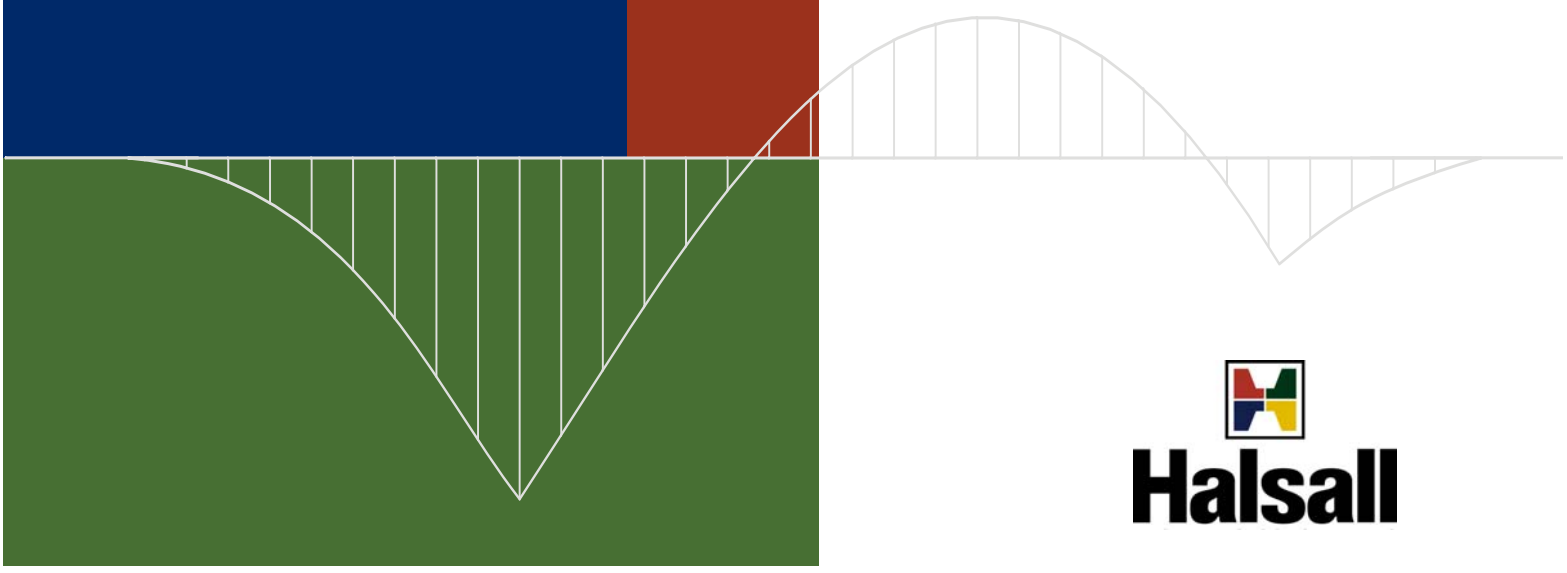
GREEN "VEGETATIVE" ROOF BUILDING STANDARD FOR THE CITY OF TORONTO

Wednesday June 20, 2007



Halsall

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Scope and Objectives of this Study

The Toronto Green Roof Design Standard is to provide City Staff with the technical foundation necessary for the development of a Green Roof By-law consistent with the City of Toronto Act, and to provide certainty and clarity for the green building industry active in Toronto.

This standard is not intended to be a textbook on the design of green roofs but provide certainty and clarity for builders, developers, manufacturers and designers when designing and building green roofs in the City of Toronto.

The scope of the Standard shall provide recommendations for design requirements of a Toronto green roof building standard and include analysis of how identified potential green roof standards will support the City's key policy objectives and performance criteria. The Standard is to address:

a) New construction and retrofit;
b) Small and large scale residential buildings; and
c) Industrial, commercial and institutional buildings.

Key policy objectives of the City of Toronto include:

- Reduced urban heat island;
- Storm water management impacts (quantity and quality);
- Impacts on building energy consumption; and
- Improved air quality.

A fifth key objective has been added which is Green Roof *"Durability/Maintainability"*.

Performance criteria of the City of Toronto include:

- coverage of growing media
- roof slope
- runoff coefficient
- depth of growing medium

Generally the roof will not vary depending on the type of building, but rather on its size. Large buildings with low sloped "flat" roofs will form one category. Smaller residential buildings with sloped roofs will form the other category.

Background

Section 108 of the "City of Toronto Act 2006" includes the following related to the construction of green roofs:

- 108.(1) Without limiting sections 7 and 8, those sections authorize the City to pass a by-law requiring and governing the construction of green roofs if the provisions of the by-law do not conflict with the provisions of a regulation made under the *Building Code Act, 1992* respecting public health and safety, fire protection, structural sufficiency, conservation and environmental protection and the requirements respecting barrier-free access.

- (2) A by-law under subsection (1) prevails over a regulation made under the *Building Code Act, 1992*, despite section 35 of that Act.

- (3) For the purposes of subsection (1), "green roof" means a roof surface that supports the growth of vegetation over a substantial portion of its area for the purpose of water conservation or energy conservation.

Green roofs are an emerging technology in North America, and as a result, there are currently no standards incorporated into Ontario's Building Code for the City to measure the design and construction of green roofs against.

2. ONTARIO BUILDING AND FIRE CODE REQUIREMENTS

2.1 General Requirements

The following Table 2.1 presents requirements of the 2006 Ontario Building Code ("OBC") from the Building Code Act and Division B - Parts 3, 5, 7 and 12 that apply to the design and construction of green roofs.

Table 2.1

Item	Item Description	Green Roof Implication	Notes
Building Code Act 9.-(1)	"The chief building official may allow the use of materials, systems, and building designs that are not authorized in the building code if"...they "will achieve the level of performance required by the building code."	Mechanism by which a municipality can authorize a green roof.	None
Division A 1.2.11.(1)	"Compliance with Division B shall be achieved by complying with the *applicable solutions* in Division B, or by using *alternate solutions* that will achieve the level of performance required by the applicable *acceptable solutions* in respect of the objectives and functional statements attributed to the applicable *acceptable solutions* in Supplementary Standard SA-1."	None	None
Division B 3.1.15.1 and 3.1.15.2	Every roof covering shall have a classification determined in accordance with CAN/ULC-S107-M, "Fire Tests of Roof Coverings".	Testing to this standard is generally not available. Green roof coverings may not comply with this standard, particularly if vegetation were to die.	This potential fire risk should be addressed by the Toronto Standard.
Division B 3.3.1.17	A guard not less than 1070mm high shall be provided around each roof to which access is provided for other than maintenance.	"Maintenance" is not defined. Some green roofs may encourage activities that are beyond what could reasonably be considered "maintenance" and lead to increased risk to persons undertaking the	A policy decision is required with respect to whether guards are mandated in certain or all instances. As a minimum, guards

Table 2.1			
Item	**Item Description**	**Green Roof Implication**	**Notes**
		work. Examples might include manual irrigation, or tending vegetable gardens.	should be required where the green roof is used for producing vegetables or flowers that are to be harvested.
Division B 3.8.2.1(1)	Barrier-free path of travel from entrances shall be provided "within all normally occupied *floor areas* served by a passenger elevator, escalator, inclined moving walk, or other platform equipped passenger elevating device".	As a green roof is not a floor area, design for barrier-free access is not required.	None
Division B 3.8.2.1(2)(f)	"The provision of a barrier-free path of travel…does not apply to attic or roof spaces."	Green roofs do not require design for barrier-free access.	None
Division B 4.1.1.3.(1)	"buildings and their structural members…shall be designed to have sufficient structural capacity and structural integrity to safely and effectively resist all loads, effects of loads and influences that may reasonably be expected…"	Requires the structural design engineer to account for the increased loads that arise from the green roof. This also applies to the green roof ability to resist loads imposed by wind.	None
Division B 4.1.4.1.(b) and (e)	Dead loads to be considered in the structural design include "the weight of all materials of construction incorporated into the building to be supported permanently by the member", and "the vertical load due to earth, plants and trees.	Design is to account for the additional loads imposed by the green roof system.	None
Division B 4.1.3.2.(7)	"Load factor" applied to achieve the desired factors of structural safety for "soil, superimposed earth, plants and trees shall be increased to 1.5, except that when the soil depth exceeds	Increased dead load factor is to be applied for most green roofs (where soil depth is less than 1,200mm (4 feet).	Prior to the 2006 OBC, a structural designer could choose to apply a lower load factor (1.25) to the green roof

Table 2.1			
Item	**Item Description**	**Green Roof Implication**	**Notes**
	1.2m, the factor may be reduced…".		dead load.
Division B 4.1.7.1.(4)	Wind loads are to be calculated using a reference velocity pressure for "a probability of being exceeded in any one year of 1-in-50".	Specifies the basic wind pressure to which green roofs should be designed for.	Prior to the 2006 OBC, design could be limited to lower wind pressures; those for a 1 in 10 year probability.
Division B 5.1.4.1.(1)	"Building materials, components and assemblies…shall be designed and constructed to…resist or accommodate… (b) all structural loads…"	Reinforces the need to design and construct green roofs so as to be structurally adequate.	None
Division B 5.1.4.2.(1)	Materials used shall be "resistant to any mechanisms of deterioration that may reasonably be expected".	Requires that the green roof assembly be durable.	Additional mechanisms of deterioration would include potential for membrane root damage and corrosion of metals used for flashings or drainage system.
Division B 5.1.4.2.(3)	"Design and construction of assemblies separating dissimilar environments and assemblies exposed to the exterior shall be in accordance with good practice such as described in CSA 478, Guideline on Durability in Buildings." This standard requires buildings, components and assemblies to be designed, operated and maintained to meet or exceed their design service life. The appropriate design service life of each component is to consider difficulty/expense of maintenance, and consequence of failure.	Green roofs result in more difficulty maintaining the waterproofing function. While this standard does not impose any specific requirements, it does require designers to consider the need for increased durability or other measures required to achieve and maintain acceptable performance.	None

