Public Works and Government Services Canada

Travaux publics et Services gouvernementaux Canada

Technology Directorate

INTRODUCTORY MANUAL FOR

GREENING ROOFS

Canada

INTRODUCTORY MANUAL FOR

GREENING ROOFS

FOR PUBLIC WORKS AND

GOVERNMENT SERVICES CANADA

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2002 12 13
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DISCLAIMER

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INTRODUCTION

"We do not seek to imitate nature but rather to find the principles she uses."
Buckminster Fuller, architect

Recent statistics reveal that 80% of all Canadians live in major cities. During the current century urbanization will escalate. Canadian cities represent dense development with more and more people living on less and less land. The scarcity of urban land demands an increasingly creative use of roofs and terraces to replace the land that is lost. The reduction of ground level urban land for open space demands the fullest utilization of green roofs. Building green roofs, stormwater management and green spaces in the city have become major topics in the planning process.

Rooftops traditionally are considered as remnant spaces and abandoned to housing elevator shafts and mechanical systems, should now be used for accessible social and recreational purposes. Well researched green living landscapes including roofs, balconies, terraces and walls provide a linkage to the street and open spaces beyond. Greening rooftops provide many benefits to users, developers and those who enjoy the view from adjoining buildings. Green rooftops are an undervalued economic asset and are often not appreciated as an environmental resource. A fully developed green roof as a source of urban recreation is a welcome developmental asset for the building occupants and the immediate neighbourhood. The evident benefits of green rooftops may potentially outweigh the cost of installation and add to the enjoyment of a city. Vegetation on roofs increase the bio-mass of the city, reduce pollutants, improve the micro-climate, reduce heat island effects and delay stormwater runoff.

A successful green roof requires research and analysis, as well as understanding the complexity of the required construction profile, namely: a) waterproofing, roof protection and drainage, b) light weight growing medium, c) vegetation.
There are two distinct types of green roofs:

1. Intensive: an accessible roof with park-like features of trees and shrubs, and
2. Extensive: an inaccessible roof to be viewed from surrounding buildings with a thin layer of growing medium.

"Never doubt that a small group of thoughtful committed citizens can change the world. Indeed it's the only thing that ever has."
Margaret Mead, anthropologist, 1958

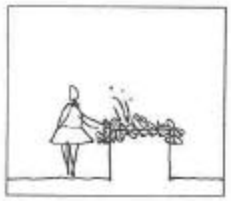
This manual was written as a guide for greening roofs throughout Canada.

1. POTENTIAL ADVANTAGES & BENEFITS to Green Roofs

"The bottom line of green is black."
Ted Saunders, businessman, 1994

"Air binds us all together as a single living entity extending through time and space."
The Sacred Balance by David Suzuki, 1997

"When the waters again run clear and their life is restored, we might see ourselves reflected whole."
Earth in Mind by David Orr



Raised beds for accessibility.

1.1 Economic

- Increased insulation value => less mechanical cooling and heating = energy savings.
- Increased stormwater retention => less strain on stormwater sewer system.
- Amenity space for users = more comfortable and satisfied staff
- No land costs for this benefit, more usable space => more valuable property.
- Reduced May reduce costs for maintenance of roof membrane, protected from ultraviolet rays, extreme temperature fluctuations, and maintenance wear and tear.

1.2 Air quality

- Through photosynthesis of plant life, the air has less carbon dioxide and carbon monoxide, more oxygen.
- Plant materials absorb heat and lower ambient temperature, thereby reducing 'Urban Heat Island Effect' (city hotter than surrounding countryside).
- Plant materials raise humidity.
- Through evapo-transpiration plants filter airborne particulates.
- Management of wind patterns can be enhanced by strategic placement of built elements and planting.

1.3 Water Management

- Stormwater retention, achieved with permeable surfaces, results in gradual run-off, less strain on sewers.
- Vegetation absorbs pollutants from rainwater.
- Recycled water can be used for irrigation.
- Drip irrigation is an efficient means of using water.
- Cisterns and dry wells can store water for later use.
- Integrate with grey water system (natural filtration system with plants and/or gravel).
- Cities, such as Portland Oregon, are developing programs to provide financial incentives for green roofs in order to decrease stormwater runoff and therefore future infrastructure costs.

