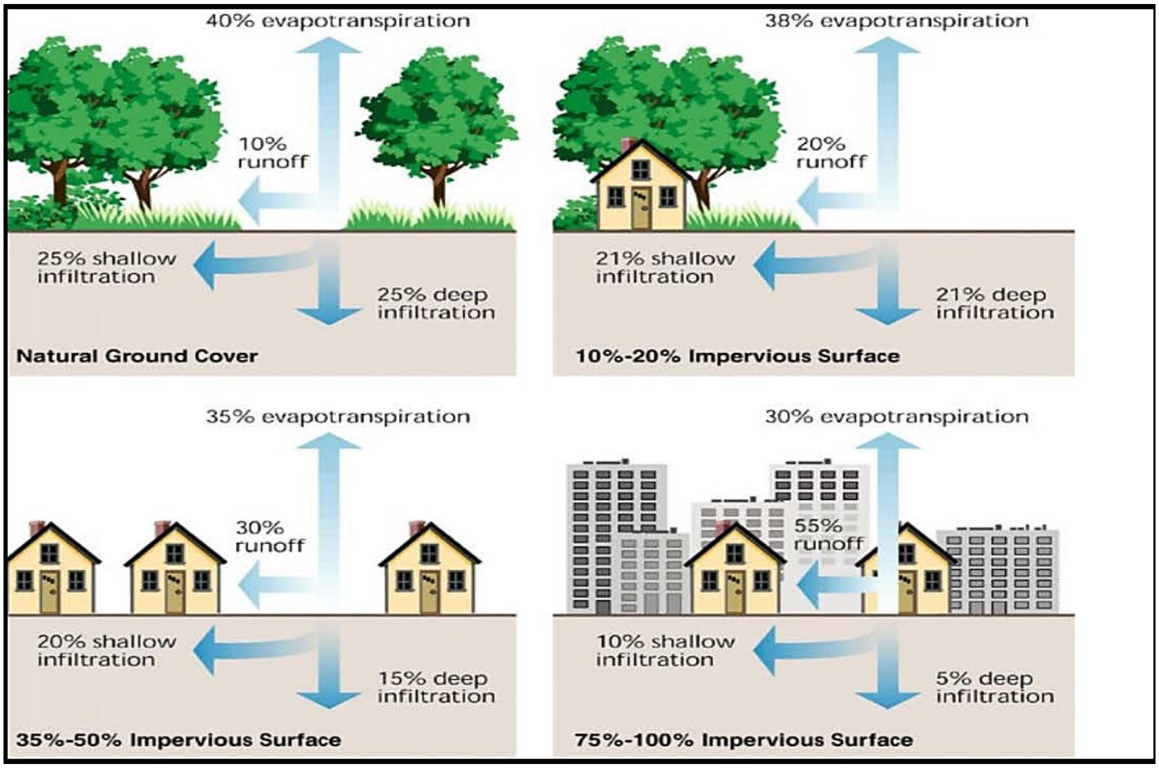

ILLUSTRATION 6 — THE IMPACT OF CONVENTIONAL URBANIZATION ON THE HYDROLOGIC CYCLE
{Source: [72] Toronto and Region Conservation Authority, Credit Valley Conservation Authority, 2010.}

In surface hydrology, hydrogeology and physical geography, the term pervious land is used to describe surfaces promoting stormwater infiltration and that tend, in conjunction with other factors, to reduce runoff.

There is no formal mathematical relation between the perviousness coefficient and the runoff coefficient. The two coefficients are used in different formulas to determine the transformation of rain into runoff flow. It is nevertheless important for designers to understand these two phenomena (runoff and soil perviousness) when designing parking lot surfaces to reach the objective of reducing the urban heat island effect.

Raindrops first reach existing surfaces (vegetation, buildings, etc.), then run off and start to fill depressions and infiltrate into the soil where possible. The infiltrated water is either transported toward aquifers, returned as flow into waterways or retained in the soil to evaporate or be absorbed and transpired by vegetation. Once soil is moist and certain parameters are in place (slope and type of soil), stormwater then runs off to lower points in the watershed (phenomenon known as the “Horton mechanism” or “Hortonian runoff.”)

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5.6.4 Role of pervious surfaces

The increase in impervious surfaces (roads, highways, parking lots, etc.) not only contributes to the heat island effect, but also to the amount of stormwater runoff and pollutant loads rapidly draining into receiving water bodies (waterways, lakes) or into sewer systems. Some 80% of direct surface stormwater runoff can be traced to the impervious surfaces intended for vehicle use.

Pervious surfaces, on the contrary, present various advantages. They retain water and help lower temperatures, reducing the urban heat island effect through the evaporation of the infiltrated water. They allow water to filter naturally and continue its cycle through an infiltration process in the soil. The water, as it percolates through pervious soils, lowers volumes and peak flows, reduces the loads destined for the sewer system, lowers flood peaks from waterways and limits the risk of erosion of the banks of receiving water bodies. Finally, once it has infiltrated, the water contributes to recharging aquifers or sustaining vegetation that absorbs it, ensuring its survival. It should be remembered that water from parking lot runoff may contain various polluting substances that risk contaminating the soil. It is therefore important to take the necessary precautions (see Clause 5.6.6).

5.6.5 Role of vegetation in rainwater management

Vegetation plays an important role in reducing runoff. Leaves, branches, stems and trunks of vegetation intercept rainwater, a part of which evaporates from their surfaces. The average interception rate of a hardwood forest could be 15% to 25%, and that of a softwood forest 25% to 40% [8]. The interception rate of precipitation varies according to the age, species and density of the forest stand. In the case of an individual tree or other plant, the interception rate is based on the amount of foliage, its structure, the type of bark and the season. Interception also varies according to the rain’s intensity and duration, the presence of wind and other weather-related factors [8], [48], [53]. In general, trees intercept more rain than shrubs and, shrubs, more than herbaceous plants [55]. A single tree could intercept 6.6 m^3 of water in the course of a year [48].

Some of the water initially retained by the tree will eventually reach the soil, either by running down the trunk as stem flow or falling directly from the canopy [8]. The force of impact of raindrops on the soil and the resulting compaction are therefore greatly reduced by the passage of rain in vegetation, helping to keep the soil pervious [15], [33].

Illustration 7 presents these phenomena for the specific case of the Montmorency forest.

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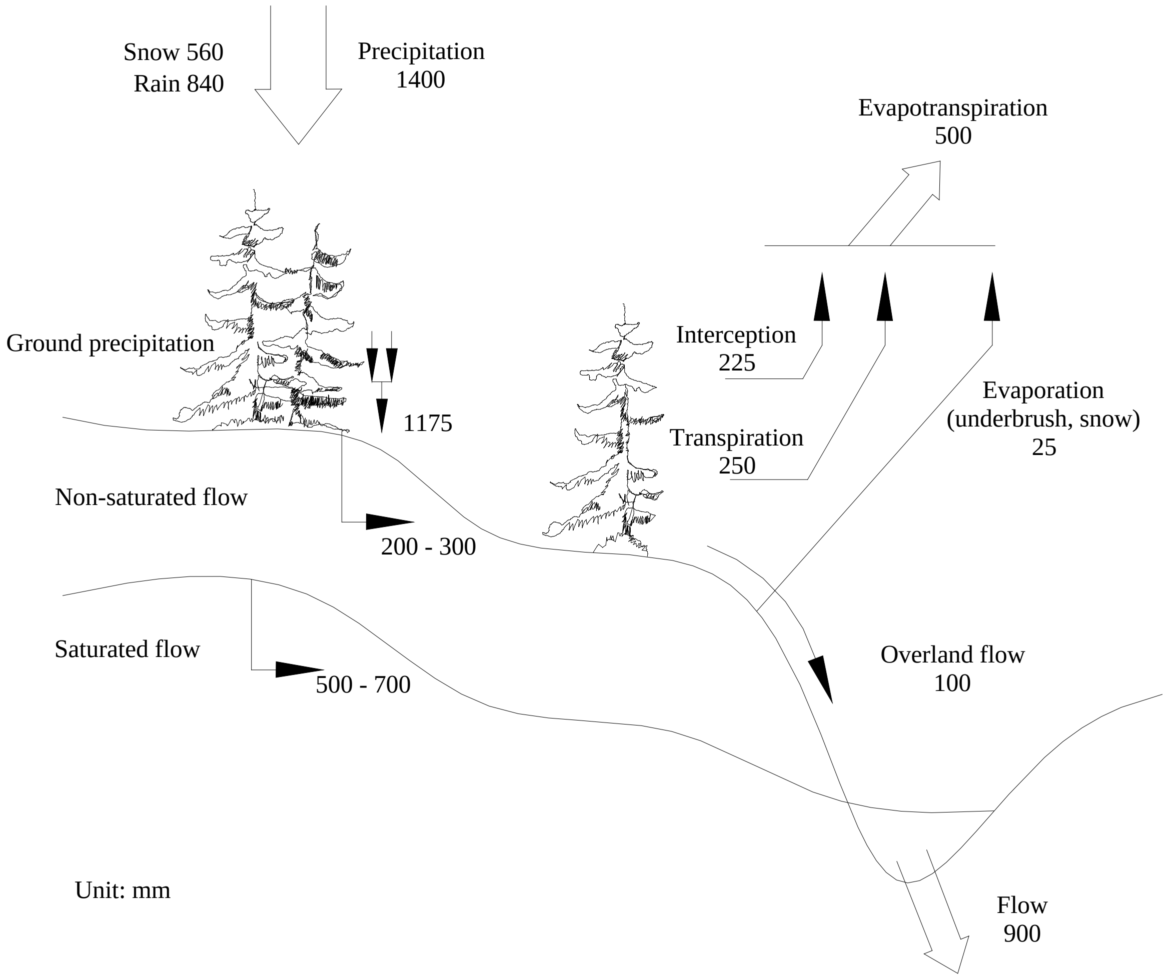

ILLUSTRATION 7 — TERRESTRIAL HYDROLOGICAL CYCLE AND RECORD IN MILLIMETRES A YEAR FOR THE MONTMORENCY FOREST

{Source: [8] Barry et al, 2009 (adaptation).}

The presence of vegetation also increases water infiltration into the soil. When water infiltrates, it contributes to recharging aquifers and sustaining the vegetation that absorbs it. In the latter case, some of the water will return to the atmosphere through transpiration. It is estimated that around 50% to 64% of rainwater infiltrates into the soil (29% recharges aquifers and 35% is absorbed by plants, for a total of 64%) [5], [67]. All these mechanisms reduce water runoff and peak flows.

Transpiration along with water evaporation from the soil and vegetation (evapotranspiration) help cool the ambient environment. Transpiration counts for almost half of evapotranspiration [8], [51]. From 300 kilograms to 700 kilograms of water are transpired by vegetation for every kilogram of biomass produced. It is estimated that a large-sized oak tree can transpire more than 151 400 litres (40 000 gallons) of water a year [35]. These numbers highlight the importance of this phenomenon.

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Vegetation will generally not transpire during a period of drought. Transpiration occurs through stomata, small openings usually located under the leaves. They, however, remain closed in a period of drought to prevent needless loss of water from the plant [57]. It is therefore beneficial to maintain a sufficient level of water in the soil in a period of drought to supply vegetation and maintain the cooling effect of evapotranspiration. This can be done either by conserving the water present in the soil through the use of mulch or by watering or irrigation [29], [60]. Note that flooding the root system hinders respiration and, therefore, the root's ability to function by absorbing water [9]. Saturating vegetation roots for too long should be avoided, unless the selected species require it.

5.6.6 Vegetation and water quality

A parking lot's water quality is an issue:

- For the integrity of the aquatic environment and groundwater;
- For the safety of surface and groundwater;
- For the survival and growth of vegetation in contact with this water.

Stormwater runoff from a road or parking lot contains a variety of polluting substances, such as suspended solids (SS), oils and grease, heavy metals and metalloids (arsenic, cadmium, chromium, copper, lead, mercury and zinc), de-icing salts (sodium chloride) and various types of nutrients (nitrogen, phosphorus) [64], [75]. These substances stem from several sources: oil and gas products used to propel or maintain vehicles, pavement or vehicles deterioration (oils and grease, other gas products, metals and metalloids), winter maintenance (sand, de-icing salts), animal excrements (nutrients, bacteria, fecal viruses), landscaping maintenance (pesticides, herbicides, nutrients), and even the atmosphere [5].