Table 2.1			
Item	**Item Description**	**Green Roof Implication**	**Notes**
Division B 5.6.1.1	A building component or assembly shall "(a) minimize ingress of precipitation into the component or assembly, and (b) prevent ingress or precipitation into interior space."	Standard requirements for acceptable roof performance with respect to resisting water ingress apply to green roofs.	None
Division B Part 7 (General)	Provides requirements for design and installation of storm water drains.		None
Division B 7.4.10.4.(1)	The hydraulic load is the maximum 15 minute rainfall (25mm for the City of Toronto) multiplied by the area of the surface drained and one half the largest adjoining vertical surface.	This design load should not change despite the green roof altering rainwater retention and run-off characteristics.	Clarify that the storm water design does not change from that mandated in the Code.
Division B 7.4.10.(2)	Control flow roof drains may be installed provided "(b) the roof structure has been designed to carry the load of the accumulated water, (c) one or more scuppers are installed so that the maximum depth of water on the roof cannot exceed 150mm..."	Similar to control flow roof drains, green roofs similarly impede/retain rain water and reduce storm water run-off from the building.	A similar requirement to limit water depth would be prudent in the Toronto Standard.
Division B 12.2.1	Energy efficiency design is required in compliance with good engineering practice such as "ASHRAE 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings" or the "CCBFC - Model National Energy Code for Buildings".	The extend to which a green roof is energy efficient depends on weather and green roof conditions. Design shall comply with ASHRAE 90.1 disregarding the effect of the green roof on energy consumption	None
Division B 12.2.1.2	As of 2012, energy efficiency of all building shall be designed to exceed by not less than 25% the energy efficiency levels attained by conforming to the "CCBFC - Model National Energy Code for Buildings"	Insulation levels incorporated within green roofs that meet current standards may be obsolete in comparison with 2012 requirements. Upgrading green roofing assembly insulation is more difficult than with other roofs.	Consideration could be given to mandating higher roof thermal performance to account for pending change and difficulty retrofitting green roofs.
Division B	For residential occupancy,	Insulation requirement for	This requirement

Table 2.1			
Item	**Item Description**	**Green Roof Implication**	**Notes**
12.3.2.1.(4) and Table 12.3.2.1	specifies a minimum RSI 7.00 (R40) thermal resistance of insulation for a ceiling below attic or roof space for Toronto (Zone 1; less than 5000 degree days). This is upgraded to RSI 8.80 (R50) where electric space heating is employed.	residential occupancy where provided below the green roof assembly.	applies to roofs with attic spaces. These roofs usually have a pitch that is too steep for a green roof.
Division B 12.3.2.1.(4) and Table 12.3.2.1	For residential occupancy, specifies a minimum RSI 4.93 (R28) thermal resistance of insulation for a roof assembly without attic or roof space for Toronto (Zone 1; less than 5000 degree days)	Insulation requirement for residential occupancy where provided within a green roof assembly.	None
Division B 12.3.3.6	Allows thermal resistance of an assembly for residential occupancy to be reduced by not more than 20% provided total calculated heat loss is in conformance with minimum requirements.	Potential to decrease roof insulation if total building system is properly designed.	None
Division B 12.3.4.2.(1) and Table 12.3.4.2.A	For non-residential occupancy, specifies a minimum RSI 3.91 (R22) thermal resistance of insulation for a roof for Toronto (Zone 1; less than 5000 degree days). Requires taking into account thermal bridging in the assembly as determined by Supplementary Standard SB-10.	Total assembly thermal resistance requirement for non-residential occupancy where provided within a green roof assembly.	None
Division B 12.3.4.3	"Air infiltration" section requires an air barrier to be provided.	No change in this requirement arises with green roofs.	None
Division C Part 3	Qualifications are required for designers. Specific requirements are established for persons completing design required by the OBC. This includes designers being qualified for "Building	Complexities related to determining green roof loads and impact on building roof structure and on the building structure in general requires structural engineering.	Engineer should be qualified under Part 4 – "Building Structural".

Table 2.1			
Item	**Item Description**	**Green Roof Implication**	**Notes**
	Structural", "Large Buildings" or "Complex Buildings", and "Plumbing – All Buildings".		

2.2 Part 9 Buildings

The following Table 2.2 presents requirements of the 2006 Ontario Building Code ("OBC") that apply to the design and construction of green roofs for OBC Division B Part 9 buildings (smaller buildings and houses).

Table 2.2

Item	Item Description	Green Roof Implication	Notes
Division B 9.3	"Materials" section nor other sections do not include generic requirement for materials to be selected so as to be appropriate for use	Green roof designer should be made responsible to select materials and complete design so that problems with premature deterioration do not develop.	Should require compliance with 5.1.4.1.(1) and 5.1.4.2.(1).
Division B 9.4.1.1	Structural members shall be designed to Part 9 requirements or "CWC Engineering Guide for Wood Frame Construction" or Part 4.	Part 9 and CWC Engineering Guide do not cover all potential loads that may be imposed by some green roofs, and may not properly account for the nature of the green roof loading.	Structural members should be designed in compliance with Part 4.
Division B 9.4.3.1	(2) "Dead loads need not be considered in computing deflections…". Maximum roof deflection as per Table 9.4.3.1 is 1/360 where ceiling is plaster or gypsum board.	Ignoring weight of green roof when designing structure for deflection would not be reasonable when green roofs are applied; excessive deflections may result, both initial and long term.	It should be clarified that green roof dead loads must be considered in computing deflections.
Division B 9.8.8.1	Guards are required where there is a difference in elevation of more than 600mm or where the slope of the adjacent surface is more than 1 in 2. Guards are not required where access is provided for maintenance purposes only.	"Maintenance" is not defined. Some green roofs may encourage activities that are beyond what could reasonably be considered "maintenance" and lead to increased risk to persons undertaking the work. Examples might include manual irrigation, or tending vegetable gardens.	A policy decision is required with respect to whether guards are mandated in certain or all instances. As a minimum, guards should be required where the green roof is used for producing vegetables or flowers that are to be harvested.
Division B 9.23.4.5	Provides additional structural requirements for "heavy roofing materials" such as roofing tile. Joist,	Requires additional structural capacity for weight of green roof if it is defined as a heavy roofing	Green roofing could be defined as a heavy roofing material so that the

Table 2.2			
Item	**Item Description**	**Green Roof Implication**	**Notes**
	rafter, beam and lintel spans in tables are to be reduced to account for the additional loads.	material.	weight is accounted for. Better to simply require structural engineering in compliance with Part 4.
Division B 9.23.15.7	Refers to tables that specify the thickness of roof sheathing where and where not used as "a walking deck".	Roof sheathing design for weight of green roof materials is not accounted for by these tables. Adequate sheathing thickness for structural adequacy is not assured.	Roof sheathing/decking should be designed in compliance with Part 4.
Division B 9.25.2.2.(4)	"Type 1 expanded polystyrene insulation…shall not be used…applied above the roofing membrane."	Green roofs using a protected membrane configuration shall continue to use extruded polystyrene.	None
Division B 9.26.1.1	"Purpose of Roofing" is to shed rain and prevent water from entering. Includes "platforms that effectively serve as roofs with respect to accumulation or drainage of precipitation."	Green roofs are required to be designed to fulfill the purpose of a roof.	None
Division B 9.26.2	"Roofing Materials" identifies applicable standards for waterproofing membranes, shingles and tiles.	There is no limitation on what roofing materials within a green roofing system could be relied upon for preventing water entry. Proposed applications	Green roofing systems should be limited to application over suitable waterproof membranes. Application over shingles or tile should not be permitted.
Division B 9.26.3	Minimum slopes for roof coverings are specified in Table 9.26.3.1. Minimum 2% for modified bitumen, 2% to 4% for built-up roofing	Green roof assemblies should also be required to provide adequate drainage at the level of the roofing membrane. It should be clarified that the minimum slope requirements of this section applies to the green roof design.	Slope for drainage at membrane waterproofing within green roofing system should comply with Table 26.3.1 and be a minimum of 1 in 50.

Table 2.2			
Item	**Item Description**	**Green Roof Implication**	**Notes**
Division B 9.26.3	Maximum slopes for roof coverings are also specified in Table 9.26.3.1.	Maximum slopes do not account for risk for green roof materials sliding or slipping where applied to an excessively sloped surface.	Standard should limit the permissible slope for green roofs and requirements for adequate design to assure stability if a specific slope is exceeded.
Division B 9.26.4	"Flashing at Intersections" required except where omission does not adversely affect adjacent elements. Minimum thicknesses of acceptable sheet metals are specified.	Some metals have been found to suffer problems with corrosion when integrated within a green roof. In particular, aluminum can be vulnerable.	Require compliance with 5.1.4.2.(1).
Division B 9.26.11	"Built-up roofs" identifies minimum requirements for built-up roofing membrane construction. Requires minimum No. 15 felts and minimum 3 mopped down layers of roofing felt.	Minimum membrane requirements for this type of waterproofing that might be incorporated into a green roof. Increased membrane quality would be judged to be prudent by most professionals	As minimum, require minimum 4 plies of Type IV glass fibre felts.
Division B 9.31.2.1	"Plumbing systems shall conform to Part 7".	Plumbing for green roofs on Part 9 buildings must comply with Part 7.	None
Division C Part 3	Qualifications are required for designers. Specific requirements are established for persons completing design required by the OBC.	Complexities related to determining green roof loads and impact on building roof structure and on the building structure in general requires structural engineering.	Engineer should be qualified under Part 4 – "Building Structural".

2.3 Existing Buildings

The following Table 2.3 presents requirements of the 2006 Ontario Building Code ("OBC") that apply to the design and construction of green roofs for existing buildings.