1.4 Social, Therapeutic

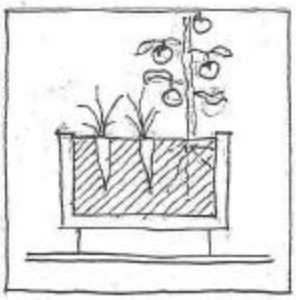
- Variety of sights, smells, sounds of a garden can add to richness of experience, quality of life.
- Social and recreational spaces, e.g. sitting, viewing, walking, games, gardening, invite healthy past-times.
- A well-designed, aesthetically pleasing roof garden can

enhance the views from surrounding buildings and provide its own building's inhabitants a green oasis.
- Less vandalism and assault occur at roof levels than at gardens at grade => greater security.
- Communal gardens are an excellent social space, at lunch time for example.
- A more desirable micro-climate can be created by influencing the temperature, humidity, wind, and solar exposure.

"Many cities have millions of square meters of unused and unattractive roofs. They represent enormous wasted opportunities for improving the quality of city life."
Building Green by J. Johnston and J. Newton.

1.5 Biodiversity
- Green roofs are may an opportunity to provide natural habitat for resident and migratory birds and insects (especially if the roof provides as many as possible of their basic needs - food, shelter, water, place to breed). Consult local naturalists for selection of appropriate wildlife-friendly plants.
- Planting can be selected to replenish threatened indigenous species.

1.6 Sound Absorption
- Planted areas absorb more sound than hard surfaces.
- Planted areas are natural sound insulators to spaces below the roof.



1.7 Food Production (on accessible roofs)
- Natural foods, such as seeds and berries, can be provided for birds and insects.
- Roof spaces may provide opportunities for food gardens.
- Fresher produce that hasn't traveled long distances could be available to residents.
- Organic methods can be promoted with known ingredients in growing medium, fertilizers, and integrated pest management.
- A greenhouse option would extend the growing season.

1.8 Green Building Assessment
- Techniques have been developed to assess the environmental performance of buildings.
- BREEAM, Building Research Establishment Environmental Assessment Method was conceived in the U.K. as a tool to encourage more environmentally friendly office buildings. BREEAM/Green Leaf has been developed and used primarily in Ontario by Public Works and Government Services Canada.
- LEED, Leadership in Energy and Environmental Design, is a program adopted by the U.S. Green Building Council which provides standardization and independent oversight for

environmental performance in non-residential buildings. Canada has yet to formally adopt LEED as a standard.

- Green roofs can earn one LEED rating point for Landscape to reduce heat islands if the green roof is used for at least 50% of the roof area. A green roof also can contribute to one point for stormwater management that meets LEED criteria.

2. BARRIERS
to Green Roofs

"How often it is, in the various fields of design, that negative factors can with study be turned to advantage."
Lessons by John O. Simonds 1999

2.1 Economic
- Strengthening of structure may be required.
- Additional costs can include the new roof components and the cost of a crane to install.
- Accessible roofs must have an additional elevator stop and second stair. This is a code requirement.
- Additional maintenance may be required, though this will vary greatly depending on the design. A planted roof requires more maintenance than a gravel roof.

2.2 Safety Issues
- Accessible roofs must have full perimeter protection.
- Adequate protection must be provided for maintenance staff (meet health and safety requirements.)

2.3 Maintenance Issues
- If leaks do occur, they are more difficult to trace.
- When roofing components need replacement, a more complicated process is likely: plant material and growing medium need to be removed and replaced.
- Accessible roofs need on-going care. The more complex the planting scheme, the more care is required, e.g. pruning, etc.

2.4 Education
- Training of users may be required, e.g. a natural garden is more sustainable than lawn; methods of organic food production.
- Training of maintenance staff may be required, e.g. re composting and mulching; promoting urban wildlife.

2.5 Permits
- Fire protection of dry plant material may need negotiating with local officials.
- Access and egress on existing roofs may mean adding a stair or getting a variance.
- Accessibility for disabled persons on existing roofs may be difficult to achieve.

3. DESIGN and CONSTRUCTION Considerations

"The larger the green roof, the greater the environmental benefits."
Building Green by J. Johnston and J. Newton.