The presence of contaminants, in particular de-icing salts in the form of salt spray or saline water, can compromise the appearance, growth and even the survival of vegetation. Pollution should therefore be removed at the source, by restricting or limiting the use of de-icing salts and using other products such as calcium-magnesium acetate to maintain surfaces in winter. Salt-resistant vegetation should also be selected [4], [17], [27], [72]. Disposing of dirty snow in certain areas should also be avoided.

Studies on wastewater treatment through the use of various vegetation-related projects conclude that vegetation is generally effective in removing contaminants, especially in the presence of a pre-treatment system (to remove sediments and separate oils [6, section 11.4]). Vegetation favours filtration and the deposits of suspended solids [55], [70]. Several contaminants, such as phosphorus, certain heavy metals and certain bacteria or viruses from suspended solids are also removed from water at this stage [15]. Vegetation promotes organic compound degradation by microorganisms that proliferate around their roots. Plants also absorb a part of the nutrients, heavy metals and other contaminants present in the runoff water [15], [76]. Designers should note that the phosphorus content in the substrate is between 10 parts per million and 30 parts per million at planting and should be kept in this range of values to promote vegetation growth without releasing phosphorus into the effluent.

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Precautions should be taken to prevent chlorides and sodium (highly soluble substances) or any other contaminant from infiltrating into the groundwater table and being dispersed into the aquatic environment. It is generally suggested that a minimum clearance of over 1.2 metres be respected between the bottom of the planted area and the highest level of the groundwater table when there is a possibility that water could infiltrate [6], [72]. In addition, water from high traffic areas where large amounts of de-icing salts are applied should not be allowed to migrate to the groundwater table. If water is overly polluted, infrastructures with impervious bottoms should be used, and the drain located at the bottom of the planted area should transport the water to the urban drainage system [6], [72].

5.6.7 Best practices for managing stormwater runoff

The best practices for managing rainwater runoff are based on three basic principles to reduce the urban heat island effect in parking lots:

- Increase stormwater infiltration / reduce impervious surfaces, to lower the SRI;
- Increase evaporation and transpiration, to lower surface heating;
- Store and treat stormwater runoff by bioretention and soil humidification, to optimize vegetation survival.

The best practices that can be implemented in parking lots are:

a) Pervious paving or surfaces;

b) Grass-covered ditches and grass swales;

c) Filtering trenches;

d) Rain gardens or bioretention areas;

Designers should refer to Chapter 11 of the *Guide de gestion des eaux pluviales*, referred to in section 5.6.1 of this standard, for the technical details and exact design parameters for the best practices for managing rainwaters since the information provided here is cursory. Designers can also consult the literature that exists on this topic, including several references presented in Annexes H and I.

As mentioned in Clause 5.6.6, parking lot stormwater runoff could be contaminated with sediments, hydrocarbons, de-icing salts and heavy metals [64], [72], [75]. Consequently, designers should use pre-treatment mechanisms before implementing rainwater management practices. Possible pre-treatment mechanisms include the use of oil and sediment separators, grass swales with check damns or weirs, filter strips or specific pre-treatment cells (stone trench, mulch, sediment trap). A hydrodynamic separator is used to control discharges upstream from other work for small-sized sites (under 2 ha). Several types exist, but the two main categories are oil and water separators and oil and sediment separators. A hydrodynamic separator is compatible with urban drainage systems and has a long life span if appropriate maintenance is ensured. It can be easily installed due to its standard design. These systems are not however appropriate for dissolved or emulsified oils.

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Figure 1 inserted after Chapter 6 presents a drawing comparing a parking lot's conventional drainage and two other drainage methods that integrate best practices.

The following paragraphs provide a description of several best practices for managing stormwater runoff.

a) Pervious paving

Pervious paving (Photos 1, 2 and 3, Illustration 8) is designed to promote infiltration through surfaces that are more or less pervious (high runoff coefficient). Water first penetrates the paving material used and is then intercepted by perforated drains that transport it to a drainage system, or it can infiltrate through a granular base and into layers of soil as need be.

PHOTO 1
(Source: G. Laliberté, Saint-Hyacinthe, 2012.)

PHOTO 2
(Source: G. Laliberté, Saint-Hyacinthe, 2012.)

PHOTO 3
(Source: G. Laliberté, Saint-Hyacinthe, 2012.)

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Pervious surfaces generally include porous asphalt, porous concrete, concrete pavers and open-grid systems in concrete or plastic. Their use is particularly suitable for low traffic areas, such as bicycle paths and parking lots, as well as for residential streets, due to their reduced structural capacity [6, section 11.5.12].

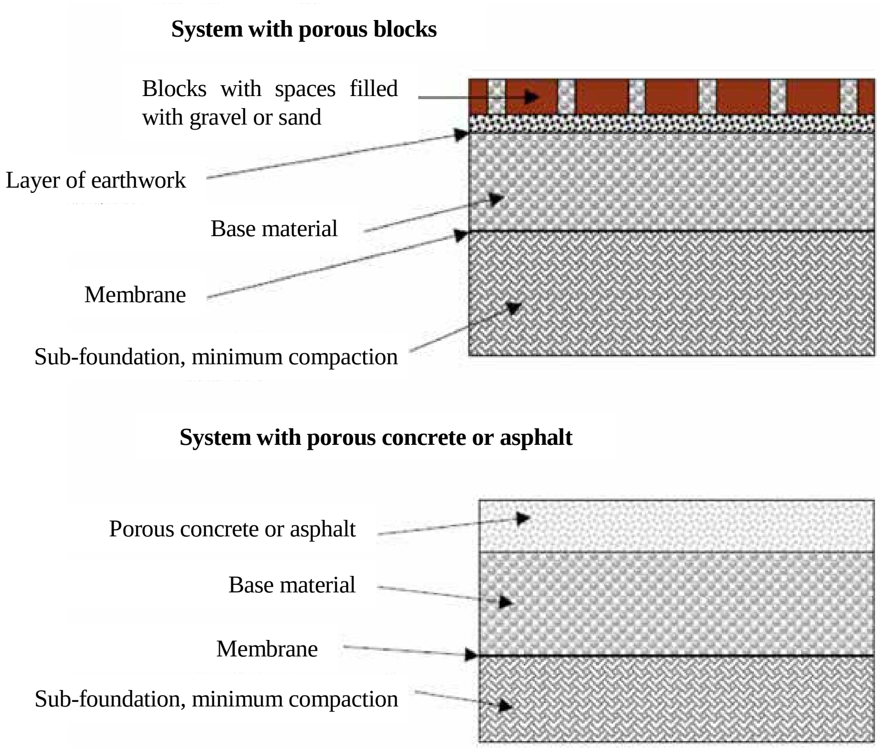

ILLUSTRATION 8 — TYPICAL CUTS OF SYSTEMS WITH BLOCKS OR POROUS COVERS
{Source: [6] MDDEP, Chapter 11 (adapted from [19] City of Portland, Oregon, 2005).}

b) Grass-covered ditches and grass swales

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These grass ditches or swales are designed to control peak flows and treat stormwater runoff [6, Section 11.6 and Photo 4]. The grass or vegetation that grows in the swales help reduce the flow velocity, prevent erosion, capture sediments and, as such, retain contaminants carried by the water. Another effect is to help recharge the groundwater table through the infiltration of water.

PHOTO 4
(Source: [6] MDDEP, 2011.)

Grass swales are different from dry swales with a drain, both in function and in size [21]. The dry swale is generally designed to meet a quantitative criterion (transport of flow for a given period and control of erosion), while the grass swale is much bigger, with its long gentle slopes. Swales often have a filter bed with perforated drains to evacuate water more rapidly and hold back the flow for quality control. Pre-treatment is always recommended to catch sediments upstream from swales.

These grass-covered ditches and grass swales suit parking lot drainage well. However, they can only treat a relatively limited tributary surface. They require more maintenance and are not appropriate in sectors vulnerable to erosion or where it is difficult to maintain dense vegetation.

c) Filter trenches (infiltration trenches)

Filter trenches [6, Sections 1.5.8 and 11.6.4] are particularly sensitive to the potential problem of clogging and require effective pre-treatment of water before it reaches the trench.

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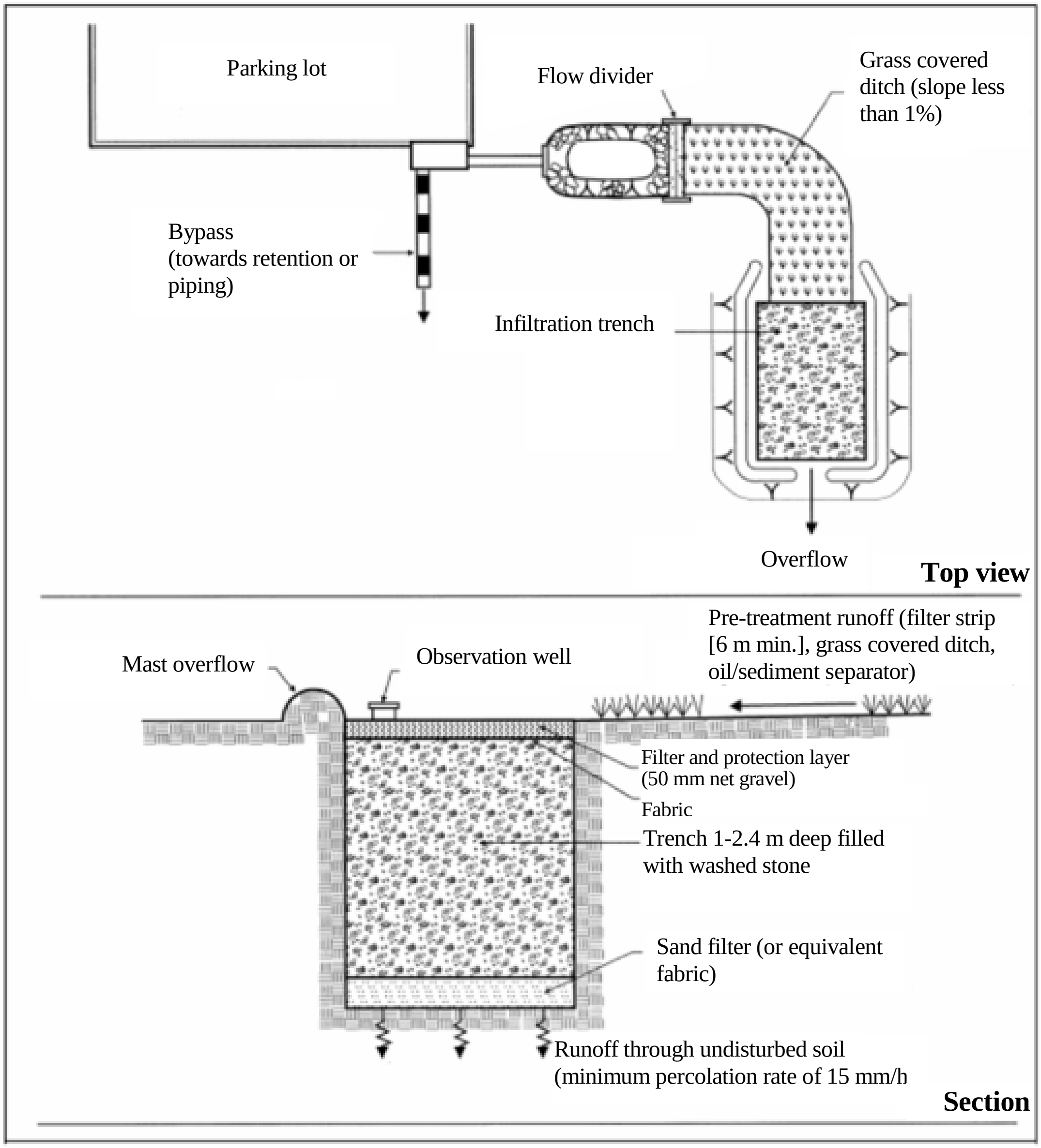

ILLUSTRATION 9 — EXAMPLE OF FILTER TRENCH SYSTEM
{Source: [6] MDDEP, 2011, Chapter 11 (adapted from [79] Vermont Agency of Natural Resources, 2002).}

These trenches (see Illustration 9) help reduce the volume of runoff, and are effective in removing sediments (including finer sediments), metals, nutrients and bacteria adsorbed on them along with organic substances. They are not however appropriate for all industrial or commercial sites, where major amounts of contaminants may be released, and are dependent on soil conditions, land use and the depth of the groundwater table.