Table 2.3

Item	Item Description	Green Roof Implication	Notes
Building Code Act 1.-(1)	"Construct means to do anything in the erection, installation, extension or material alteration or repair of a building"	If installing a green roof is deemed a material alteration or repair, it is considered to be categorized under "construct".	None
Building Code Act 8.-(1)	No person shall construct…a building or cause a building to be constructed…unless a permit has been issued".	A building permit is required if installing a green roof is deemed a "material alteration or repair".	A building permit would be required for a green roof if deemed" a material alteration or repair".
Division B 11.1.1.2	"Building system means a combination of elements or components that form a complete major division of construction…including a structural or framing system, a waterproofing system, a drainage system,…a roofing system…"	Green roofs can be defined as a building system.	For clarity, the Toronto Standard should define a green roof to be a "building system".
Division B 11.3.1.1	Where an existing building system is materially altered or repaired, the performance level…shall be at least equal to the performance level…prior to the material alteration or repair.	Introducing a green roof is likely to be categorized as a material alteration or repair. If true, this cannot decrease the performance level.	The Toronto Standard should define the introduction of a green roof as a "material alteration" to require that Part 11 of the OBC applies to design and construction.
Division B 11.3.3.2	Where existing…roof assemblies are substantially removed in an existing building and new interior walls, ceilings or floor assemblies are installed, structural and fire resistance elements shall be constructed in compliance with the requirements of the other Parts.	Other OBC requirements are triggered if removing existing roofing to install a green roof as well as installing new interior walls, ceilings and floor assemblies.	None

Table 2.3			
Item	**Item Description**	**Green Roof Implication**	**Notes**
Division B 11.4.3.2	Where the performance level of an existing building is reduced…(a) remedial measures shall be taken to support the proposed loads".	While not specifically referencing increases in dead loads that would arise from a green roof, it would reasonably follow that a reduction in the ability for an existing structure to accommodate loads specified by the current OBC would be an unacceptable reduction in performance level that would also need compensating measures.	The Toronto Standard should define increased loads introduced by a green roof as "reducing the performance level" if the existing building structure is not capable of accommodating the increased loads and the loads specified by the current OBC.
Division C Part 3	Qualifications are required for designers. Specific requirements are established for persons completing design required by the OBC.	Complexities related to determining green roof loads and impact on building roof structure and on the building structure in general requires structural engineering.	Engineer should be qualified under Part 4 – "Building Structural".

2.4 Ontario Fire Code

The following Table 2.4 presents requirements of the 1997 Ontario Fire Code ("OFC") that relate to green roofs.

Table 2.4

Item	Item Description	Green Roof Implication	Notes
OFC 2.4.2.1	"Combustible materials shall not be stored on a roof or adjacent to any building so as to create a fire hazard to the building or its occupants."	Requires avoid materials on a roof that may create a fire hazard.	None
OFC 2.11.1.2	"The installation of insulation including the replacement of insulation, shall be carried out in accordance with the Building Code."	Requires green roof insulation to comply to OBC.	None
OFC 2.11.1.2	"Unless otherwise approved, combustible insulation shall be protected as prescribed in the Building Code."	Requires green roof insulation to comply to OBC.	None
OFC 2.11.1.3	"Insulation shall not be placed in building roof-ceiling…assemblies, as described in Parts 3 and 9 of the Building Code, where the assemblies are required to have a fire resistance rating unless the insulation does not reduce the fire resistance rating of the assemblies."	Requires green roof insulation to comply to OBC.	None

2.5 Summary Discussion Regarding Building Code Objectives

2.5.1 Structural Safety – Gravity Loads

Division B - Part 4 of the OBC appears to reasonably address the structural requirements for green roofs with respect to structural design to account for the increased loads that occur.

One exception is defining how the additional loads that arise from the green roof are to be calculated. Additional requirements need to be imposed to assure structural loads are properly accounted for.

Another potential concern relates to assuring there are overflow scuppers provided as a safety measure to limit accidental water accumulation such as may be necessary in the event of drains becoming obstructed. There is also potential for confusion regarding the reference height for the overflow scuppers (the constructor might confuse the overflow scupper height as being measured above the finished green surface or other layer above the waterproofing resulting in higher water load than accounted for by the design). A mechanism is required for clearly understanding the materials that have been accounted for by the structural engineer, and the height of the overflow scuppers above the waterproofing membrane.

Division B - Part 9 of the OBC does not reliably account for the increased loads from a green roof. The prescriptive requirements for the structure do not apply. A qualified structural engineer should be required to complete design in accordance with Part 4.

2.5.2 Structural Safety – Lateral Wind Loads

Division B - Part 4 of the OBC requires design to resist, green roof blow-off by wind. However, specifics as to how this is to be accomplished are not provided. Loose-laid protected membrane roofing systems are accepted practice, despite limited design information for addressing wind resistance. Wind performance characteristics and design guidelines for green roofs are different and not clearly understood.

Additional green roof requirements to resist wind should be defined to limit risk to the public related to loose-laid green roof materials blowing from roofs.

2.5.3 Fire Safety

For non-combustible buildings, green roofs likely do not comply with the OBC related to combustible vegetative covers.

Additional precautions should be mandated to minimize the impact on fire safety.

2.5.4 Safety in Use

The OBC requires guards around roofs where access is provided for other than maintenance. It is not clear as to the extent that post-installation activities on a green roof should be categorized as maintenance, and where activities are clearly beyond maintenance so that guards are necessary.

A decision is required to define which activities are beyond maintenance and hence require guards to protect persons from falling from the roof.

As a minimum, it should be clarified that access to green roofs used to produce and harvest vegetables, flowers or other crops is not considered maintenance; guards are required for these situations.

2.5.5 Materials / systems BMEC compliance

Green Roof materials and systems must be approved by the BMEC. Any dispute regarding compliance with the technical requirements of the Building Code should be resolved through the BCC.

3. SCOPE OF CURRENT STANDARDS AS THEY RELATE TO GREEN ROOFS

As required in the RFP, we have identified the standards and guidelines currently used in other jurisdictions to evaluate and regulate the design, installation, and maintenance of Green Roof Systems. We have reviewed these documents, and summarized their intent and general content in a tabular summary that presents each in relation to the City's stated policy objectives.

3.1 BACKGORUND

Five years ago, the City's Toronto 2000 Environmental Plan recommended that a strategy for Green Roof implementation be prepared within the framework of a general plan to promote green roof development and research in the City.

This initiative led to a partnership with Green Roofs for Healthy Cities, The Toronto Atmospheric Fund and the Federal Government and the development of two Green Roof demonstration projects: 300 m^2 in Toronto's City Hall Building and 465 m^2 on the Eastview Neighborhood Community Centre. The objective of these projects was to understand the technical, financial and information barriers to the widespread implementation of green roof systems. These sample roofs were instrumented, and have been providing data on the stormwater and energy benefits of green roofs since their completion.

In 2003, City Council established a Green Roof Task Force, under the Roundtable on the Environment, with a mandate to develop a strategy to further investigate and promote Green Roof benefits. Toronto's Roundtable on the Environment is a group of volunteer experts created to advise City Council on sustainability issues affecting the City.

The Green Roof Task Force commissioned a team from Ryerson University to prepare a technical report evaluating the costs and benefits of Green Roofs. This report was completed with feedback obtained from stakeholders on green roofs, and published as "Making Green Roofs Happen".

"Making Green Roofs Happen" is a discussion paper that:

- compiles information about the costs and environmental benefits of Green Roofs;
- examines international policies developed by leaders in Green Roof development; and
- summarizes the findings from workshops with the stakeholders.

The report provides a range of alternatives that the City could use to promote the implementation of green roof technologies.

The report was presented to the Toronto's Roundtable on the Environment in a dedicated session in November 2005. The results of the study were accepted positively, and deputations were supportive of the report. After some additions and amendments to the proposed options, the Roundtable created their own set of recommendations, which were adopted by Toronto City Council on February 1, 2006.

In response to these recommendations, the City is preparing a strategy comprising the following initiatives:

1. Installation of green roofs on City buildings
2. Pilot grant program
3. The Development Approval Process
4. Publicity and Education program

The development of the Green Roof Standard would fall under the third initiative.

3.2 STANDARDS, GUIDELINES, AND RATING SYSTEMS

Below is a summary of existing systems reviewed. We define the three systems as:

- GUIDELINES - describe green roof systems that achieve specific performance metrics;
- STANDARDS - describe testing methods for determining the physical properties of green roof components or the green roof system. Standards are used (often in conjunction with other information such as local weather data) to establish the expected performance indicated in the guidelines; and
- RATING SYSTEMS – scoring systems that provide a framework for evaluating and rewarding green roof installations that best meet local objectives.

3.2.1 Guidelines

3.2.1.1 German Landscape and Landscape Development Research Society (FLL) *Guidelines for the Planning, Execution and Upkeep of Green-roof sites* (English Version)

For many years, the only well accepted guidelines for green roof construction were those developed by Forschungsgesellschaft Landschaftentwicklung Landschaftsbau. e.V. (FLL), in Germany.

This guideline has been updated on 2002 and reflects state-of-the-art technologies for the construction of reliable green roofs. The Guideline relies on, and refers to, DIN (Deutsches Institut für Normung) testing standards as the basis for requirements described. This guideline addresses the following aspects of green roofs:

- Different forms of cultivation (intensive, extensive)
- Site conditions for vegetation (climate and soil types)
- Requirements related to construction and materials (Roof slopes, Roof designs, Design loads, Protection against falls, Draining, Watering, Compatibility of materials)
- Technical Requirements (Protection against root penetration, mechanical damage and corrosion, Drainage facilities, joints and borders, Protection against emissions, Wind loads, Fire prevention)
- Drainage Course (material groups and types)

- Filter Course (material groups and types)
- Vegetation Support Course (materials groups and types)
- Requirements for Sowing Seeds and Planting

3.2.1.2 FM Global Property Loss Prevention Data Sheet 1-35; Green Roof Systems, Factory Mutual Insurance Company, January 2007

Guidelines established by US based Factory Mutual (FM) are generally considered to provide the most comprehensive requirements and data for roofing design necessary to limit risks, primarily those associated with wind damage or blow-off, fire, and leakage damage. Some property insurers require that Owners comply with these guidelines when applying roofing, and many roofing material manufacturers and roof designers refer to FM design standards and requirements. This data sheet provides a definition of a green roof and establishes design and installation guidelines for green roofs necessary to limit risk for loss prevention.

Right now there are no specific green roof assemblies approved by this guideline, but it refers to each one of its performance aspects: Section 2 addresses all aspects of the Green Roof related to construction and suitable locations, such as building heights, wind speed, gravity loads and drainage characteristics, and provide guideline for the design and selection of each one of the green roof components.

3.2.2 ASTM Green Roof Standards

The rapid development of the North American Green Roof market over the last five years created a need for specific performance guidelines to be followed by North American Green roofing products and systems that otherwise had to be tested under European standards. This need was addressed by the ASTM (American Standards for the Testing of Materials) Green Roof Task Force (E.06.71.07) which has developed guidelines and testing procedures specifically for green roof products.