3.1 General Design Principles

- Set specific goals to be achieved by the green roof, e.g. collect 100% rainwater, provide 75% permeable surfaces, etc. See the high performance building assessment tool, LEED criteria for suggestions.
- Reduce weight wherever possible, e.g. lightest growing medium, strategic placement of planting, lightweight pavers.
- Research the local climate - solar hours, rainfall, wind, exposure, temperatures, and humidity patterns.
- Use rainwater as primary water source, with drip irrigation as a back-up.
- Use hardy, native plants. Shallow rooted plants are preferable.
- Pave as little as possible. Slope paving to landscaped areas. Consider permeable pavers or pavers on pedestals.
- Provide for urban birds and insects.
- Use durable products. Use salvaged or recycled materials when possible.
- Optimize material use by designing to standard sizes and minimum requirements. Reduce waste and avoid complicated design.
- Provide a place for mulching and composting, and recycling if the roof is accessible.
- Encourage recycling bins for different waste during construction.
- Design the roof to create a variety of spaces/ outdoor rooms for certain activities, to provide stimuli to all the senses, and to create visual compositions. Roof systems per se or random plantings do not achieve these goals unless they are incorporated into a holistic design.
  For example the Quiet Space at the Provincial Government Complex, Robson Square, Vancouver provides a restful oasis in the middle of the city.

"Successful design begins with the nature of place, and ends with appeal to the users."
Lessons by John O. Simonds 1999

3.2 Collaboration of Design Team

- From the outset, involve all design disciplines – structural, mechanical and electrical engineers, architects, and landscape architects. For best results the design team should include roofing design professionals. This joint effort will lead to maximizing the benefits of each decision, e.g. the stair and elevator shaft can provide shade and windbreak, can be the starting point for irrigation, drain pipes.
- Regular meetings of the full team will allow for efficient integration of all components.

- Involve the users and maintenance people at an early stage for sharing of needs and sustainability concepts.

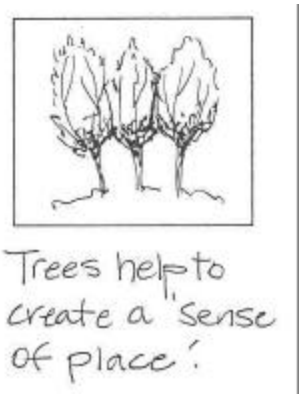
3.3 Aesthetics

- The overall composition of the roof should be based on a design concept of colour, texture, shapes and materials.
- Plant material softens the built environment and adds visual interest to walls and roofs. The extent of planting is determined by the allowable loading on the roof.
- There are two broad types of green roofs:

1. Accessible roofs (Intensive green roofs or roof gardens) are designed for building occupants and/or public use as parks or terraces. The soil depth on accessible roofs can be up to 60 cm or more in areas that support trees. Roof gardens often require irrigation and intensive maintenance.
2. Inaccessible roofs (Extensive roofs) have a wide application as they commonly weigh no more than a gravel-bed roof surface. They are primarily built for environmental and visual benefits. Minimum soil depths are required for alpine-like plants, selected for their ability to withstand extreme roof conditions such as intense heat and cold, harsh winds and no irrigation (after the plants have been established). Companies such as Suprema, Garland and American Hydrotech sell complete packages of green roof systems. Purpose built inaccessible roofs allow for individual design expression.

"One of the most attractive benefits of a green roof is its visual appeal."
Building Green by J.Johnston and J.Newton

"Humans have physiological reactions to natural beauty and diversity, to the shapes and colors of nature, especially to green, and to the motions and sounds of other animals." Frederick Law Olmsted



3.4 Structural Loads

(Please note - This work must be done by a structural engineer.)

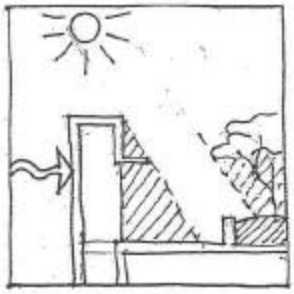
- Existing roofs: evaluate existing load capacity. Calculate how much landscaping can be accommodated? Can it accommodate people loads?
- Can the strength be increased with strategically placed additional structural components (columns, beams, -braces) without the high costs of altering foundations?
- On existing roofs: place heaviest components on or near column heads and over beams to reduce mid-span stresses.
- For new roofs: coordinate landscape requirements with structural engineers.
- When calculating loads use saturated weights of growing medium.
- Anchors required for trees also need to be coordinated with structural engineer.
- Coordinate anchors for maintenance safety harnesses with other structural requirements.

3.5 Building Codes, Safety Issues – Public and Staff

- Existing roofs: check with local authorities to see if some code requirements can be relaxed, e.g. accessibility by elevator, second means of egress.
- Review Workers Compensation Board requirements for workers safety requirements, particularly for inaccessible roofs. For example - can gardeners working near the edge of the roof use the same harness fastenings as window washers?
- Check codes re disabled persons needs - wheelchair paths and ramps, visually impaired persons needs, etc.