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The filter strip is a grassy, gently sloped area comprised of trees, shrubs or herbaceous plants aimed at filtering, slowing down and infiltrating a part of the underground flow [19].

d) Rain gardens or bioretention areas

The rain garden is an effective solution for removing fine sediments, metals, nutrients, bacteria and organic matter [6]. It is a bioretention area designed to remove runoff contaminants through several processes, including in particular interception, absorption, adsorption, filtration, volatilization, ion exchange and decomposition [6, sections 11.5.9, 11.5.10 and 11.6.3]. When well designed and properly maintained, bioretention areas are even more aesthetic when they incorporate a plant landscape (see Photo 5).

An inconvenience with this technique is the accumulation of sediments that can lead to clogging the site. Pre-treatment is therefore recommended for this purpose along with regular maintenance. This type of infrastructure works well inside and on the outside limits of parking lots. It cannot however be used to treat large tributary surfaces.

PHOTO 5
(Source: M. Glorieux, Saint-Hilaire, 2012.)

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5.6.8 Maintenance

In all cases, projects associated with best management practices (involving vegetation or not) require proper and regular maintenance to ensure system performance, reduce the urban heat island effect and manage rainwater. The main maintenance duties include:

- Regularly inspect systems;
- Prune vegetation and control weeds;
- Plant vegetation;
- Remove debris.

Designers should consult the *Guide de gestion des eaux pluviales* [6, Chapter 12] for more details on this topic.

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6 EXAMPLE OF A PARKING LOT DEVELOPMENT PROJECT

6.1 GENERAL

This chapter draws upon the principles set out in this document to reduce the urban heat island effect to design an average-sized parking lot with 80 spaces.

This exercise aims to clarify the design steps and explore the methods recommended to develop a parking lot.

Several illustrations are included to show designers how the overall landscape plan was developed.

The selections to be made at each of the steps in the process are explained in detail in the following paragraphs and are inspired by the mitigation measures presented in Clause 5.2.

6.2 STEP 1 — REDUCE THE SURFACE OF PARKING SPACES AND CONSERVE EXISTING VEGETATION

For the purpose of this exercise, the site is an empty space with no buildings or other constructions on it, leaving the coast clear for the designer to develop the parking lot.

Usually, a standard parking lot comprises spaces of 2.70 m by 5.5 m and traffic lanes that are 6.0 m to 7.5 m wide, which enables users to easily maneuver in the parking lot. For the purpose of this exercise, the width of the traffic lanes was set at 6.0 m.

According to data, a standard parking lot comprising 80 spaces would occupy an asphalt surface of approximately 1836 m^2.

By reducing the dimensions of the spaces to 2.5 m by 5.0 m and maintaining the traffic lanes at 6.0 m, it is possible to reduce the asphalt surface by 188 m^2, a reduction of 10% (see Illustration 10).

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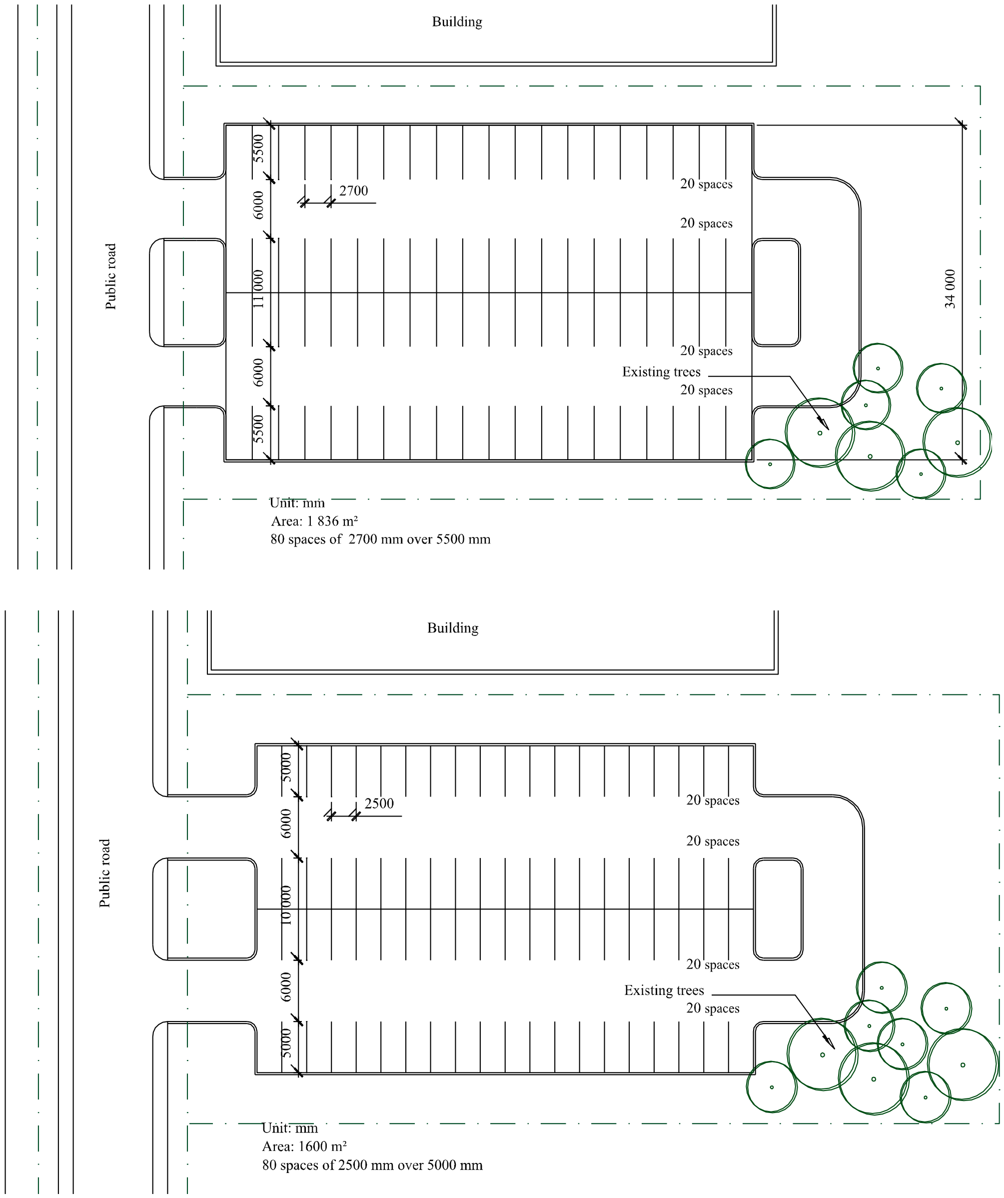

ILLUSTRATION 10 — REDUCTION OF THE PARKING LOT AREA
(Source: Groupe IBI DAA.)

In this case, the length of the parking spaces was reduced by 0.5 m and the width by 0.2 m, which creates space for planting. The city's bylaws concerning space to be respected were consulted. The result appears in Illustration 11.

Reducing the parking space dimensions will enable the parking lot owner to save on infrastructure construction costs, while contributing to reducing the heat island effect.

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When drawing the parking lot design plan, the designer took into account the site's dimension, topography, orientation and presence of vegetation. The designer preserved the existing vegetation when developing the overall plan, and special vegetation protection measures will be applied during the course of the work.

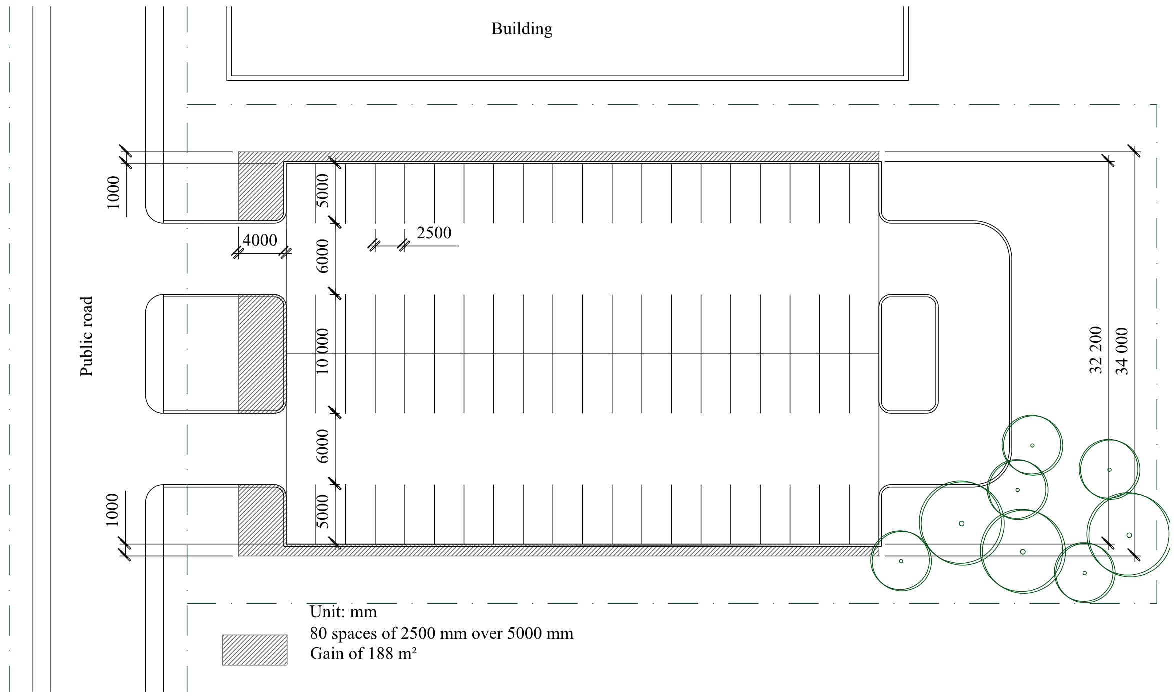

ILLUSTRATION 11 — GAIN IN AREA BY REDUCING PARKING SPACE SURFACE

(Source: Groupe IBI DAA.)

6.3 STEP 2 — HIGH SRI COVER

Once the parking lot surface area is reduced, it is possible to use surface materials with a high SRI. There are many possible combinations, since these materials can be used on the entire parking lot surface or on one or more portions. The choice may depend on several factors, like municipal regulations, the size of the areas to shade, the activity level of the parking lot, the construction budget, etc.

In this case, all the traffic lanes will be in asphalt and the parking space surfaces will have a high SRI material (pale-colour concrete pavers, application of a pale-coloured surface coating, turfgrass, gravel chips, etc.). This will result in reducing the asphalt surface by 62.5%, regardless of the choice of cover type (see Illustration 12).

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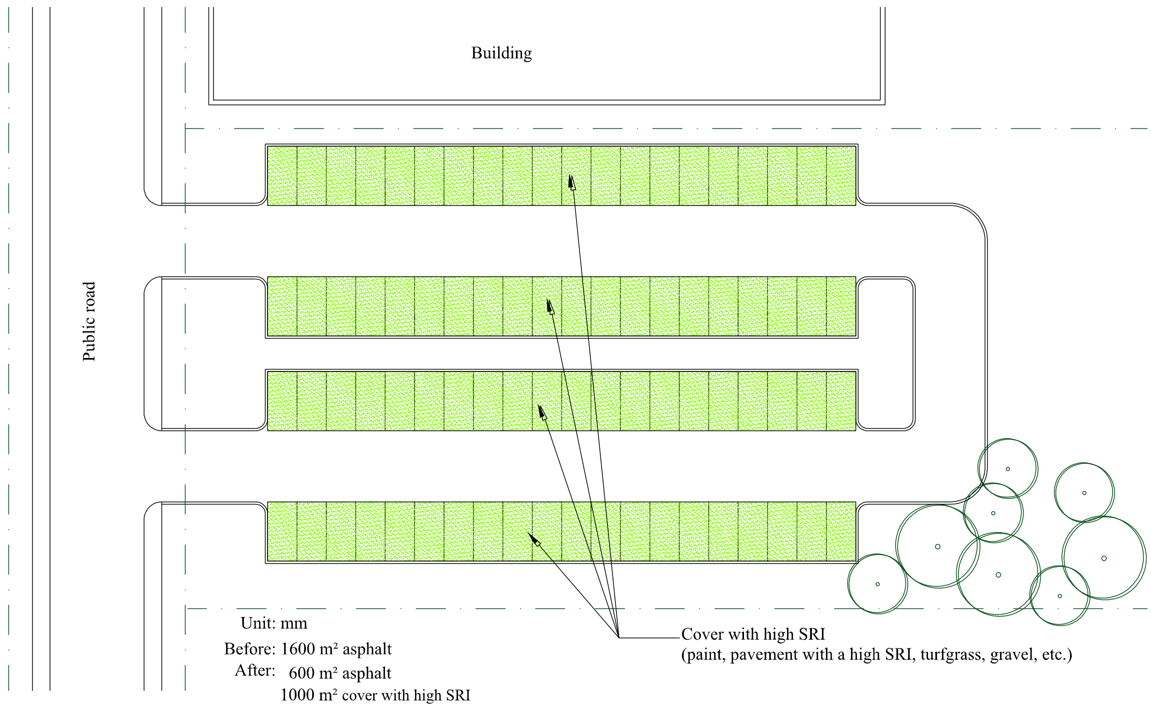

ILLUSTRATION 12 — USE OF A COVER WITH A HIGH SRI
(Source: Groupe IBI DAA.)