While development continues, five standards have already been completed and published. These five standards establish a common basis for comparing fundamental green roof properties, such as weight and moisture retention potential. They are designed to measure critical properties of green roof materials under conditions similar to those encountered in the field:

E2396-05 Standard Test Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green Roof Systems

This test method is used to determine the water permeability of coarse granular materials used in the drainage layer (100% of material retained on a 2.25 mm sieve) under low-head conditions typical of horizontal flow in green roofs. The method allows for direct comparison with alternative components, such as geocomposite drain layers. Also measured in the test is the wet density of the granular medium.

The resultant water permeability is used to calculate the runoff coefficient.

E2397-05 Standard Practice for Determination of Dead Loads and Live Loads associated with Green Roof Systems

This method is used to predict the overall weight of a green roof system, including components typically encountered (membranes, non-absorptive plastic sheets, metallic layers, fabrics, geocomposite drain layers, synthetic reinforcing layers, protection boards, insulation, growing media, granular drainage media and plants. The procedure addresses the weight under two different conditions: 1) weight under drained conditions following rainfall or irrigation (including retained and captured water) and 2) weight during active rainfall when the drainage layer is completely saturated. The first condition is considered the dead load and the difference between the two conditions, approximated by the weight of transient water in the drainage layer is considered the live load. The procedure does not account for live loads associated with architectural elements, construction activities, snow or wind.

E2398-05 Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems

This method determines the water and media retention of synthetic drain layers used in green roof systems typically consisting of cup-like receptacles on the upper surface (shaped plastic membranes and closed-cell plastic foam boards). The standard does not apply to products manufactured from water-absorptive materials. The standard involves filling the drain layer with sand and water to determine the volume. To account for the difference in water capture depending on roof slope, the tests are performed under different inclinations of the drainage layer.

The resultant water retention is used to calculate the runoff coefficient.

E2399-05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems

This test method is used to determine the maximum density of media used for dead load analysis. The method also provides a measure of the moisture content and the water permeability measured at the maximum media density. The procedure is suitable for media with less than 30% organic content. The test comprises of compressing moist media into a perforated cylinder using a Proctor hammer, immersed it in water and then determining the density and moisture content using standard gravimetric procedures. The sample is allowed to dry for 2 hours and is again measured to determine the maximum media density. The 2-hr value can be directly compared to media densities determined using the most common international procedures for establishing green roof dead load values.

E2400-06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems

This guide covers the criteria considered for the selection, installation and maintenance of plants of a green roof system and applies to both intensive and extensive roof types. The primary considerations for plant selection are design intent, aesthetics, climate (macro and micro), plant characteristics including longevity, rate of establishment and pest resistance, and, media composition and depth. Also covered are installation methods including precultivation (followed by transplant to the roof), direct seeding and seasonal issues. Maintenance issues include passive and active irrigation, plant trimming/cultivation and the use of fertilizers.

These standards address several of the fundamental green roof performance aspects, but doesn't address issues as materials compatibility, physical and mechanical performance of the different green roof components, fire prevention or wind loads.

3.2.3 Rating Systems

Rating Systems are compliance tools typically used in conjunction with incentive programs.

3.2.3.1 FLL Rating System

In jurisdictions within Germany, where performance metrics are required, the FLL rating system (1998) is used. This system is used to ensure green roof performance meets the established requirements and criteria for submitting building permit approvals and construction acceptance.

The basis of the rating system is the thickness of the green roof construction penetrable by roots, from which 10 base points per cm are calculated. The roof must also meet minimum requirements for the following performance metrics:

- Water retention capacity of the growing medium;
- Water retention capacity of the drainage layer;
- Number of plant species for extensive green roofs; and
- Plant biomass for intensive green roofs.

In addition to the above quantitative elements, the FLL system identifies qualitative characteristics according to type of roof construction. The qualitative parameters are:

- Soil
- Surface water
- load shedding from the sewer system
- Groundwater recharge
- Purification of storm water
- filtering of air
- Oxygen production
- Temperature leveling
- Flora and fauna habitat
- Landscape and urban scenery

- People / leisure / healing.

These are typically used to determine if a project is suitable for ecological compensation according to the Federal Nature Conservation Act, which considers green roofs as a mitigation measure to offset the ecological damage caused by urban development. The green roof system evaluated will be rated according to its ecological mitigation capacity on a scale of Low, Medium or High.

3.2.3.2 Karlsruhe Rating System

Another example for qualifying the performance of the Green Roof is the rating system used by the city of Karlsruhe. This model compares different types of green roof systems and rates them according to five natural aspects: soil, climate, flora, fauna and water balance. This system rates the performance of the Green Roof as an ecological compensation measure.

3.2.4 Summary of Guidelines And Standards

The following table 3.2.4 summarizes the content of the Guidelines and Standards discussed above related to the City's policy objectives as well as general performance requirements.

Table 3.2.4			
Policy Objective / Performance Criteria	**Design Strategy Discussed**	**Referenced Guideline**	**Requirement**
Stormwater Management (Rate and Quantity)	Course depth and form of vegetation to determine: Water retention capacity, run-off coefficient, annual coefficient of discharge	FLL	Extensive Systems • Course depth: 2 -20 cm • Vegetation: Moss, sedum, grass • Water retention capacity 40%-60% Intensive Systems • Course depth: >20 cm • Vegetation: Lawns, shrubs, coppices, trees • Water retention capacity 60%-100%
Stormwater treatment	Definition of organic content in soil substrate to reduce water Nitrogen levels	FLL	Less than12% mass of organic content for intensive green roofs, less than 8% for multi-layer extensive green roofs and less than 4% for single Green layer extensive green roofs
Drainage	Drainage requirements	FLL	Minimum drainage rate = 60-min duration, 100 year MRI rainfall event rate
Heat Island Effect	None	None	None
Energy consumption	None	None	None
Air Quality	None	None	None
Soil selection	selection installation and maintenance	FM	Minimum 80 mm of uniform depth growth media

Table 3.2.4			
Policy Objective / Performance Criteria	**Design Strategy Discussed**	**Referenced Guideline**	**Requirement**
Drainage / Protection fabric	Definition of water retention capacity, Compressive strength	FM	Water retention less than 5.0 l/m Vertical capillary rise less than 100 mm in five minutes Mimum compressive strength to support design loads. Water-permeable protection fabric less than 285 grams/m2
Membrane	Definition root barrier requirements	FM	Asphalt-based or bituminous waterproofing membranes AND all systems with less than150 mm of growth media require a root barrier greater than 0.8 mm continuously sealed at all root seams with a150 mm lap.
Plant selection	Selection, Installation, and Maintenance of Plants for Green Roofs	ASTM standard guide E2400-06	Plant Selection,: According to design intent, climate, and soil media Definition of planting methods Definition of irrigation and plant maintenance methods
		FM	60% of vegetation must be sedum Full-grown height of the vegetation 0.9 m
Site Selection	Building high restriction and Limitation of Geographical areas where Green roofs are permissible	FM	Special design conditions for buildings higher than 46m. Maximum wind speed 45m/s (for all building heights)

3.2.4.1 Standards

The previous guidelines refer to the individual performance of green roof components are based in testing methods regulated by different standard associations. Table 3.2.4.1 summarizes the standards regulating the physical properties of green roof components necessary to achieve the performance requirements.

Table 3.2.4.1

Performance Criteria	Design/Strategy	Standard
Stormwater Management	Define growth media permeability and drainage mat water retention capacity	ASTM E2398-05, ASTM E2396-05, DIN 4045- annual coefficient of discharge
Structural requirements	Gravity Loads, slope thresholds	ASTM E2397-05, E2399-05
Wind resist	Security of roof elements	DIN 1055
Maintenance	Irrigation and fertilizers needs Membrane selection installation and maintenance	ASTM: D 1777, D 1621, D 4716, D-5261, D-4833, D-4533, D-4491, D-4751, D-4355, D-D-5329/CGSB-37.50-M89, D-5329/ CGSB-37.50-M89 EPA: CG 1500, CG 1600 CGSB-37.50-M89
Energy Use	Reduce building energy consumption	ASHRAE 90.1-99*

(*) ASHRAE 90.1-99, *Energy Standard for Buildings Except Low-Rise Residential Buildings*
This standard allows for reduced insulation in roof systems when using a reflective roof in hot climates, but it might be expanded to include green roof systems in a broader range of climates.

3.3 USE OF GREEN ROOF STANDARDS AND GUIDELINES

The use of these different standards for evaluating Green Roofs and their components is not homogeneous in North America. On one hand we have found that companies in North America who import Green Roof components from European markets, or are licensees for European green roof systems and methods, often test materials using European standards. On the other hand, most North American manufacturers of Green Roof components regulate their products using existing standards for ballasted roofs and don't refer either to FLL or ASTM standards for Green Roofs. These companies rely on other approval sources such as EPA (Environmental Protection Agency) or FM (Factory Mutual) for testing physical properties of these materials specifically related to Green Roof performance (such as root resistance). Currently only one of the surveyed Green Roofing companies incorporates the mentioned ATSM standards for Green Roofs in its specifications.
Some North American organizations are developing guidelines for independent components of the Green Roof, such as the "Green Roof Guidelines" by the Canadian Roofing Contractors' Association (CRCA). This document includes a brief overview of different green roof types, design and construction issues and specifications, giving information about contractor qualifications, manufacturer/supplier requirements and maintenance and warranty issues.

3.3.1 Canada

In Canada, several municipalities are developing bylaws affecting green roof as a tool to enable regulation or incentives to promote Green Roofs.

Other cities, including Montreal and Waterloo, are targeting similar policy objectives as the City of Toronto. As part of this process, they are conducting research with Green roofing companies and research institutions to establish a base for performance, and for system selection suitable for their geographical and climatic characteristics. In most jurisdictions, green roofs are considered a strategy for addressing storm water management objectives, and energy reduction targets in the building sector. At this time, none that we are aware of refer to specific standards to regulate performance requirements.

In British Columbia, the Canadian Standards Association and BC Association of Landscape Architects in conjunction with the BC Landscape and Nursery Association are developing green roof standards as part of the BC Landscape Standard to establish performance requirements to be incorporated in municipal bylaws. This document is still a work in progress and has not yet been released for public review.