3.6 Microclimate

- Microclimatic conditions on a roof will determine choice of plant material and, if it is an accessible roof, what modifications will be necessary for visitor comfort. See Bibliography: Brown, R.D. and T. J. Gillespie.
- Study sun angles for each season to provide number of hours per day of sunshine. This will be a determining factor for choice of plant material. Wind studies are also critical both for health of plants and comfort of people. 3D-computer modeling can be used to simulate microclimates and human thermal comfort conditions, to give designers an understanding of future environmental conditions.



- Wind can burn leaves and lead to plant dehydration. Choose plants that tolerate windy seaside conditions and check with local nurseries for wind tolerant plant material. Wind breaks or screens may mitigate strong winds. Study wind patterns to understand swirling and eddying when wind breaks up.
- Sunshine on accessible roofs: offer a choice of conditions. Few people prefer direct exposure to the sun. Glare can be a problem even where excessive heat is not. Plant material and light absorbing (dark coloured) paving materials can reduce glare on roofs.
- Roof gardens produce a cooling effect on the rooms adjacent to the garden.

3.7 Other rooftop elements

- Provide areas for storage of maintenance equipment and composting.
- Inaccessible roofs, without a parapet, require provision for safety of maintenance workers, e.g. railings or rings for harnesses.
- Collect rainwater for re-use, either at roof level or at grade with a pump.

- Consider providing an area for research equipment to measure temperature of air and water runoff and other roof garden performance parameters.
- Rooftop intake and exhaust fans/ hoods can alter the local conditions for people and plants. Design the roof garden with these in mind. Ensure design collaboration between mechanical engineer and landscape architect.
- If photovoltaic cells or solar panels are used, place them to provide desired shade or shelter.

3.8 Membranes, Protection Board, Root Barriers

- Membranes: Keep the roof from leaking. Either applied as a liquid monolithic layer or in sheets which are seamed or lapped. Choice of membrane is governed by positive experience with a product, roof conditions, budget, and ease of repair.
- Protection Board is an essential component of the roof system and is placed directly over the membrane. It protects membrane during construction and from UV breakdown.
- Root Barriers – Best protection against root damage to roof membranes is the choice of shallow rooted plants. Some manufacturers of roof 'systems' and/or membranes incorporated a chemical root-repelling agent in the membrane.

3.9 Paving Materials, Planter Boxes

- Paving materials: Use lightest possible pavers. To adjust grade over varying slopes an/or to raise the grade, use adjustable pedestal system, e.g. made from shims, spacers and lengths of PVC.
- Planter Boxes: Consider weight and long term aesthetic values of materials. Line with pre-fabricated drainage system with soil separation mats to ensure good drainage.
- The bottom of the planter box must slope to drain.

3.10 Growing Medium

- Use a lightweight growing medium weighing approximately880 kg per cubic metre in moist condition. A commercially available mix is composed of 1/3 sand, 1/3 pumice and 1/3 Humus Builder - a product based on composted wood and composted fertilized.
- Ensure growing medium is mixed off site before it is placed by the contractor.
- For convenience, growing medium can be delivered in

bagged condition or blown on to the roof.
- Wet growing medium and allow to drain thoroughly before planting plugs.

3.11 Drainage

- Place drainage system across the entire roof.
- Consider prefabricated drainage mat systems which direct water and are light weight and long lasting, and include a non-woven filter fabric to keep fine soil from clogging the layers below.
- Direct rainwater to the planted area where plant roots can filter, moderate the temperature and slow runoff of the water.

"A building should be like a tree, it should thrive on the sun's energy, while enhancing its surroundings."
William McDonough, architect
1993

3.12 Storm Water Retention

- Green roofs have a big potential for stormwater management and reducing the destructive impacts of impervious area on the aquatic environments.
- Provide storage facilities on roof or in basement to store rainwater for future re-use – as irrigation or for flushing toilets.

Growing medium raised to the roof in a bucket.

3.13 Plant Materials, Herb and Vegetable Gardens

- Use shallow rooted plants with regenerative qualities, resistant to direct sunlight, drought, frost and wind. The right choice of plant material for the existing conditions will reduce maintenance and increase visual enjoyment of the roof. Sufficient attention must be paid to the selection of plants that will thrive in the local climate and conditions.
- Refer to Plant Hardiness Zones, see Bibliography - Information on Plant Material.
- Plant material (+ growing medium) can be delivered to the roof by means of a crane if internal access is not an option.
- Trees and shrubs create visual impact. Trees can by planted in minimum soil depth of 0.60 m. Anchor root ball for stability.