6.4 STEP 3 — PLANT VEGETATION

The designer opts to plant large-growing trees and shrubs in the soil to replace grass. It is noteworthy that by designing continuous planting holes, the tree root system can develop more effectively.

The trees will be planted on the south side of the parking lot to ensure maximum shading, and a green wall will be installed on the north side building to improve the thermal performance of the overall site.

In this case, the designer selects large-growing vegetation that is drought-resistant or drought-tolerant and resistant to de-icing salts and salt spray.

At this step in the process, the designer provides space for snow disposal, unless the snow is not stored on-site. In the snow disposal area, no trees will be planted; a grass surface will be appropriate (see Illustration 13).

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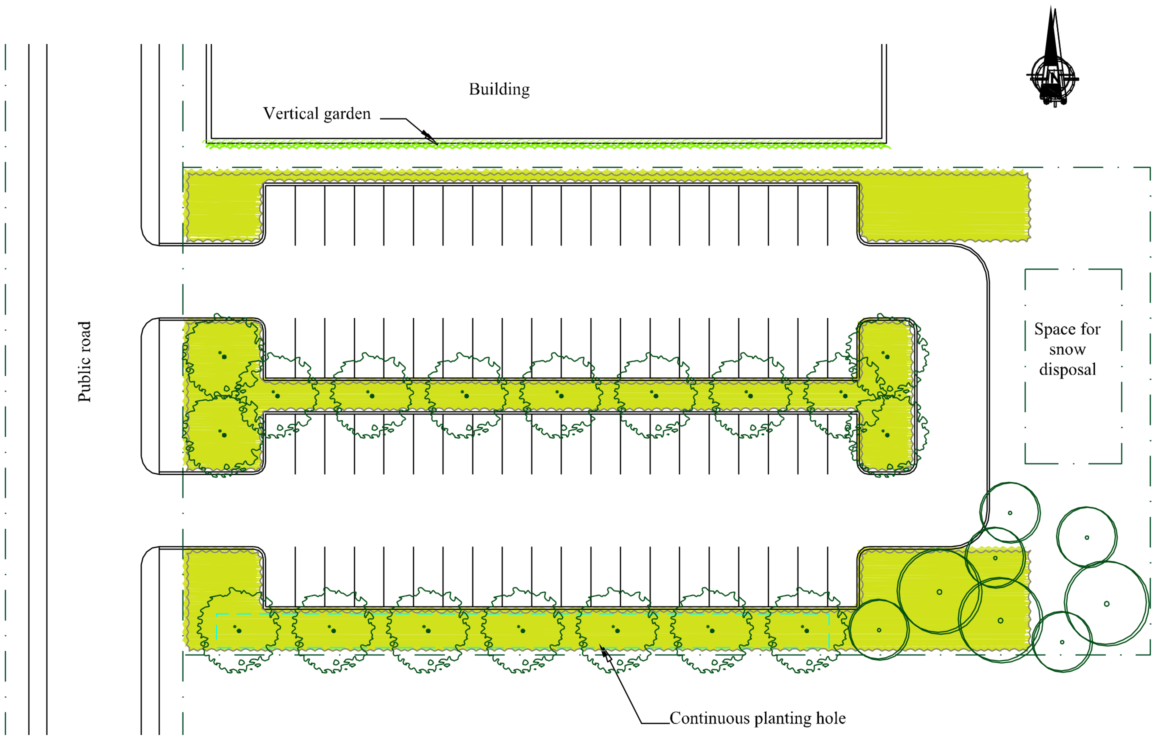

ILLUSTRATION 13 — PLANTING OF VEGETATION
(Source: Groupe IBI DAA.)

All the work to be completed is shown in Illustration 14. The designer will complete the parking lot plans with the specifications related to the selection of trees, shrubs and other vegetation along with the specifications for the surface materials.

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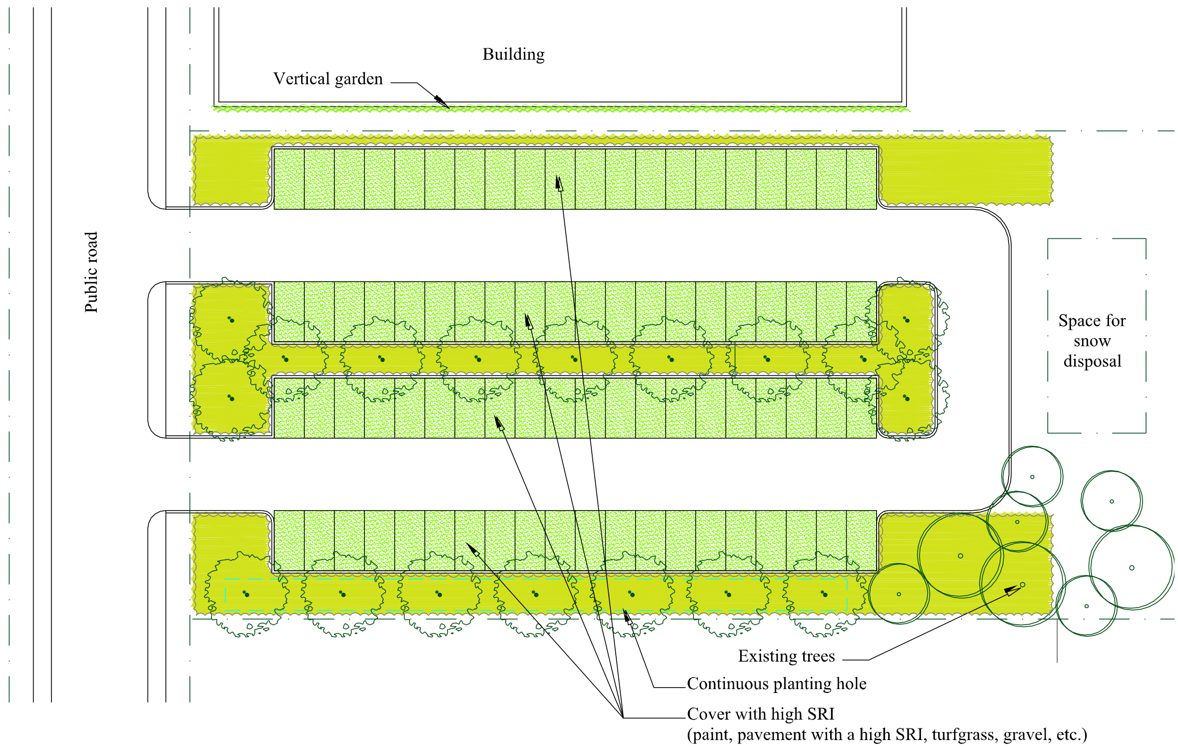

ILLUSTRATION 14 — OVERALL PARKING DESIGN
(Source: Groupe IBI DAA.)

6.5 STEP 4 — MANAGE STORMWATER RUNOFF

There are several possibilities for managing stormwater runoff water with the aim of reducing the urban heat island effect:

- Install a cover with a high SRI and allow stormwater runoff to infiltrate into the soil (turfgrass, draining pavement, gravel). With this technique, a granular base should enable water to be stored and a sub-foundation should enable it to infiltrate into the groundwater table. In addition, stormwater infiltrating into the soil must not contain any contaminants (hydrocarbons, phosphorus) that could enter the groundwater table. Over time, it is common for fine suspended solids to clog paver joints and the granular base, impeding system performance.

- Build a grass swale or trench (with centre or periphery drain) on the site for runoff. Normally, this swale should include an overflow system (catch basin) connected to the city's rainwater system (see Illustration 15). A cross-sectional view is shown in Illustration 15, demonstrating how water accumulates inside the swale.

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There are stormwater runoff management practices that are more specific to the underground rainwater holding capacity. They are not intended specifically to reduce the heat island effect, but can contribute to improving water quality and recharging the groundwater table. Here is a description of this type of strategy:

- Install a conventional stormwater management system comprising catch basins and pipes. The pipes transport the stormwater runoff to a treatment unit that recovers the suspended solids and hydrocarbons and then sends the water to an infiltration bed located under the parking lot surface. The medium recovers any phosphate. The water recharges the groundwater table through infiltration and can then evaporate or be absorbed by tree roots and contribute to evapotranspiration. This technique can reduce the diameter of pipes used for holding the stormwater runoff. It diverts a large part (if not all) of the parking lot stormwater runoff from the municipal rainwater sewer system. The infiltration bed has an overflow system connected to the municipal system. This technique is increasingly used in Québec.

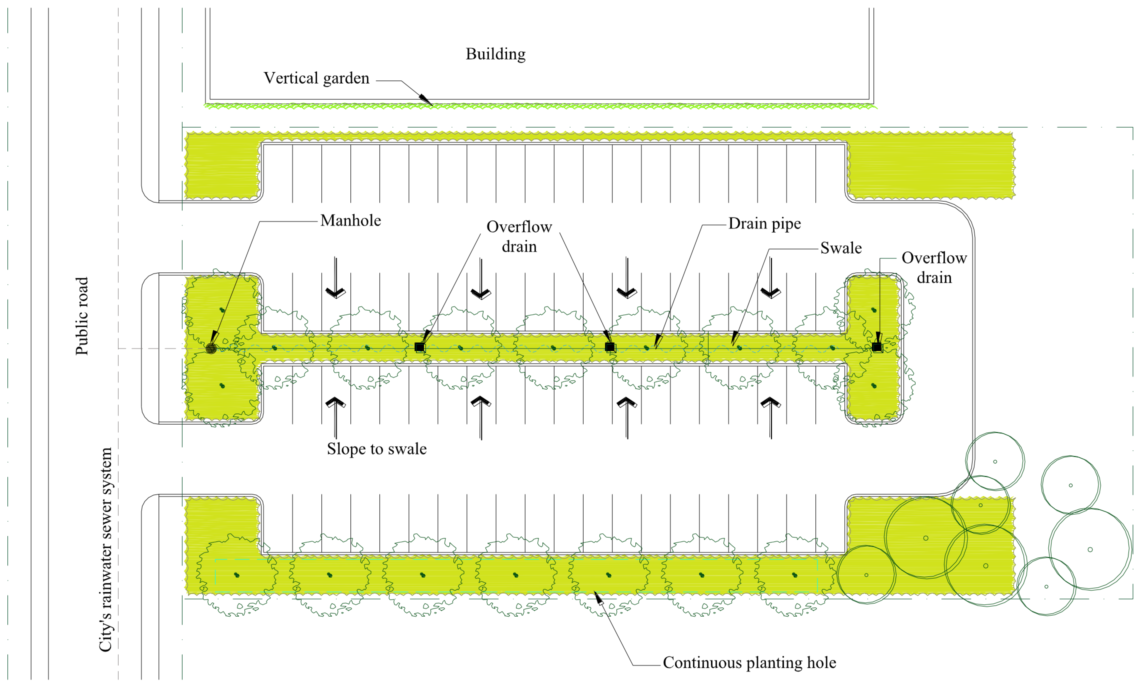

ILLUSTRATION 15 — DRAIN TRENCH OR SWALE WITH OVERFLOW
(Source: Groupe IBI DAA.)