To bridge the gap between policy development and performance standards for green roofs information from the BCIT's Centre for the Advancement of Green Roof Technology can be considered as a base line to define performance metrics in bylaws. This organization was created to conduct research on green roof performance in the Vancouver climate. For this purpose they have created a database with performance metrics of green roof systems. They test different roofing systems and evaluate the results providing third party certifications of product performance, thus supporting green roof market development. They also provide training and education to the green roof industry though demonstration projects.

The testing is conducted using the Roofing Evaluation Module (REM). This module is a simulated indoor environment with capacity for installing different types of green or conventional roof systems. This system compiles real time performance data on the green roof systems installed.

The main performance metrics targeted are storm water rate and quality, thermal performance and plant viability. For this purpose, the products mainly tested are vegetation mats, soil medium, vegetation support mats, drainage layers and water retention systems. This type of testing allows green roof products to be compared in base to reliable and objective performance data, and allows for third party verification making the product more reliable and competitive in the market.

We have requested further information, including test results, from BCIT.

3.3.2 USA

Several cities in USA are implementing policy measures to promote Green Roofs. These include:

- Portland's density allowances in their Zoning Code, and the implementation of a storm water discount program:
- Chicago's Energy Conservation Code which refers to green roofs as a possible strategy to substitute for high albedo roofs (no performance metric are provided);
- New York City has an ongoing contract with Earth Pledge to monitor air quality and stromwater management in several pilot green roofs across the city. The aim is to develop performance metrics and standards for the city. No results have been published yet.
- Los Angeles City Council directed the Environmental Affairs Department (EAD) to create a City task force to develop and implement Green Roof technology as an energy efficiency technology in the motion CF#04-0074, *Incorporate Rooftop Green Spaces as an Energy Efficiency Mechanism*. Recommendations about permissible structural loads and fire safety are presented in the resultant report *Green Roofs, Cooling Los Angeles, a Resource Guide* published by the Department of Environmental affairs of the City of Los Angeles.

3.3.3 Europe

The country ahead in Green roof implementation and design is Germany. In this country, Green Roof implementation is linked to collective benefits and their implementation is regulated in local development plans.

In terms of performance standards, many jurisdictions don't establish performance metrics. In the jurisdictions where performance metrics are required, the FLL rating system (1998) is used. This system is used to ensure green roof performance meet the established requirements and as criteria for submitting building permit approvals and construction acceptance.

The use of financial incentives to promote Green Roof performance in Germany is limited to stormwater management. German FLL guidelines, referring to water storage and run-off coefficients, are used to establish a discount on water discharge fees for reduction in water discharge to the sewer system. As an example the North Rhine Westphalia Program subsidizes green roofs with the aim of improving water quality in the area. This subsidy program requires that the green roof have a runoff coefficient of less than 0.3. There are two ways that this performance goal can be achieved: by requiring a minimum depth (penetrable by roots) of 15 cm, or by requiring proof (i.e. independent certification) that the green roof product has a runoff coefficient of less than 0.3 (Mainz, 2004). This subsidy program is so important to the industry that specific products are being developed and tested to meet this performance, i.e "Optigrün-Extensivsubstrat Typ NRW 03" , which meets the requirements of the 0.3 runoff coefficient requirement while maintaining the lowest possible thickness and weight.

In the rest of Europe, FLL guidelines and DIN testing methods are primarily used and adapted to specific normative in each country.

4. RECOMMENDED FRAMEWORK STANDARD

4.1 ONTARIO BUILDING CODE CONSIDERATIONS

4.1.1 General Considerations

The City of Toronto Act authorizes passing a By-Law for green roofs providing it does not conflict with the provisions of the Building Code Act with respect to public health and safety, fire protection, structural sufficiency, conservation and environmental protection and the requirements respecting barrier-free access. This section provides general discussion regarding these requirements and how the framework standard should address them.

4.1.2 Structural Sufficiency

a) Gravity Loads

Structural sufficiency is required by the OBC. Introducing green roofs should not present any conflict with the structural requirements of the OBC provided the increased loads that arise are properly accounted for by the structural design, and the allowances are in turn respected by the design and installation of the drainage system and growing media.

In addition to the loads applied by the growing media and water normally retained within the green roof system, there may be increased risk for drains becoming obstructed. As many roofs will also have increased parapet heights to accommodate the increased roof depth and to control wind loads, overflow scuppers need to be located through the parapets to limit structural overloading. These scupper drains need to be located at a maximum height specified by the structural engineer, and designed by the mechanical engineer to assure that the retained water level is limited to avoid risk for structural overloading.

In some instances, there could be risk that the green roof may be subject to regular maintenance by landscapers that leads to a steady addition of growing media. The design limitations should be clearly stated within the design documents to facilitate evaluating and limiting such activities to within the design limits.

To promote design definition and coordination, we recommend that a "Green Roof Design Declaration" form be created and integrated into the building permit process. This would be similar to "The Control Flow Roof Drainage Declaration" form created by the Joint Committee of the Engineers, Architects and Building Officials (EABO). This form would solicit the information and confirmation including: growing media depth; maximum retained water depth - overflow scupper drain height; drainage design and over-flow scupper drain design.

b) Wind Loads

The OBC requires that uplift pressures at the roof perimeter and corners need to be accounted for by the design. Typical green roofs are generally held in place by gravity; uplift pressures can be reduced by increasing parapet heights. However, there is limited information available to designers to be able to evaluate the ability for a green roof to resist uplift and blow-off.

The "FM Global Property Loss Prevention Data Sheet 1-35: Green Roof Systems" provides specific recommendations for wind design. As FM Global is generally respected as a reliable and conservative source of design information for roof performance, and in the absence of other standards or design information to facilitate wind design, we recommend adopting their requirements.

The FM Global requirements include a full grown vegetation height limitation of 0.9m. An exception might be provided for taller vegetation if properly accounted for by structural design; this may require the use of guy wires to assure adequate retention.

The "Green Roof Design Declaration" form could be used to solicit confirmation from designers that wind design has been completed and that the specific FM Global requirements have been accounted for.

4.1.3 Fire Protection

The green roof system may present increased fire risk as a result of the fuel load presented by the vegetation. The prescriptive requirement of the OBC that requires roof coverings be in compliance with "CAN/ULC-S107-M, Fire Tests of Roof Coverings" presents a challenge. We have not located testing or research having been completed to evaluate the fire risk of vegetation integrated into green roofs. We expect that some vegetation may be more combustible than typical roof coverings, particularly when dry or at times when dead materials may accumulate.

The OBC also provides the ability for a designer to propose *alternate solutions* that will achieve the level of performance provided by the *acceptable solutions* that are presented in the OBC Division B. The objectives and functional statements attributed to acceptable solutions for OBC Division B 3.1.15 requirements for roof coverings are referenced in the OBC Supplementary Standard SA1 as follows:

> F02: "To limit the severity and effects of fire or explosions"
>
> OP1.2: "An objective of this Code is to limit the probability that, as a result of its design or construction, a building will be exposed to an unacceptable risk of damage due to fire caused by collapse of physical elements due to a fire or explosion"

> OP3.1: "An objective of this Code is to limit the probability that, as a result of the design or construction of a building, adjacent buildings will be exposed to an unacceptable risk of damage due to fire caused by fire or explosion impacting areas beyond the building of origin".

We expect that a prudent designer(s) could achieve these objectives and functional statements when designing a green roof. This will require careful consideration of the potential risk presented by the vegetation, and coordinating the design of other elements that are exposed to the green roof. Factors that may need consideration will include: avoiding vegetation that presents excessive fire risk; keeping the vegetation away from walls, parapets, mechanical equipment; providing non-combustible claddings at areas exposed to the green roof; providing fire breaks to limit vegetation areas; appropriate location of natural gas line supply; consideration of the potential impact of burning vegetation on paths of egress, and; requirements for fire fighting (portable extinguishers and adequate water supply and/or fire hoses).

The "FM Global Property Loss Prevention Data Sheet 1-35: Green Roof Systems" provides specific recommendations for some of these design variable to limit risks related to fire. As FM Global is generally respected as a reliable and conservative source of design information for roof performance, and in the absence of other standards or design information to facilitate fire safety design, we recommend adopting their requirements.

The FM Global requirements include a full grown vegetation height limitation of 0.9m. An exception might be provided for taller vegetation if properly accounted for within the design for fire safety. This would require specific consideration of the proximity of this vegetation to penthouse walls or adjacent building walls, and possibly the availability of adequate water supply for fire fighting.

The "Green Roof Design Declaration" form could be used to solicit confirmation from designers that fire safety design has been completed and that the specific FM Global requirements have been accounted for.

4.1.4 Public Health and Safety

Green roofs are generally not expected to conflict with OBC requirements respecting public health and safety. The one identified potential concern relates to potential increase in fall risk associated roof edges not protected by guards. The green roof may promote landscapers or other persons being present on the roof that are not trained or familiar with safety requirements pertaining to these unprotected areas.

As a minimum, guards should be mandated where the green roof is intended for producing crops such as vegetables or flowers.

Safety could further be increased to mandate guards be provided on all new buildings 3 storeys in height or greater.

4.1.5 Conservation and Environmental Protection

Green roofs are consistent with conservation and environmental protection. We have not identified any risk for a City of Toronto green roofs standard or By-Law to conflict with the OBC provisions in regards to conservation and environmental protection.

4.1.6 Barrier Free Access

While a designer may choose to provide barrier free access to a roof terrace, the OBC does not require barrier-free access to roofs. We have not identified any risk for a City of Toronto green roofs standard or By-Law to conflict with the OBC provisions in regards to barrier-free access.

4.2 CITY OF TORONTO POLICY OBJECTIVES

4.2.1 General Considerations

The City of Toronto has the following policy objectives related to creating a By-Law pertaining to green roofs; reduced urban heat island, improved storm water management, reduced energy budget of individual buildings, improved air quality, and adequate roof durability. This section provides general discussion regarding these requirements and how the framework standard should address them.

4.2.2 Reduced Urban Heat Island

Green roofs are known to provide benefits with respect to reducing urban heat island; the tendency for the city to become warmer than naturally vegetated areas. Green roofs reduce urban heat island by avoiding a dark roof covering that absorbs solar energy and by evaporative cooling of rainwater that is retained by the system.