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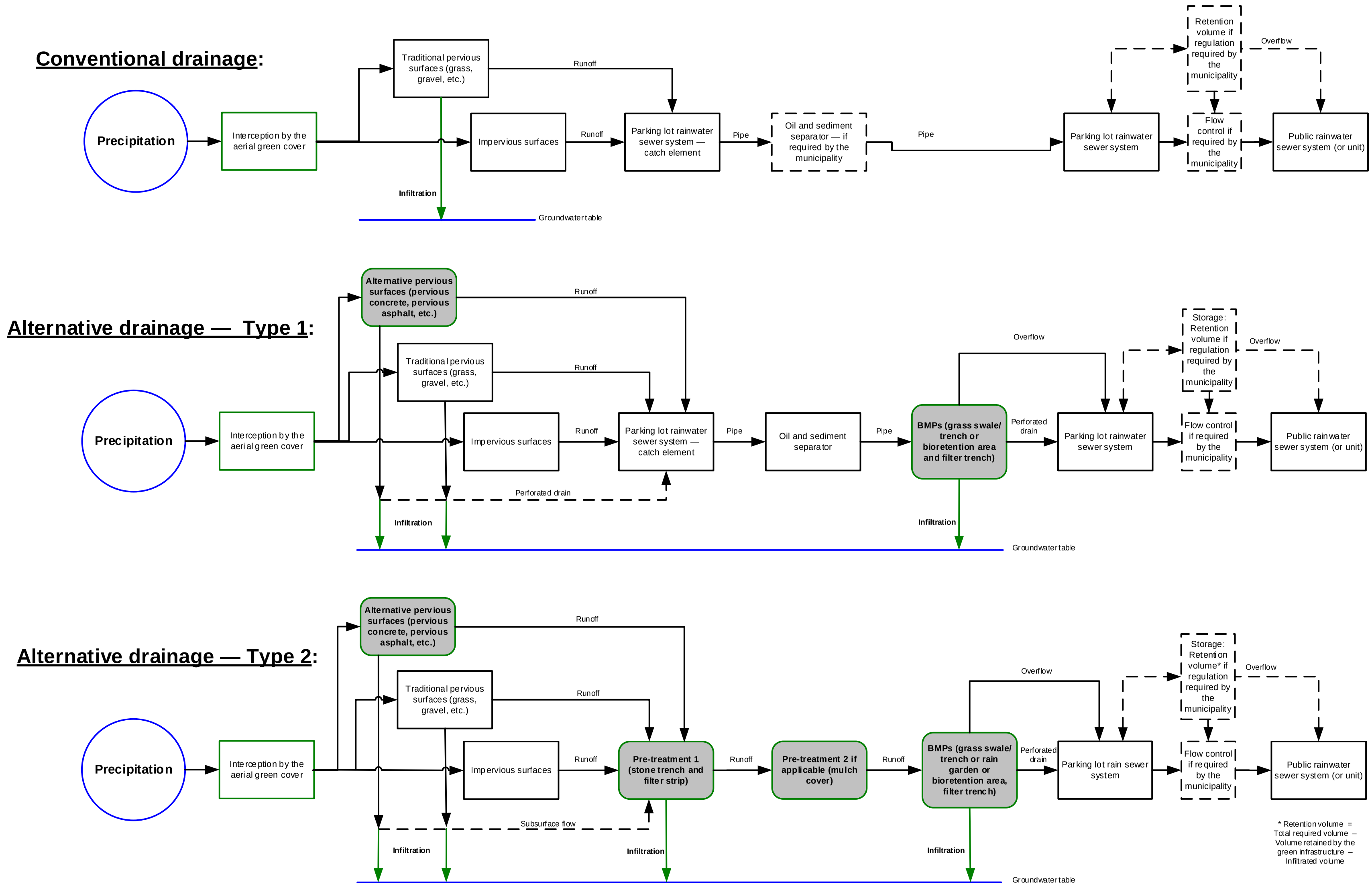

FIGURE 1 — CONVENTIONAL AND ALTERNATIVE DRAINAGE IN PARKING LOTS
(See enlargement at the end of the document.)

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ANNEX A

THERMAL MAPPING OF URBAN HEAT ISLANDS IN COMMERCIAL SECTORS

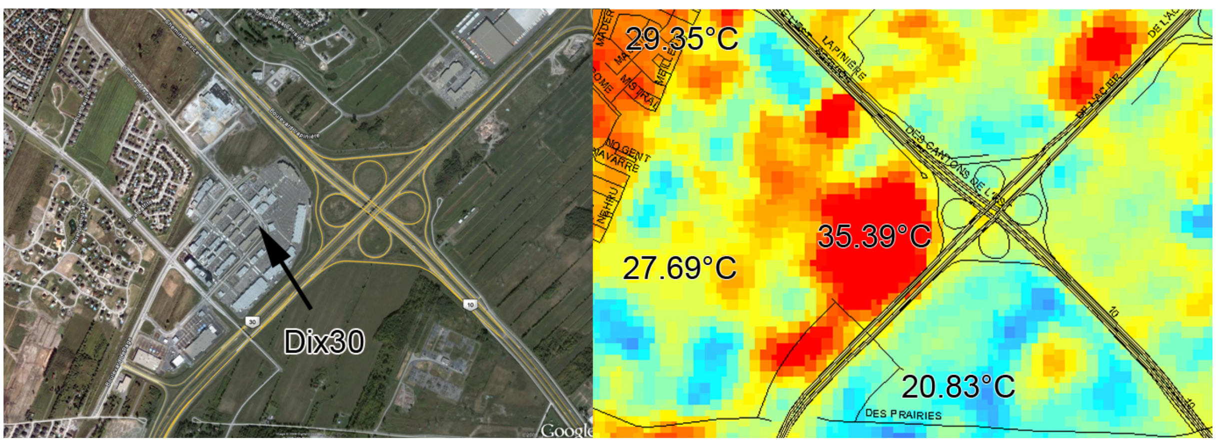

FIGURE A.1 — EXAMPLE OF SURFACE TEMPERATURES RECORDED NEAR THE DIX30 SHOPPING DISTRICT IN BROSSARD
(Sources: Figure on left: Google Earth map; Figure on right: Y. Baudouin and P. Martin, UQAM, Landsat 5 Image taken July 5, 2008.)

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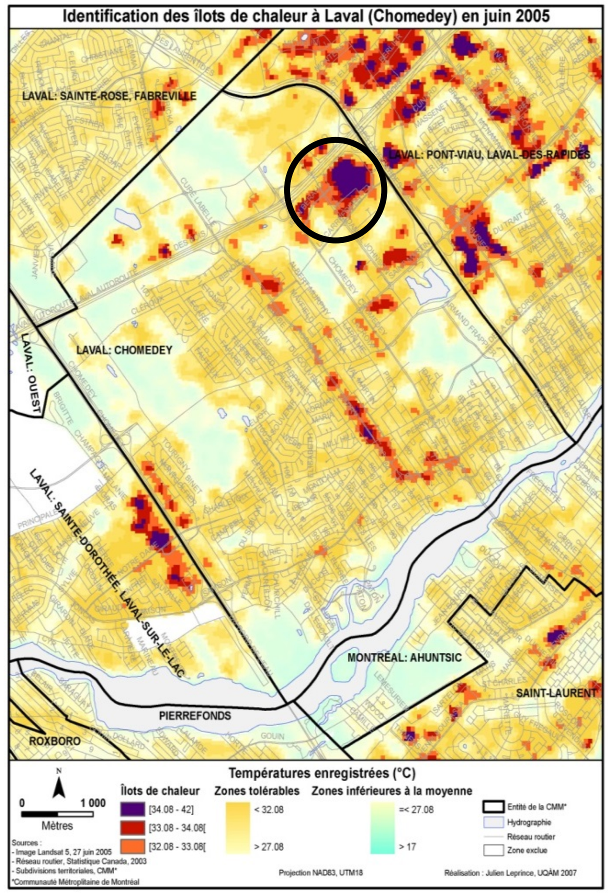

FIGURE A.2 — TEMPERATURE RECORDED AT CARREFOUR LAVAL
(Sources: Figure on left: Google Earth map; Figure on right: Y. Baudouin and J. Leprince, UQAM, Landsat 5 Image taken June 27, 2005.)

{It can be noted that the materials used (asphalt, dark roof) impact surface temperatures, causing them to rise [superior class] (from 34.08°C to 42°C).}

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ANNEX B

PARKING LOT AVERAGE SRI CALCULATION

Project name: ______________________________

Location: ______________________________

Firm: ______________________________

Evaluation conducted by: ______________________________

Date: ______________________________

Calculation hypothesis: Without shade ☐ With shade ☐

Comments: ______________________________

____

Type of Surface	**Area (A)**, in m^2	**Weighted Area (C)**, C = A/B	**SRI of Surface (D)**	**Average SRI**, C × D
Total area of parking lot **(B)**			Average SRI of parking lot	

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ANNEX C

ELEMENTS FOR DESIGNING A PARKING LOT

C.1 GENERAL

The objective of this annex is to propose various parameters for designers to consider when developing or redeveloping a parking lot.

The analysis of each of the parameters involving operation, traffic, users, physical and social environments should lead to a more precise definition of a parking lot. With this approach, better adapted methods and interventions can be implemented to reduce the urban heat island effect.

The design elements to consider for parking lots of private residences are not addressed in this annex.

C.2 PARAMETERS ASSOCIATED WITH BUILDING USE

The parameters for developing a parking lot can be defined according to the type of building and its users.

Parking lots are usually classified according to the following uses: public, commercial, industrial and residential. To diversify the classification, other categories can be added.

For each specific use, designers can seek to understand the characteristics that could enhance the parking lot design. A non-exhaustive list of several parameters to consider is provided below. Other parameters may be added to the list based on the specific context for developing each parking lot:

- **Health**: This parameter involves measures to implement that would impact the health and wellbeing of parking lot users (e.g. hospital).
- **Quality of infrastructure**: This parameter would orient the design and selection of materials according to vehicle traffic requirements, with the aim of improving durability and convenience (civil engineering, e.g. transportation industry).
- **Organization's reputation**: This parameter would showcase the company's ethics and corporate image, with quality landscaping contributing to reducing the heat island effect (e.g. hotel).
- **Aesthetics**: This parameter would feature better integration into the urban environment and greater social acceptability (e.g. restaurant).

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An analysis of the benefits sought provides guidance on design principles, but these principles should then be linked with various methods used to reduce the urban heat island effect.

Other very important elements should be analyzed and evaluated when designing a parking lot, including:

- Number of parking spaces for employees;
- Number of parking spaces for visitors;
- Traffic intensity.

C.3 PARAMETERS ASSOCIATED WITH HOW LONG AND HOW OFTEN THE PARKING LOT IS USED

The design and management of a parking lot can be greatly influenced by parameters associated with how long and how often the parking lot is used.

Below are several of the parameters that could be analyzed:

- parking period duration;
- time of day that the parking lot is used (day, night, morning, afternoon);
- days of the week that the parking lot is used (week, weekend);
- periods of the year that the parking lot is used;
- special events, such as an annual festival, monthly or seasonal meetings;
- planned pedestrian drop-off zone;
- authorization for long-stay parking;
- types of events handled;

Designers may add other parameters to their analysis table.

C.4 PARAMETERS ASSOCIATED WITH PARKING LOT USERS

Parking lot users should be known so the design can be tailored to the parking lot clientele. The aim of studying these parameters is to design traffic diagrams, position the parking areas for each user and develop priorities for access or proximity of services.

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A non-exhaustive list of several parameters includes:

- Cars;
- Electric cars and charging points;
- Trucks;
- Minivans;
- Pick-up trucks;
- Motorcycles, scooters;
- Bicycles (personal or public);
- Pedestrians;
- Persons with reduced mobility;
- Public transit (buses, tramways).

The parameters associated with the parking lot’s users can also be associated with other parameters, for example, those associated with the building’s use.

C.5 PARAMETERS ASSOCIATED WITH A PARKING LOT’S PHYSICAL LOCATION

The parking lot’s physical location should be analyzed in order to design the landscaping, including the planting of vegetation, rainwater management, snow storage areas, pedestrians paths, holding tanks and other facilities.

A non-exhaustive list of several parameters includes:

- **Sunlight**: Evaluating sunlight (how long and where) can prove to be strategic for positioning facilities to reduce the urban heat island effect and for the comfort of users; evaluating the percentage of shade is a parameter often used in municipalities to determine whether facilities comply with bylaws.