The primary factor that will influence the extent to which the green roof By-Law will achieve reduced urban heat island will be the extent of coverage achieved. To promote achieving this objective, the standards should specify a minimum amount of vegetative cover. It will not be possible to achieve 100% coverage owing to the need to include non-vegetated areas for elements such as fire breaks, walkways and mechanical equipment. As recommended in the City of Toronto 2005 "Making Green Roofs Happen Discussion Paper", and consistent with the Toronto Green Development Standard, we recommend the standard require a minimum vegetated area of 50% of the building footprint.

We have not found information or data that can differentiate or quantify the reduced urban heat island benefit provided by one green roof system versus another; we expect that any healthy green roof will promote achieving this policy objective.

One exception may be ultra-light green roof systems; these may not retain sufficient rain water to provide consistent evaporative cooling (without irrigation). While these would be appropriate systems for retrofit applications that have limited structural capacity, they may not facilitate reduced urban heat island. Minimum requirements to achieve storm water management objectives (see discussion within next section) are also expected to address this policy objective.

4.2.3 Improved Storm Water Management

Green roofs are known to provide benefits with respect to rain water retention and improving the quality of the water discharged to storm sewers. Where separate storm and sanitary sewers are not provided, reduced storm water flow can reduce risk for discharge of inadequately treated sewage to the lake.

A specified minimum vegetated area (as referenced under the urban heat island discussion) will act to promote achieving this policy objective.

The standard should promote adequate rain water retention to achieve this policy objective. In green roof design, this is generally expressed as the "annual coefficient of discharge"; the proportion of rain water that falls on a roof surface that is not retained and instead flows into the storm sewers. This coefficient is dependent upon roof elements that achieve water retention and drainage (including the depth of growing media), as well as the pattern of rainfall (frequency, duration, intensity).

The standard could specify a minimum coefficient of discharge. However, a calculation process would have to be defined. European "Rating Systems" provide specific examples, usually centred on depth of growing media, of how some jurisdictions have devised a performance requirement.

For new buildings, a minimum depth of growing media should be specified to promote adequate rainwater retention and vegetation health. A decision as to the appropriate threshold is required; this could be selected to be between 80mm to 150mm as per referenced recommendations and standards. We recommend a minimum depth of 150mm to better promote achieving the policy objectives and to minimize risk for inadequate vegetation health and increased water consumption for irrigation (see discussion regarding adequate durability).

Setting this minimum criteria is expected to promote the policy objectives and reduce risk, but may not fairly account for systems designed with a lower growing media depth and greater water retention provided by other elements. The criteria might expanded to permit lower growing media depths if specific threshold volumes of water are retained by other elements. However, we did not find a precedent incorporating such criteria.

For retrofit to existing buildings, storm water retention and the growing media depth will be limited to the structural capacity and the need to achieve adequate vegetation health.

We have not found information or data that can differentiate or quantify the quality of storm water discharge provided by one green roof system versus another. We expect that any healthy green roof will promote achieving this aspect of this policy objective.

4.2.4 Energy Budgets of Individual Buildings

Green roofs are known to provide benefits with respect to individual building energy consumption, primarily as a result of evaporative cooling.

A specified minimum vegetated area (as referenced under the urban heat island discussion) will act to promote achieving this policy objective.

We have not found information, data or policies in other jurisdictions that promote, differentiates or quantifies benefits related to individual building energy performance provided by one green roof system versus another. We expect that standard requirements that promote rainwater retention will adequately address this policy objective as it relates to evaporative cooling.

The minimum requirements for insulation (thermal resistance) provided by Division B Part 12 of the OBC are expected to already be adequate, having been selected considering cost-benefit of insulation and energy loss through the roof assembly. The insulating properties of a green roof are not accurately quantified and vary depending on the condition of the media (frozen, saturated, dry). As a result we don't recommend that the green roof system provide any of the insulating value required by the OBC.

OBC requires that minimum roof insulation be increased as of 2012. Considering that green roofs are expected to be durable and provide a long service life, and considering that it will typically be difficult to retrofit these assemblies with additional insulation, consideration could be given to requiring compliance with the 2012 OBC insulation requirements now.

4.2.5 Improved Air Quality

Green roofs are believed to provide benefits with respect to improving air quality, including converting carbon dioxide to oxygen and helping to capture and retain air-born particulate.

We have not found information, data or policies in other jurisdictions that promote, differentiate or quantify the air quality benefits provided by one green roof system versus another; we expect that any healthy green roof will promote achieving this policy objective.

A specified minimum vegetated area (as referenced under the urban heat island discussion) will act to promote achieving this policy objective.

4.2.6 Adequate Durability

Given the cost and difficulty associated with applying and replacing a green roof, the standard should include some consideration to durability to limit risk for the policy imposing undue burden on owners.

The materials applied over the roofing membrane present increased difficulty and cost in locating and repairing defects that cause leakage. The quality of the roofing membrane should be adequate to reduce the risk for leaks developing over a reasonable service life. We have included some recommendations to preclude some improper waterproofing membranes from being applied. However, membrane selection to promote durability is complex, being dependent upon factors that include the roof substrate, workmanship and quality control. Remaining decisions that influence durability will be the responsibility of the designer.

4.2.7 Summary

Healthy, low maintenance vegetation is in the best interests of the City and building owners. The extent to which the green roof policy will lead to an increase in water demands for irrigation will not be consistent with water conservation efforts. Systems that require an ongoing cost for irrigation are also more likely to be at risk of being neglected by owners, potentially leading to increased fire risks associated with dead and dry vegetation. The selection of the minimum depth of growing media should consider these risks. While a lesser depth of growing media may be shown to be adequate to sustain vegetation and achieve an acceptable coefficient of discharge, a depth of 150mm is recommended to limit these risks.

We have considered the ability to complete further analysis to substantiate this minimum growing media depth recommendation. We have standards that (for a particular rainfall pattern) provide formula for calculating the coefficient of discharge for different soil types and depths, and for different retention matts. However, it is more difficult to predict the impact of vegetation type. Through calculation, and some on-site testing, it is reasonable to develop a rating system, similar to the FLL Rating System that provides options for thinner growth media that achieve the run-off objective.

4.3 FRAMEWORK STANDARD RECOMMENDATIONS

The following table 4.3 provides the recommendations for the performance standards and prescriptive measures that should be adopted in preparing a municipal by-law that would permit and require green roofs to be installed in the City of Toronto. Each column is defined as follows:

"Category": This defines the category of the performance measure under consideration.

"OBC Compliance": These recommendations are to promote compliance with the requirements of the Ontario Building Code, and/or OBC objectives as stated in Part 2.

"City Green Roof Objectives": These recommendations are to promote achieving the City of Toronto key policy objectives for the green roof strategy; Reduced Urban Heat Island; Storm Water Management Implications; Energy Budgets of Individual Buildings, and Improved Air Quality.

"Optional Upgrades": These recommendations are identified options to further improve the performance standard or apply more restrictive measures.

All the recommendations provided are Code compliant.

Table 4.3				
Item	**Category**	**Requirements**		
		Related OBC Requirements	**City Green Roof Objectives**	**Optional Upgrades**
1	General Compliance with OBC	1. Unless noted otherwise, require green roof design and installation shall comply to the stricter requirements of the OBC or the Standard. 2. Define a green roof to be a "building system". 3. For existing buildings, define the installation of a green roof as a "material alteration or repair" and require a building permit for the work. 4. Permit applications should require a designer qualified and registered under "Building Structural".		
2	Structural – Gravity Loads	1. Structural design and analysis for green roof loads shall comply with OBC Division B - Part 4. 2. Green roof loads to be determined using "ASTM E2397.05 – Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems" and "ASTM E2399.05 – Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems".		6. Create a "Green Roof Declaration" form integrated within the building permit process. This would be signed by the applicable designers (structural engineer, mechanical engineer, architect and/or landscape architect) to confirm the design has been coordinated to limit loads to within structural limits. This would be similar to, and integrated into the building permitting process

Table 4.3				
Item	**Category**	**Requirements**		
		Related OBC Requirements	**City Green Roof Objectives**	**Optional Upgrades**
		3. Parapet height and/or overflow scupper locations shall be specified by the design as required to limit retained rain water loads to within structural limits in the event of obstructed internal drains, with analysis in conformance with OBC Division B 4.1.6.4.(4). 4. For roofs exceeding a slope of 11° (20%), the structural design shall include anti-shear measures to prevent green roof materials from sliding on or off the roof. 5. Green roofs are not to be applied on roofs sloped in excess of 22° (40%).		in the same way as "The Control Flow Roof Drainage Declaration" form created by the Joint Committee of the Engineers, Architects and Building Officials (EABO).
3	Structural – Wind Loads	1. Design for green roofs to comply with OBC Division B Part 4. 2. Design for wind uplift in conformance with FM Global Property Loss Prevention Data Sheet 1-35 Section 2.2.3. 3. Provide parapet walls and non-vegetated border zones in conformance with FM Global Property Loss Prevention Data Sheet 1-35		7. Include wind design as an item on the "Green Roof Declaration" form integrated as part of the building permit process. 8. Permit vegetation taller than the 0.9m limit specified by FM Global if designed and provided with securement as necessary to prevent blow-off.

Table 4.3				
Item	**Category**	**Requirements**		
		Related OBC Requirements	**City Green Roof Objectives**	**Optional Upgrades**
		Section 2.2.14.		
4	Fire Safety	1. Provide non-vegetated border zones in conformance with FM Global Property Loss Prevention Data Sheet 1-35 Section 2.2.14. 2. Grasses and mosses that become dry and present a fire hazard are to be avoided. 3. The mature height of vegetation shall not exceed 0.9 m. 4. Design must provide an *alternate solution* to achieve compliance with OBC Division B and the objectives and functional statements.		5. Include fire safety design as an item on the "Green Roof Declaration" form integrated as part of the building permit process. 6. Consideration should be given to how poorly maintained green roofs will be addressed under property standards. In particular, the fire risk maintenance shall include annual removal of dead vegetation that does not promptly compost and presents a fire risk.
5	Safety in Use	1. Intended use and occupancy of the roof shall be stated in the Building Permit App. If the roof is to be accessible for uses other than maintenance, all OBC required associate with the stated occupancy shall be met (i.e. exits, guard rail, live load capacity, accessibility, etc.) 2. Where green roofs are used to produce and harvest crops including vegetables or flowers, guards are required		4. For improved safety, guards should also be required for green roofs on all new buildings, or only for those that are 3 storeys in height or greater. While this would act as a disincentive, this may not be significant. 5. Guards could also be required on existing buildings. However, in some instances they would be more difficult to retrofit than for new construction

Table 4.3				
Item	**Category**	**Requirements**		
		Related OBC Requirements	**City Green Roof Objectives**	**Optional Upgrades**
		at the perimeter of the green roof to protect against the fall hazard in accordance with OBC Division B 3.3.1.17. 3. For buildings 3 storeys in height or greater, if guards are not provided at the roof perimeter, the vegetation free-zone at the roof perimeter where there is a fall hazard shall be a minimum 2m wide, or alternate safety measures shall be present to facilitate maintenance such as adequate safety tie-back anchors for workers to safely access the vegetation for maintenance. System must allow for compliance with applicable workplace safety laws.		so there is risk this would act as a disincentive to the city green roof policy.
6	General Green Roof Design	1. Comply to the requirements of Part 5.	2. A minimum of 50% of a new building footprint area shall be provided with growth media and vegetation. 3. The design shall consider and target industry standards of good practice related to achieving a functional, healthy, and durable green roof system as reflected by documents such as the "FLL	4. To better achieve policy objectives, increase the minimum area of growth media and vegetation to cover a greater percentage of the building area. 5. For existing buildings, consider incentives to provide increasing percentage of green roof area.

Table 4.3				
Item	**Category**	**Requirements**		
		Related OBC Requirements	**City Green Roof Objectives**	**Optional Upgrades**
			Guidelines for the Planning, Execution and Upkeep of Green-Roof Sites".	
7	Water-proofing Membrane		1. Green roof assemblies shall incorporate a waterproofing membrane, applied in a protected membrane configuration. 2. Green roof assemblies shall not be applied over shingles or tiles. 3. Built-up roofing membranes shall consist of a minimum of 4 plies. Organic based #15 felts shall not be permitted; felts shall be glass fibre based Type IV as a minimum. 4. Sheet applied modified bitumen membranes shall be a minimum of 2 plies. 5. Liquid applied membranes shall be reinforced and be applied with a minimum 2 plies. 6. Waterproofing membranes shall be adequately protected from damage from other green roof assembly materials, and from assembly installation activities.	
8	Drainage	1. OBC Division B Part 9	2. Positive slope to drain shall	

Table 4.3				
Item	**Category**	**Requirements**		
		Related OBC Requirements	**City Green Roof Objectives**	**Optional Upgrades**
		buildings shall be provided with slope to drain at the level of waterproofing membrane in compliance with Table 9.26.3.1.	be provided at the level of the waterproofing membrane. 3. New buildings shall be provided with minimum 2% slope to drains. 4. Drainage panels, mats or equivalent free draining materials shall be employed to permit effective drainage beneath the growth media. 5. Provide a vegetation free zone around all drains in conformance with FM Global Property Loss Prevention Data Sheet 1-35 Section 2.2.14.	
9	Insulation	1. For new buildings, insulation shall comply to the requirements of Part 12.	2. Extruded polystyrene insulation shall be applied above the waterproofing membrane. Designers may use alternate insulation products but they must show equivalent long term performance (thermal and durability) in wet conditions.	3. For existing buildings, minimum insulation requirements could be mandated for green roof retrofit on to promote energy individual building energy conservation (such as 75% or 100% of OBC Division B Part 12 requirements). 4. Upgrading the roof insulation by a further 25% could be mandated to account for the OBC requirements in 2012, the

Table 4.3				
Item	**Category**	**Requirements**		
		Related OBC Requirements	**City Green Roof Objectives**	**Optional Upgrades**
				difficulty retrofitting a green roof and the expected long service life that the design should target.
10	Water Retention Mats		1. Water retention mats or equivalent materials shall be employed as required to promote vegetation growth.	
11	Membrane Root Protection		1. The design shall include materials that adequately protect the waterproofing membrane from damage from roots. Chemical root barriers are only permissible if in compliance with environmental law.	
12	Growth Media		1. Growth media shall be selected so as to support the vegetation 2. Measures shall be taken to prevent growth media blow-off pending establishing vegetation 3. For new buildings, provide minimum 150mm deep growth medium. 4. Existing buildings shall be provided with growth media as necessary to support the vegetation, and as limited by structural capacity.	5. For new buildings, a greater minimum growth medium depth would help promote policy objectives. 6. To better promote storm water management objectives, consideration could be given to establishing incentives to promote achieving greater growth media depths. Incentive thresholds could be: for existing buildings 50mm-100mm-150mm; for new buildings

Table 4.3				
Item	**Category**	**Requirements**		
		Related OBC Requirements	**City Green Roof Objectives**	**Optional Upgrades**
				minimum-300mm and 500mm.
13	Irrigation		1. Adequate measures shall be provided as necessary to permit irrigation necessary to initiate and sustain the vegetation.	
14	Vegetation	1. The vegetation shall not contain any noxious weeds as defined by the Noxious Weed Act (Ontario Regulation 1096).	2. Vegetation shall be appropriate for use in the green roof application. It shall be appropriate for the Toronto climate and building exposure, be sufficiently drought resistant, have root systems that are accommodated and resisted by the assembly design, and provide adequate surface coverage to bind the growing media. 3. Seeds for groundcover plantings shall be sown at a rate not less than 325/m^2, cuttings shall be distributed not less than 12kg/100m^2, and pre-grown plugs shall be installed not less than 11/m^2. 4. The planting design, planting, maintenance, and re-planting (as necessary) shall assure that healthy and complete cover is achieved	5. For clarity, reference could be given to require that the vegetation not contain any noxious weeds as defined by the Noxious Weed Act - Ontario Regulation 1096. 6. To obtain increased confidence in successful vegetation design, a Landscape Architect registered in the Province of Ontario could be required to affix their professional stamp to the design of the green roof assembly. 7. The use of native plants are encouraged. See http://www.toronto.ca/trees/pdfs/Fact 2 How to Select and Buy Native Plants.pdf

Table 4.3				
Item	**Category**	**Requirements**		
		Related OBC Requirements	**City Green Roof Objectives**	**Optional Upgrades**
			within 2 or 3 growing seasons.	

APPENDIX A: SUMMARY OF GREEN ROOF REPORTS

DOCUMENT REVIEW

We have reviewed both green roof standards and guidelines for information relevant to the Proposed Toronto Green Roof Standard. Below we have provided for each a narrative describing the intent and general content of the document and a tabular summary of data/information that relate to the City's stated policy objectives and related performance criteria.

A.1 Guidelines

A.1.1 Design Guidelines for Green Roofs. Canadian Mortgage and Housing Corporation (Steven Peck and Monica Kuhn)

This report provides general information on roof types and components, a good comparison table between intensive and extensive roofs, a list of quantifiable benefits for owners as well as the general public, including heat island effect, storm water management, air quality and habitat creation. Chapter 3 deals with general design and implementation considerations, including references to the Ontario Building Code, but does not specify values or language that can directly be incorporated into a standard. The most useful section is a detailed cost estimate for the design, installation and maintenance of intensive green roof. The paper also includes 3 brief case studies including costs, but without identifying any quantifiable benefits.

Table A.1.1

Policy Objective / Performance Criteria	Design Strategy	Quantitative Data	Standard or Testing Protocol
Reduced Urban Heat Island		Analysis for the City of Chicago: Every one degree Fahrenheit decrease in ambient air temperature results in 1.2% decrease in cooling energy use	Bass, B., Kuhn, M., Peck S., "Greenbacks from Green Roofs: Forging a New Industry in Canada" (GBGR), CMHC. 1998, p.30
Stormwater Management (Rate and Quantity)	Stormwater retention rates vary with: • Saturated infiltration capacity	None	"Urban Heat Island Initiative Pilot Project: Final Report"

Table A.1.1			
Policy Objective / Performance Criteria	**Design Strategy**	**Quantitative Data**	**Standard or Testing Protocol**
	• Thickness of growing medium • Field capacity • Porosity • Drainage layer retention and flow • Drain spacing • Maturity of vegetation • Time of year (climate)		by Roy F.Weston et. al.
Energy Use			
		20 cm (8") of growing medium and thick layer of plants has combined insulating value of RSI 0.14 (R20)	Bass, B., Kuhn, M., Peck S., "Greenbacks from Green Roofs: Forging a New Industry in Canada" (GBGR), CMHC. 1998 p. 24.
Improved Air Quality		10 m^2 of grass roof could remove 2 kg of airborne particulate annually	Minke, 1982, p. 11 in GBGR

A.1.2 Introductory Manual for Green Roofs. (2001). Public Works and Government Services Canada

This is a short introductory manual on green roofs. Good discussion of potential benefits, including air quality and water management. Also presents barriers to green roof implementation. Chapters 3 and 4 present guidelines on design and construction and include good diagrams describing the types and components of green roofs. Most importantly, it includes a five page listing of green roof product suppliers (drains and drainage materials, roof garden systems, planters, light-weight growing medium, drip irrigation, nurseries) as well as a list of references (light on technical information)

No quantitative data was provided.

A.1.3 Green Roofs Resource Manual for Municipal Policy Makers Canadian Mortgage and Housing Corporation (Gail Lawlor et al.)

The manual is an overview of international and Canadian green roof policies and programs, and is intended to guide policy makers by highlighting the rationale behind those policies and programs. Each case study is organized according to the following sections: description of municipality and green roof policy, key motivators, implementation process, effectiveness, lessons learned, future predictions and applicability to Canada. Key motivators discussed are: control Stormwater runoff, reduce urban heat island effect, lower building energy consumption, reduce air pollution, increase green amenity space, maintain biodiversity and reduce escalating infrastructure costs. Some of the tools used by municipalities to encourage implementation and stimulate the market are: financial incentives, regulatory measures, building codes and performance rating systems.