- **Topography**: The topography of the land is an important factor in rainwater management and can lead to constraints involving the infrastructure.

- **Nature of soils**: The nature of soils can influence rainwater management and, among other things, the groundwater holding capacity; the nature of soils can also constitute a constraint for underground facilities (underground parking lot, pipework, holding tank and other).

- **Weather conditions**: The weather conditions to be studied include, among other things, the direction and intensity of prevailing winds and annual snowfall.

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- **Sound environment**: Evaluating the sound environment can involve specific items, like acoustic baffles in the form of a wall or earth berm, or structures to be installed in the parking lot that can also be associated with reducing the urban heat island effect.

C.6 PARAMETERS ASSOCIATED WITH PARKING LOT FEES

Parking lot fees and the fee structure can influence the parameters associated with how long and how often the parking lot is used. The influence of fees on these parameters can guide the design of the facilities to reduce the urban heat island effect.

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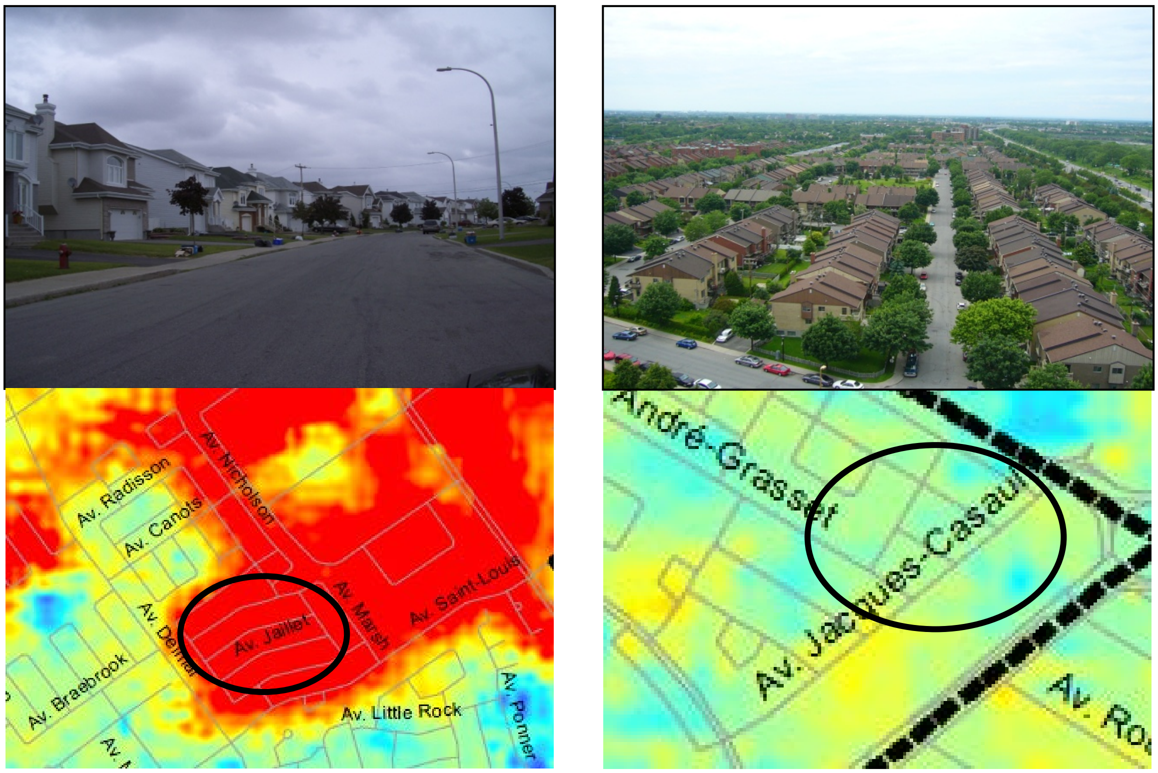
ANNEX D

THERMAL IMAGES OF TWO RESIDENTIAL SECTORS



POINTE-CLAIRE **MONTRÉAL**

FIGURE D.1 — IMAGES OF THE THERMAL EVOLUTION OF TWO SECTORS (1984-2001)
(Sources: photographs by C. Perez and P. Martin, UQAM, 2008.)

The figure shows two residential areas built around the same years (end 1980-beginning 1990). On the left (Pointe-Claire/Valois neighbourhood, around 1994), small trees recently planted offer a degraded thermal portrait (increasing), while on the right (Montréal/Borough of Ahuntsic-Cartierville, eastern sector, around 1986), landscaped trees planted when work was completed have lowered the surface temperature.

The thermal images at the bottom of the figure indicate the intensity of the difference (the change) between the two thermal images Landsat 5 of 1984 and of 2005, where the red indicates heating (up to 16°C), while the blue indicates cooling (down to -11°C).

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ANNEX E

RECOMMENDATIONS OF THE MINISTÈRE DES AFFAIRES MUNICIPALES, DES RÉGIONS ET DE L'OCCUPATION DU TERRITOIRE TO REDUCE THE URBAN HEAT ISLAND EFFECT IN PARKING LOT DEVELOPMENT

E.1 FOREWORD

Reducing the urban heat island effect through optimal parking lot development could not be considered without tackling the question of parking lot size. The size is mainly determined by the number of parking spaces, the dimensions of the spaces and the dimensions of the traffic lanes in the parking lot.

These components (number and dimensions of spaces and lanes) may be subject to provisions in zoning bylaws adopted by municipalities (*Act Respecting Land Use Planning and Development*, Sect.113). The zoning bylaw may, "prescribe, for each zone, use or combination of uses, the space which, on the lots, shall be reserved and arranged for parking, loading or unloading vehicles […] and the manner of arranging such space; to establish parking restrictions inside or outside buildings."

Municipalities also have the power to require a permit or certificate be issued for the development or redevelopment of a parking lot. The permit or certificate may be issued subject to compliance of the project to development bylaws.

Since many municipalities use their power to adopt bylaws relating to parking lot development, one of the means to reduce heat islands due to parking lots is to change the municipal bylaws.

It follows that certain recommendations by the Ministère des Affaires municipales, des Régions et de l'Occupation du territoire are given in this annex to limit the area occupied by parking lots developed in urban settings and, in so doing, to restrict asphalted areas.

E.2 RECOMMENDATIONS TO BE INCORPORATED INTO MUNICIPAL BYLAWS

The following recommendations are presented more in the form of objectives than quantifiable standards. They seek to influence the development of urban planning bylaws so that criteria for developing parking lots will be included.

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E.3 NUMBER OF PARKING SPACES

E.3.1 REDUCE THE MINIMUM NUMBER OF PARKING SPACES

As a general rule, municipalities adopt provisions for a minimum number of parking spaces, according to land use. In municipality X, a retail clothing store could be required to provide 1 space per 10 m^2 of commercial space.

With the aim of reducing the heat island effect by reducing the asphalt surface, the number of parking spaces required for certain uses could be lowered.

For example, the zoning bylaw in the Borough of Saint-Laurent was modified in December 2009 to include provisions aimed at reducing the required minimum number of spaces[1]. For residential dwellings, the required minimum number of spaces per dwelling was reduced by 36% and the required number of spaces for visitors was reduced by 33%. The minimum number of parking spaces was reduced by 20% for a commercial cluster, by 15% for office buildings, by 70% for day care centres, by 50% for meeting places and by 35% for service stations.

E.3.2 IMPOSE A MAXIMUM NUMBER OF PARKING SPACES TO ALLOW

Zoning bylaws, many of which require a minimum number of parking spaces to provide, could also set a maximum number of spaces for development.

For example, the complementary document to the Master Plan, adopted by the Ville de Montréal in 2004, requires the Borough of Ville-Marie to set a maximum number of parking spaces for the construction, extension or change in use of a building.

The Borough of Saint-Laurent modified its zoning bylaw to set a cap on the number of parking spaces that may be developed per property. This cap is set at 150% of the required minimum number of spaces. For single-family dwelling units, multi-family dwelling units and parking lots with fewer than 5 spaces, this cap was set at 200% of the required minimum. In the case of industries, businesses, offices and services, where the number of spaces exceeds the minimum requirement by 125%, parking should be underground.

In Gatineau, the number of parking spaces authorized on streets in certain heritage sectors is limited to 50% of the required minimum number per use.

1. It should be noted that Québec’s best practices described in this annex are presented for information purposes and have not been the subject of a legal analysis. It goes without saying that, before adopting any legal provisions, it is essential for a municipality to consult its legal advisors to ensure the legality of the planned provisions.

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E.3.3 REDUCE THE REQUIRED NUMBER OF PARKING SPACES ACCORDING TO FACILITIES IN THE VICINITY

Another way of reducing the asphalt surface to reduce the urban heat island effect is to lower the required number of parking spaces in certain sectors, such as those close to public transit stops, in a village core or in a heritage sector.

For example, near public transit stations (Rapibus), in its downtown area, urban core areas, on streets in heritage sectors, the Ville de Gatineau uses a minimum number of spaces that is lower than the provisions applying to other sectors on the territory. This reduction varies from 20% to 50%, depending on the situation.

As for the Ville de Québec, it bases its regulatory provisions on parking lots in sectors that it qualifies as: “dense urban”, “structuring axis” and “general.” The number of spaces to provide varies depending on the urban form. Accordingly, for certain uses in a dense urban zone, no set number of spaces is required, but a maximum number of spaces is set.

In Matane, Thetford Mines and La Malbaie, certain zones are not subject to provisions regarding the minimum number of spaces to provide.

Near metro stations and certain commuter train stations, the Ville de Montréal requires, in its complementary document, that bylaws instituted by boroughs limit the supply of parking.

E.3.4 CONSIDER THE PROXIMITY OF A PUBLIC PARKING LOT

The number of required parking spaces can also be adjusted based on the proximity of a public parking lot.

For example, the Ville de Richmond reduced the number of spaces to provide by 50% for commercial businesses located within 50 m of a public parking lot.

E.3.5 ALLOW POOLING OF PARKING LOTS

It would be possible for two or more establishments to develop a common parking lot enabling them to reduce the minimum number of spaces to provide.

The municipality of Rémigny has thus made a 20% reduction in the total required number of spaces per use, providing the parking lot is located within 300 m of establishments.

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E.3.6 ENCOURAGE SHARED PARKING

Certain municipalities encourage shared parking among various users to reduce asphalt surfaces. Parking lot peak periods of use should occur at different times. For example, from Monday to Friday, movie goers use the parking lot in the evening, while office workers use it between 8 a.m. and 5 p.m. (see Figure E.1).

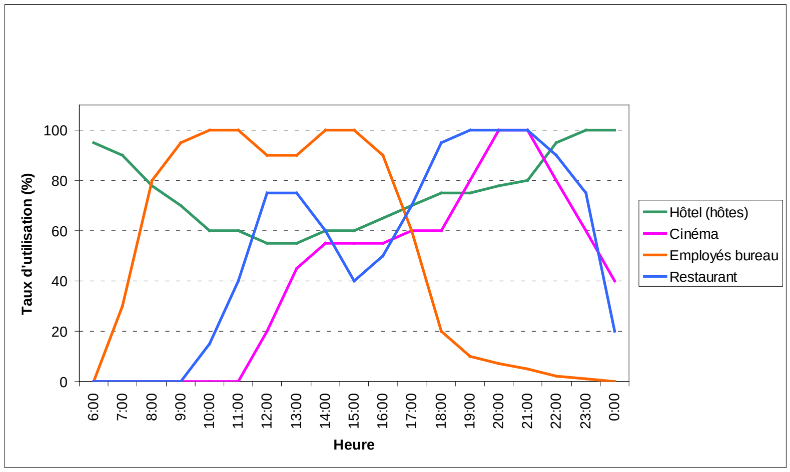

FIGURE E.1 — USE OF PARKING SPACES FOR CERTAIN USES, DAYS OF WEEK

In its zoning bylaw, the Ville de Brossard states that “where authorized in a zone’s specific provisions table, the concept of shared parking can be applied in particular to a mixed commercial project where certain uses are present, at all times, on a same site.” The shared parking provisions are based on a matrix that illustrates parking lot distribution according to use and times of day with the required minimum number of parking spaces. The zoning bylaw specifies, “that any shared parking space should be subject to a duly registered easement among the parties concerned requiring that the said parking space be maintained and shared among the users of the mixed commercial entity.”

The City of Chicago allows 100% of the spaces required for day-time activity to be provided as spaces for night-time or Sunday activity.

The City of Portland (Oregon) has a similar provision. A legal document guaranteeing access to the parking lot should be provided with the permit application. Applicants must show that the peak parking periods occur at different times.

E.3.7 ELIMINATE THE OBLIGATION OF PROVIDING PARKING SPACES

In addition to providing no minimum number of spaces in certain heritage areas, this obligation could also be eliminated in cases where no need is demonstrated. In this case, the exemption of the obligation to provide and maintain parking spaces would be accompanied by the payment of a set amount.

For residential and industrial uses, the Borough of Saint-Laurent has eliminated the obligation of providing parking spaces in cases where no need is demonstrated.

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E.3.8 REPLACE VEHICLE PARKING SPACES BY BICYCLE PARKING SPACES

The number of parking spaces to provide could also be adjusted based on the number of bicycle spaces provided.

The City of Portland (Oregon) allows 25% of required parking spaces to be replaced by bicycle parking spaces, one vehicle space for every five bicycle parking spaces.

E.4 DIMENSIONS OF SPACES

E.4.1 REDUCE THE MINIMUM DIMENSIONS OF SPACES

Municipal parking bylaws generally require a minimum width and length that varies according to the angle of the parking lot (parallel spaces, spaces at 30°, 45°, 60° or 90°).

For example, in the case of a 90° space, the minimum width required may vary from 2.5 m to 2.7 m. The minimum length varies from 5 m to 6 m and is correlated to the width of the traffic lane, which varies from 6 m to 7 m for a two-way lane. The difference in area occupied by Space A that corresponds to the minimum dimensions required, for example, by the cities of Gatineau and Drummondville (2.5 m by 5 m) and by Space B that corresponds to the dimensions required by several municipalities (2.7 m by 5.5 m) can reach 2.35 m^2. Multiplied by 100 spaces, this difference is an important one for reducing the urban heat island effect.

For example, a retail business of 200 m^2 must develop 7 parking spaces at 90°. In the municipality that requires spaces A of 2.5 m by 5 m, the parking lot will occupy an area of 147.5 m^2. In the municipality that requires spaces B of 2.7 m by 5.5 m, the parking lot will occupy an area of 168.75 m^2 for a difference of 21.25 m^2 or 14% (see Table E.1 and Figure E.2).

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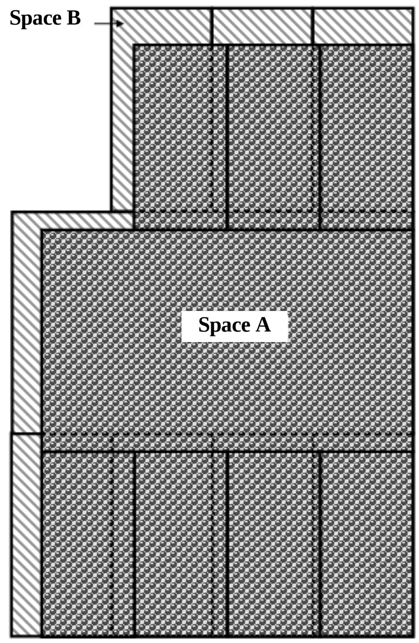

FIGURE E.2 — EXAMPLES OF PARKING LOT AREAS ACCORDING TO PARKING SPACE DIMENSIONS

TABLE E.1

PARKING SPACE DIMENSIONS IN FIGURE E.2

	A	B
Space length, in metres	5	5.5
Space width, in metres	2.5	2.7
Lane width, in metres	6	6

E.4.2 DEVELOP VARIOUS TYPES OF PARKING LOT SPACES

Parking lot development could include spaces reserved for small cars, which can reduce the asphalt area. It can also include bigger spaces. By doing this, since a number of spaces are reserved for larger vehicles, the size of conventional spaces can be reduced, without however penalizing drivers of larger vehicles.

There are now conventional parking space dimensions for large vehicles, like mid-size, compact and family cars, parking space dimensions for small vehicles, like subcompacts and two-seaters, and bigger space dimensions for pickup trucks and minivans (see Table E.2).

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Obviously, identifying the spaces for small, ordinary or large vehicles is essential and controls could be necessary from time to time. The municipality should also stipulate the proportion of the parking lot to reserve for conventional, small and large spaces.

For example, the City of Vancouver stipulates that 25% of a parking lot may be occupied by small spaces whose dimension is 2.3 m wide by 4.6 m long. Regina allows small spaces of 2.3 m by 4.9 m.

TABLE E.2

VEHICLE DIMENSIONS

Dimensions of 2011 Models of Certain Cars Sold in Canada			
Category	**Model**	**Length**, in mm	**Width**, in mm
Two-seater	Smart For Two	2690	1560
Subcompact	Mini Cooper	3723	1683
Subcompact	Toyota Yaris	4300	1690
Subcompact	Ford Fiesta	4409	1722
Family	Hyundai Elantra Touring	4485	1765
Compact	Toyota Corrola	4540	1760
Family	Kia Rondo	4545	1820
Special use vehicle	Toyota RAV4	4620	1855
Special use vehicle	Toyota Highlander	4785	1910
Mid-size	Nissan Altima	4844	1795
Minivan	Toyota Sienna	5085	1985
Full-size berlin	Ford Taurus	5154	1936
Full-size berlin	Cadillac DTS	5273	1900
Special use vehicle	Ford Expedition (largest model)	5621	2002
Special use vehicle	Cadillac Escalade (largest model)	5662	2009
Special use vehicle	Lincoln Navigator (largest model)	5672	2002
Pickup truck	Ford F-150 (largest model)	5888	2012
Pickup truck	GMC Sierra HD (multi-seat cab)	6580	2032

NOTES —

1 The categories stem from data from Natural Resources Canada.

2 The dimensions are taken from the respective auto maker websites.

E.4.3 SET MAXIMUM DIMENSIONS

On one hand, for a parking lot to operate efficiently, minimum dimensions for spaces and traffic lanes should be set. On the other hand, for the asphalt area to be limited, maximum dimensions should also be set.

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By providing dimensions for the provision of small spaces, conventional spaces and large spaces, setting minimum and maximum dimensions can be avoided.

E.4.4 PROMOTE SPACE-SAVING CARS AND BICYCLES

Again with the objective of limiting parking lot size and, as a consequence, the asphalt surface, giving a priority location to bicycle parking spaces and small spaces, such as near the building entrance, is one way of encouraging lower-polluting vehicles. For this to be effective, however, such a rule may need to have coercive measures applied to offenders.

E.5 INDOOR PARKING LOTS

To reduce the urban heat island effect, a certain number of parking spaces could be underground. Certain municipalities make underground parking mandatory to improve the urban landscape or increase a sector's built density.

For example, in certain parts of the city, the Ville de Québec requires a percentage of a parking lot to be developed underground. This percentage is variable (for example, 50% or 65%) depending on the zone and can even reach 100%.

The Borough of Saint-Laurent, in Montréal, requires that all spaces for projects involving multi-family dwelling units be underground, except for spaces reserved for visitors.

To promote the development of underground parking lots, the number of spaces to provide can be limited. The City of Chicago reduces the minimum number of spaces to provide to 50%, once all parking spaces are developed underground.

For multi-storey parking garages, bylaws can require the top storey or roof to be covered in vegetation. This requirement can also apply to the roof of an underground parking lot.

E.6 LANDSCAPING OF PARKING LOTS

Parking lot bylaws can also apply to parking lot landscaping, the presence of trees, surface materials and even rainwater management.

The zoning bylaw of the Borough of Rosemont—La Petite-Patrie, in Montréal, requires the following materials for paved parking lot surfaces, loading or outside storage areas and access lanes:

"1. Gray-coloured concrete or gravel;

2. Open-grid pavement;

3. Inert material whose SRI is 29 or higher, attested by the manufacturer's specifications or a professional opinion."

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The complementary document to the Ville de Montréal's Master Plan includes provisions for parking lots of large- and medium-sized retail businesses. It stipulates that a band of greenery must be planted at the edge of a public thoroughfare. When the parking lot borders a residential zone, a band of greenery must be situated along the property line. When the surface area of a parking lot is greater than 1000 m^2, islands of ornamental greenery should be installed in sufficient size and number to create an attractive environment that helps structure the lot and make it legible to users.

The zoning bylaw of the Borough of Saint-Laurent provides the integration of green spaces within parking lots of 20 spaces and more. It also stipulates that the canopy formed by mature trees cover 40% of parking lots.

In Québec city, parking lots with over 100 spaces must be divided into islands of 100 spaces at most. The islands shall be separated by a pedestrian path at least 1.5 m wide bordered by a green band at least 2 m wide.

In Gatineau, the zoning bylaw landscaping requirements become stricter with the increase in the number of parking spaces. For example, for parking lots with over 25 spaces, "At least 5% of the surface of an off-street parking space, excluding the area of a grass or otherwise landscaped band bordering the off-street parking space, shall be comprised of a grass or otherwise landscaped band. Each of these bands shall be bordered by a concrete edge at least 0.15 m high; *b*) In the grass or otherwise landscaped band, bordering any off-street parking space, a softwood tree with a diameter at chest height (DBH) of at least 5 cm or a conifer of at least 2 m high, when planted, shall be planted every 12 m. At least 60% of the trees planted shall be conifers." In addition to these requirements, there are also additional requirements in the Gatineau bylaws for parking lots with over 100 spaces.

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ANNEX F

CREDIT 7.1 OF THE LEED GREEN BUILDING PROGRAM

The LEED program is often used for buildings and is well known by professionals in the field, like architects. The text relating to Credit 7.1 of the LEED document [24] is reproduced on the next page.

The program also offers credits for other parameters related to the topic of this guide:

Development of sustainable sites

- Credit 5.2 Site Development: Maximize Open Space
- Credit 6.1 Stormwater Design: Quantity Control
- Credit 6.2 Stormwater Design: Quality Control

When designers seek to obtain one of these credits, the development projects they implement must correspond to the goals of the credit. A quantitative rating method is then given to determine if the credit is obtained.

Seeking to obtain one of the credits mentioned (5.2, 6.1, 6.2 or 7.1) could hinder the ability to obtain one of the other credits. Designers must then make a choice, since obtaining one credit could prevent obtaining another.

The LEED credit rating system is therefore limited when it comes to the best practices to implement for effectively reducing the urban heat island effect using the strategies in this guide. Designers should take into account limits of the LEED program when designing a project whose goal is to implement all the measures necessary to reduce the urban heat island effect.

The Canada Green Building Council published another document, the LEED Canada Reference Guide, to calculate credits and explain how to reach the goals that are proposed to reach Credit 7.1 [23].

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CREDIT 7.1 OF LEED GREEN BUILDING PROGRAM — HEAT ISLAND EFFECT: NON–ROOF

INTENT

To reduce heat islands to minimize impact on microclimates and human and wildlife habitats.

CASE 1: ALL PROJECTS

OPTION 1

Use any combination of the following strategies for 50% of the site hardscape (including roads, sidewalks, courtyards and parking lots):

- Provide shade from existing tree canopy or within 5 years of landscape installation; landscaping (trees) must be in place at the time of occupancy;
- Provide shade from structures covered by solar panels that produce energy used to offset some non-renewable resource use;
- Provide shade from architectural devices or structures that have a solar reflectance index (SRI) of at least 29;
- Use hardscape materials with an SRI of at least 29;
- Use an open-grid pavement system (at least 50% pervious).

Or

OPTION 2

Place a minimum of 50% of parking spaces under cover. Any roof used to shade or cover parking must have an SRI of at least 29, be a vegetated green roof, or be covered by solar panels that produce energy used to offset some non-renewable resource use.

CASE 2: FOR NON-CAMPUS PROJECTS ONLY

For projects where the non-roof area constitutes less than 5% of the total site area: meet the requirements of Sustainable Sites Credit 7.2: Heat Island Effect:

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Roof and Sustainable Sites Credit 2: Development Density and Community Connectivity.

POTENTIAL TECHNOLOGIES & STRATEGIES

Employ strategies, materials and landscaping techniques that reduce the heat absorption of exterior materials. Use shade (calculated on June 21, noon solar time) from native or adapted trees and large shrubs, vegetated trellises or other exterior structures supporting vegetation. Consider using new coatings and integral colorants for asphalt to achieve light-coloured surfaces instead of blacktop. Position photovoltaic cells to shade impervious surfaces.