Table A.1.3

Policy Objective / Performance Criteria	Design Strategy Discussed	Quantitative Input	Standard or Testing Protocol
Reduced Urban Heat Island	Minimum solar reflectance requirements for all new and retrofit roofs are waived if a green roof is installed.	Chicago Energy Conservation Code	
Stormwater Management (Rate and Quantity)	50% green roof coverage for all new buildings in Southeast False Creek redevelopment in Vancouver Portland requires all city buildings to be built with 70% green roof coverage and 30% Energy Star roofing materials	Greater Vancouver Regional District Stormwater Source Control Design Guidelines highlight green roofs as a possible best practice tool Portland Stormwater Management Manual	
Energy Budgets of Individual Buildings		Between 1996 and 1997, Basel, Switzerland greened 85,000 m^2 of roofs, resulting in energy savings of 4 GW/year	

Table A.1.3			
Policy Objective / Performance Criteria	**Design Strategy Discussed**	**Quantitative Input**	**Standard or Testing Protocol**
Improved Air Quality	Green roofs in Stuttgart are regulated in local development plans	Air pollution studies in the early 1990s led to development of environmental department to assess development FLL Guidelines are used as design standard	Stuttgart, Germany Municipal Regulation
Growing Medium and Plant Selection	Growing medium must be at least 80 mm deep and must use indigenous plant species		City of Munster, Germany Municipal Regulation
Biodiversity	Protection of endangered invertebrate species Provide mounds (10' diameter, 12" high) to foster insect life	Research by Dr. Stephan Brenneisen (leading green roof researcher – all green roof installation greater than 1000 m^2 must consult him during design and construction)	Basel City Building Regulations

A.1.4 Making Green Roofs Happen Discussion Paper. (2005). City of Toronto

This document was one of the milestones in the development of the City's Green Roof Strategy and was presented to Toronto's Roundtable on the Environment. Similar in scope to the CMHC Resource Manual, this paper surveys various policies used by municipal leaders in green roofs to encourage green roof development and implementation. It also discusses many options for the City of Toronto and proposes specific actions to promote green roofs. Chapter 4 is most relevant, as it describes the recommended criteria that green roofs should meet, including coverage, slope, runoff coefficient and depth of growing medium.

Table A.1.4			
Policy Objective / Performance Criteria	**Design Strategy Discussed**	**Quantitative Input**	**Standard or Testing Protocol**
Construction Requirements	Minimum Coverage should be 50% of roof footprint	Lower coverage would likely not achieve benefits Higher coverage could impede implementation largely due to structural capacity of retrofit projects	Stakeholder Workshops as well as information from the Ryerson Green Roof Study
	Maximum slope should be 10%	Despite safety concerns about installing pitched green roofs, there are many precedents including York University's Computer Science Building (10% slope)	
	The entire roof (incl. non-greened areas) should have a runoff coefficient of 50%	Recent monitoring of green roofs in Toronto indicate average rainfall retention rates of 50-55%	
	150 mm depth of growing medium is preferred but can be as low as 80 mm to provide benefits	Mountain Equipment Coop's green roof, for example, is 4 inches deep	

A.1.5 Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto. Ryerson University (Doug Banting et al.)

The report provides excellent information on the benefits of green roofs and is likely the source behind the City's key policy objectives. The reported environmental benefits include reductions in: Stormwater runoff, energy consumption, urban heat island effect and pollution emissions, and improvements in: air quality, habitat creation and green space. Each benefit is quantified, based on the assumption that all 50 million m^2 of eligible roofs greater than 350 m^2 in area are greened with 75% coverage. Also included are associated monetary benefits and costs.

Table A.1.5			
Policy Objective / Performance Criteria	**Design Strategy Discussed**	**Quantitative Input**	**Standard or Testing Protocol**
Reduced Urban Heat Island (1)	Green roofs should only be installed above conditioned spaces (excludes unheated underground parking)	Reduction in ambient air temperatures between 0.5 and 2 degrees C 0.27 kg of CO_2 reduction for every kWh of energy saved	
Stormwater Management (Rate and Quantity) (1)	Maximum runoff coefficient should be 50% (based on annual average rainfall retention of 50% for Toronto) Installed green roofs on "flat roofs" (nominally slope of 2%) If installing on zero-slope roofs, ensure proper drainage away from the root	1.3 fewer combined sewer overflows annually and 2.3% volumetric reduction with 15% green roof implementation AND implementation of proposed underground storage (Toronto Wet Weather Study) Previous study for City of Winnipeg reported that greening 100% of potential roof space (218,773 m^2 – 20% of total downtown district area) could result in: • 16% reduction in the number of combined sewer overflows • 48% reduction in overflow volume • 24.5 tonnes of CO_2 fixation (removal) annually	City of Toronto QQS model SUDS model HSPF model Toronto Wet Weather Flow Management Master Plan Study
Energy Budgets of Individual Buildings (1)	Green roofs should only be installed above conditioned spaces (excludes unheated underground parking)	Direct energy savings of 4.15 kWh/m^2/year/m^2 of green roof Direct Demand load reduction of 0.0023 kW/m^2/year/ m^2 of green roof	Lawrence Berkeley Laboratory modeling study (Akbari et al., 2004) Enermodal study for City of

Table A.1.5			
Policy Objective / Performance Criteria	**Design Strategy Discussed**	**Quantitative Input**	**Standard or Testing Protocol**
	Green roofs should only be installed above conditioned spaces (excludes unheated underground parking)	Indirect energy savings of 2.37 kWh/m^2/year/m^2 of green roof Indirect Direct Demand load reduction of 0.00267 kW/m^2/year/ m^2 of green roof *Due to reduction in urban heat island effect	Waterloo Eastview Community Centre green roof monitoring data
Improved Air Quality (1)		Reduction in contaminants (per 109.4 hectares of green roof area per year): 0.35 mg CO 1.6 mg NO_2 3.14 mg O_3 2.17 mg PM_{10} 0.61 mg SO_2	Research by Currie (2005) using the USDA Forest Service UFORE-D model
Depth of growing medium	Minimum depth of growing medium should be 150 mm (6") where not limited due to structural capacity of existing roof. Depths of down to 75 mm (3") can achieve benefits reported in study	Allows great flexibility in plant selection and improve their survival potential.	

A.1.6 Performance Evaluation of an Extensive Green Roof. NRCan and City of Toronto (Karen Liu, John Minor)

Proceedings of the 5th Greening Rooftops for Sustainable Communities Conference

This report presents performance data measurements of two green extensive roof installations the Eastview Neighbourhood Community Centre. Both test roofs contained a lightweight growing medium, 75-100 mm in depth. Reported finding include: reductions in heat flow, especially in the summer, improved memebrane durability and reduced and delayed Stormwater runoff.

Table A.1.6			
Policy Objective / Performance Criteria	**Design Strategy Discussed**	**Quantitative Input**	**Standard or Testing Protocol**
Stormwater Management (Rate and Quantity) (1)	Water retention capacity of growing medium	57% average annual reduction in flow volume compared to control roof Peak flow rate reduction of 25-60 % and a detention time between 20 and 40 minutes	Rainfall was measured using a "tipping-bucket" rain gauge Magnetic induction flow meters measured flow from the roof
Energy Budgets of Individual Buildings (1)	Insulating effect of planting media	Heat flow reductions of 70-90 % in the summer (primarily due to evapo-transpiration) and 10-30% in the winter (primarily due to reduced wind effects)	The network of thermocouple measured the temperature profile while the heat flux transducers (HFT) recorded the heat flow across the roofing systems.
Durability	Green roofs improve membrane durability and life span due to increased protection from UV exposure and temperature variations	20°C reduction in maximum roof membrane temperature in the summer 30°C reduction in daily temperature fluctuations of the roof membranes. However, most roofing leaks occur at building perimeters and penetrations. These areas are not protected by the vegetation systems.	

A.1.7 Re-greening Washington DC. **Barbara Deutsch, Heather Whitlow, Michael Sullivan, Anouk Savineau**

Proceedings of the 5th Greening Rooftops for Sustainable Communities Conference

Table A.1.7

Policy Objective / Performance Criteria	Design Strategy Discussed	Quantitative Input	Standard or Testing Protocol
Stormwater Management (Rate and Quantity) (1)	20% of eligible roofs are greened (coverage of 20% for intensive and 80% for extensive systems) Total green roof area would be approx 1.8 million m^2	68% reduction in roof surface runoff compared to traditional roof 19 million gallons (72 ML) of added Stormwater storage capacity 253 million gallons of rainwater storage per year Reductions in the number of combined sewer overflows	Model developed by Limno-Tech, Inc. specifically for the District of Columbia's assumes 2 inches of Stormwater storage for extensive green roofs and 4 inches for intensive green roofs.
Improved Air Quality (1)		Removal of air pollutants equivalent to 17,000 street trees	USDA Forest Service UFORE Model developed by Dave Nowak at the Syracuse Research Station

A.1.8 100 Extensive green roofs: Lessons Learned. Ed Snodgrass, Emory Knoll Farms

Proceedings of the 5th Greening Rooftops for Sustainable Communities Conference

Table A.1.8

Policy Objective / Performance Criteria	Design Strategy Discussed	Quantitative Input	Standard or Testing Protocol
Plant Viability	Succulent plant species (especially the Sedum genus) are the preferred choice for green roofs Use of herbaceous plants should be avoided	Succulents exhibit good ground cover, quick growth, longevity, fire resistance, drought resistance, heat stress tolerance, water conservations	Since 1999, Emory Knolls has supplied plants for over 40,000 m^2 of green roofs in the US, Canada, and Asia
Plant Selection	Selection should be divided into ground cover and accents Native species do not thrive in green roof environments and should primarily be used for accents	Ground cover species provide soil stability due to fibrous roots and are persistent year round Green roofs are man-made environments in dense urban settings with non-native soil composition	
Maintenance	Maintenance should be an integral part of green roof installation, especially during the first year establishment period	Weeding is important to allow planted species to establish themselves Fertilizers should only by applied in the first year and in limited quantities to limit nitrate and phosphate runoff	

***A.1.9 Optimization of Green Roofs for Air Pollution Mitigation*. Corrie Clark, Brian Talbot, Jonathan Bulkley, and Peter Adriaens, University of Michigan**

Proceedings of the 5th Greening Rooftops for Sustainable Communities Conference

Table A.1.9			
Policy Objective / Performance Criteria	**Design Strategy Discussed**	**Quantitative Input**	**Standard or Testing Protocol**
Improved Air Quality (1)	Air pollution mitigation depends on plant selection due to difference in plant uptake of various pollutants	Greening 10% of total roof area in Chicago (161520 acres) can remove 0.46 % of total NO_x emissions if sedum plants are used and 16% if tobacco plants are used	Experimental studies of plant uptake potential EPA annual emissions information