Consider replacing constructed surfaces (e.g., roof, roads, sidewalks, etc.) with vegetated surfaces such as vegetated roofs and open grid paving or specify high-albedo materials, such as concrete, to reduce heat absorption.

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ANNEX G

TECHNIQUES ENABLING ROOT SYSTEM DEVELOPMENT UNDER PAVEMENT

G.1 STRUCTURAL SOIL

Structural soil is a technique that enables root systems to develop under pavement. In this context, there is a stone-substrate mixture patented in the United States under the name CU-Structural Soil®. The explanations provided in the text below were taken from the document *Using CU-Structural Soil® in the Urban Environment* by Cornell University's Urban Horticulture Institute, Department of Horticulture.

> NOTE — CU-Structural Soil® is a patented product that is provided as one example; other mixtures that are not patented may be used as a structural soil enabling tree root development.

CU-Structural Soil® (U.S. Patent No. 5,849,069) is a two-part system comprised of a rigid stone "lattice" to meet engineering requirements for a load-bearing soil, and a quantity of soil, to meet tree requirements for root growth. The lattice of load-bearing stones provides stability as well as interconnected voids for root penetration, air and water movement (see the figure taken from the document on the following page [Figure G.1]). The uniformly graded 20 mm to 40 mm angular crushed stone [from ¾ in to 1 ½ in] specified for CU-Structural Soil® is designed to ensure the greatest porosity. Crushed angular stone provides more compaction and structural interface of stone-to-stone than round stone.

Since among soil textures, clay has the most water and nutrient-holding capacity, a heavy clay loam is selected for the CU-Structural Soil® system. CU-Structural Soil® should also have organic matter content ranging from 2% to 5% to encourage beneficial microbial activity.

A minimum of 20% clay is also essential for a proper cation exchange capacity. With carefully chosen uniformly-graded stone and the proper stone to soil ratio, a medium for healthy root growth is created that also can be compacted to meet engineers' load-bearing specifications. The intention is to "suspend" the clay soil between the stones without over-filling the voids, which would compromise aeration, drainage and bearing capacity. CU-Structural Soil® utilizes the patented Gelscape® hydrogel as a tackifier non phytotoxic agent.

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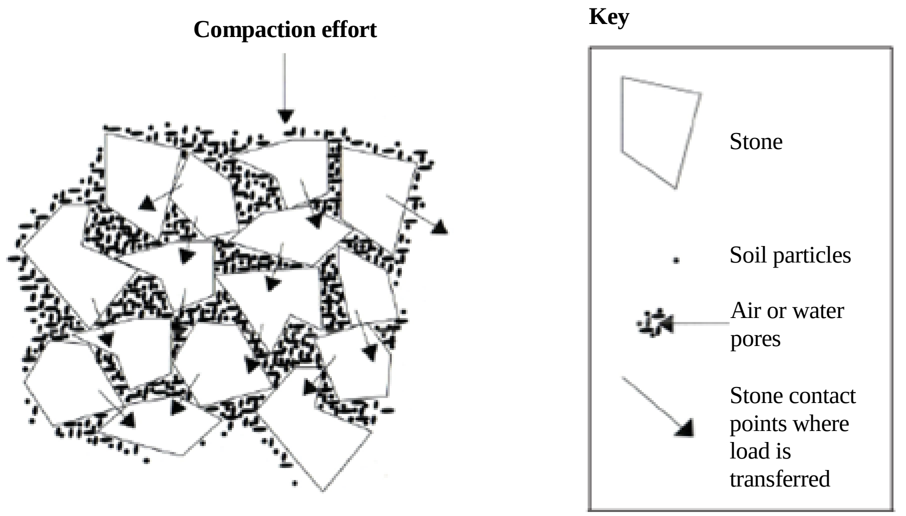

FIGURE G.1 — DIAGRAM SHOWING THE PRINCIPLE OF STONE-ON-STONE COMPACTION AND SOIL IN INTERSTITIAL SPACES
(Source: [11] Bassuk, Grabosky and Trowbridge, 2005.)

Figure G.2 shows an example of trees planted in a soil-stone mixture and illustrates in particular the root development in the area located beneath a road or sidewalk surface.

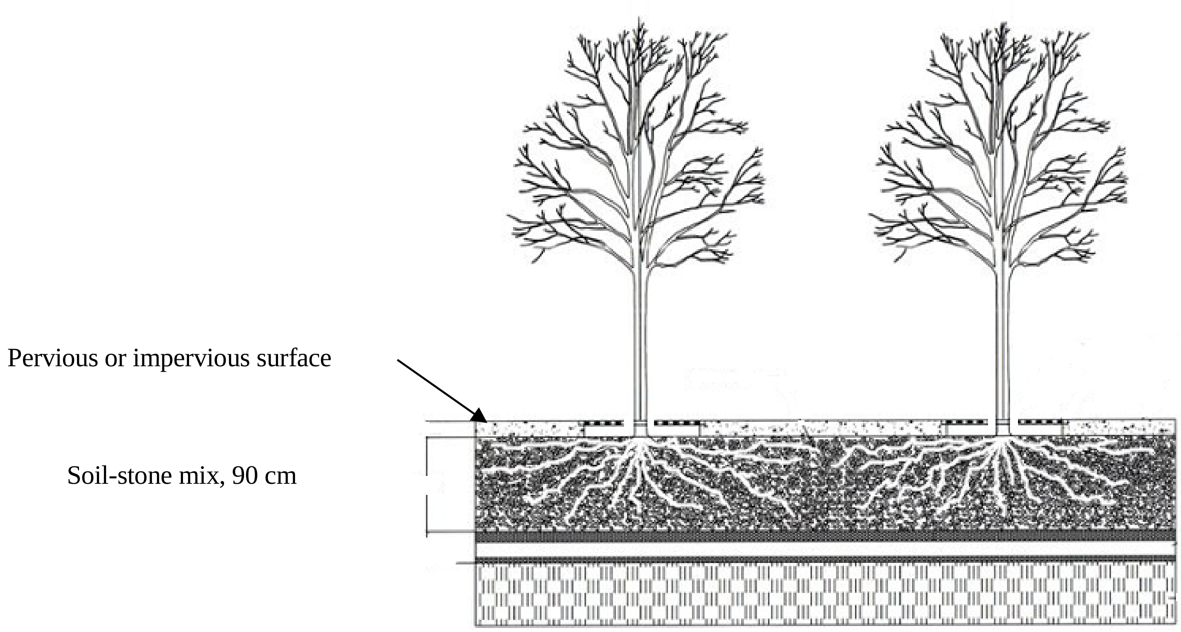

FIGURE G.2 — ROOT SYSTEM DEVELOPMENT IN A SOIL-STONE MIX
{Source: [11] Bassuk, Grabosky and Trowbridge, 2005 (adaptation).}

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Photo G.1 presents a tree planted in a soil-stone mix with a surface of pervious pavers.

PHOTO G.1
(Source: G. Laliberté, Saint-Hyacinthe, 2012.)

G.2 MODULAR CELL SYSTEMS

Modular systems made of plastic structures can support large tree growth and road vehicles while offering space for tree roots to develop properly.

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These structures are filled with a substrate that allows rainwater to infiltrate and accumulate. They have a high absorption capacity due to the non-compacted materials located in the cell.

FIGURE G.3 — MODULAR CELL SYSTEMS
(Source: [42] Greenmax, 2013.)

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ANNEX H

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ANNEX I

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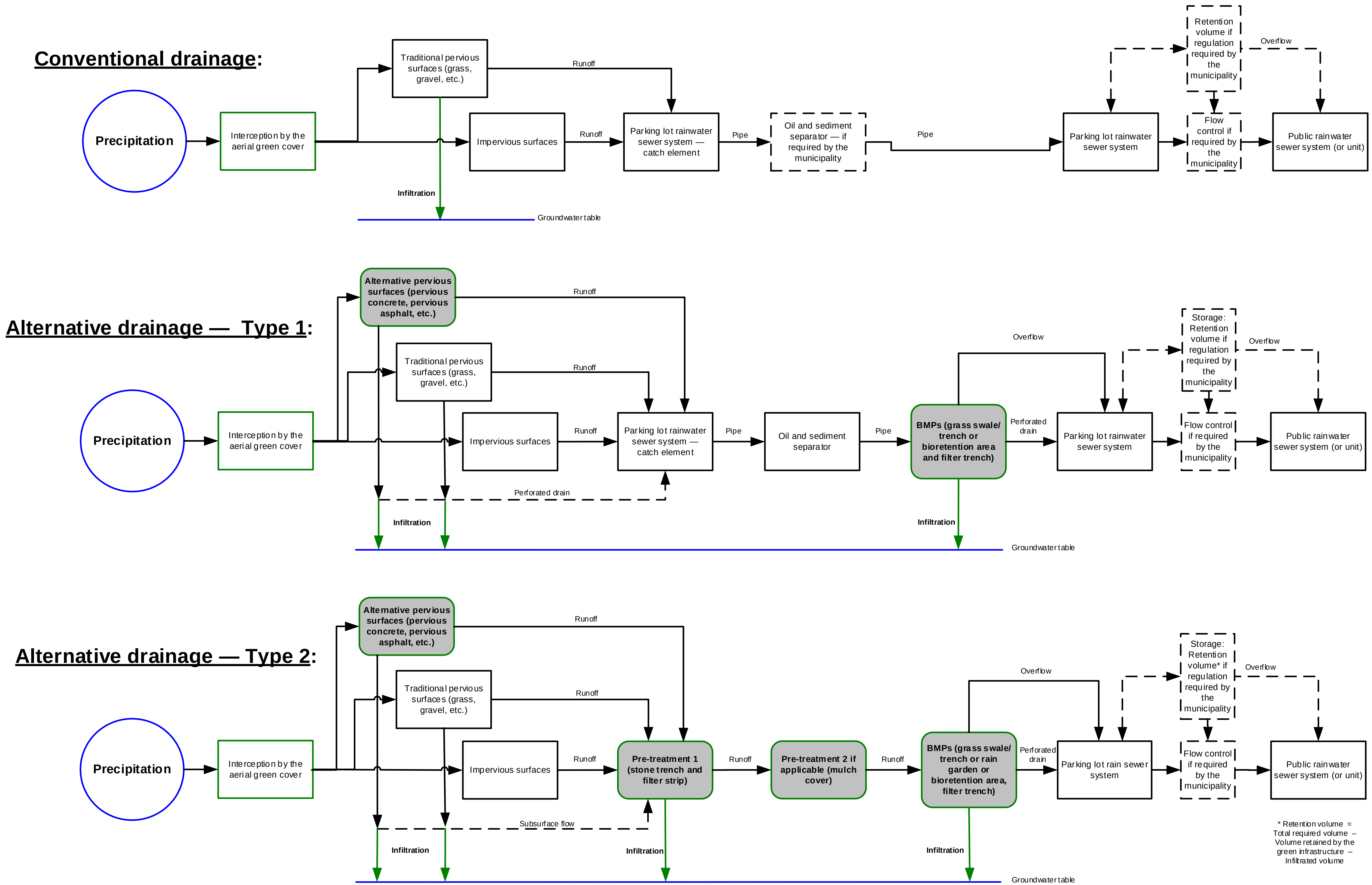

FIGURE 1 — CONVENTIONAL DRAINAGE AND ALTERNATIVE DRAINAGE IN PARKING LOTS

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- Assessment of testing laboratories of accreditation by SCC.

For the development of standards, activities at the BNQ serve to establish performance criteria related particularly to quality, safety and fitness of purpose of products, processes or services within a context of sustainable development. The distinct approach of the BNQ in this respect is to ensure that a consensus is obtained among all of the various stakeholders.

In matters concerning conformity recognition, the approach adopted by the BNQ aims at guaranteeing that products, processes or services comply at all times with the requirements of applicable standards.

For systems certification, the purpose of activities at the BNQ is to guarantee that the systems implemented by businesses conform to, and are maintained in conformity with, applicable standards.

The various accreditations and recognitions conferred upon the BNQ aim at guaranteeing that the mandates entrusted to the BNQ by their clients are completed according to international criteria that define the best practices in matters standards development, certification of products, processes and services and system certification.

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