Vegetable and Herb Gardens: With access to water, intensive vegetable production is possible –for office workers' lunchtime recreation and/or wholesale production by roof top farmers. Perhaps the biggest benefit for food gardens on roofs is the proximity to the garden for building occupants. Shade at grade, lack of arable land and security also make roof gardening desirable. Toronto Food Policy Council is supporting an initiative for a pilot roof top food production project. An example of a productive herb garden is at Vancouver's Waterfront Hotel where herbs supply the hotel restaurants.

3.14 Propagation Options

- When large quantities of plant material are required, propagation can be done from tissue culture or from collected seed. From one plant thousands of new plants can be propagated. This requires early planning.
- Plant plugs with fully established root systems for quick coverage.

3.15 Irrigation

"Of all out natural resources, water has become the most precious.."
Silent Spring by Rachel Carson

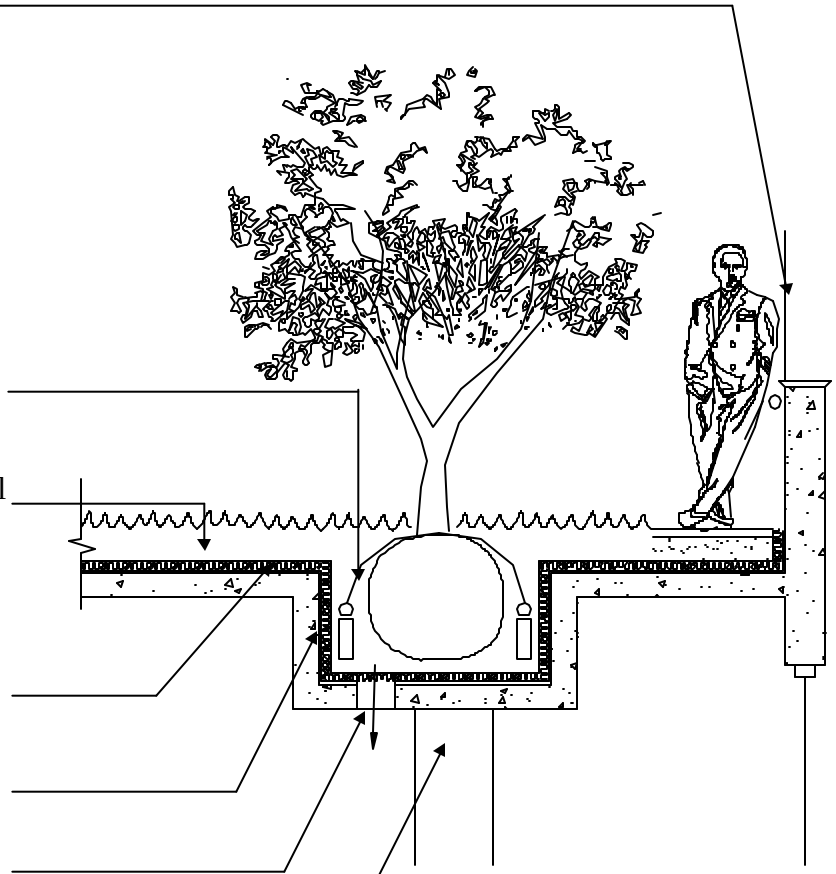
- Provide hose bibs for manual watering during the first complete growing season if an automatic irrigation system is not installed.
- Use light weight drip irrigation system for efficient use of water directly to the root zone.

3.16 Maintenance, Composting, Integrated Pest Management

- Maintenance: Inaccessible roofs require little maintenance aside from initial watering to establish plants, and periodic fertilizing, weeding and clean up. Accessible roofs require all of the maintenance of an on grade garden – pruning, dead-heading, weeding, etc.
- Composting on the roof eliminates the need for taking garden wastes through the building. It also provides an on-going source of compost for soil renewal.
- Integrated Pest Management: Healthy plants can withstand pest attacks better than plants growing under stress so plant selection is critical. Use biological controls whenever possible and do not use any chemical pesticides while plants are blossoming to avoid harm to bees.

4.1 ACCESSIBLE ROOFS "INTENSIVE"

1. Railing can be extended to become wind protection
2. Anchor tree rootballs; avoid piercing waterproof membrane.
3. Growing medium depth will vary from minimum of 50mm to 600mm for small trees
4. Non-woven filter fabric bonded to drainage layer.
5. Waterproofing membrane
6. Recessed tree pit requires drainage
7. Place large plants over columns and main beams

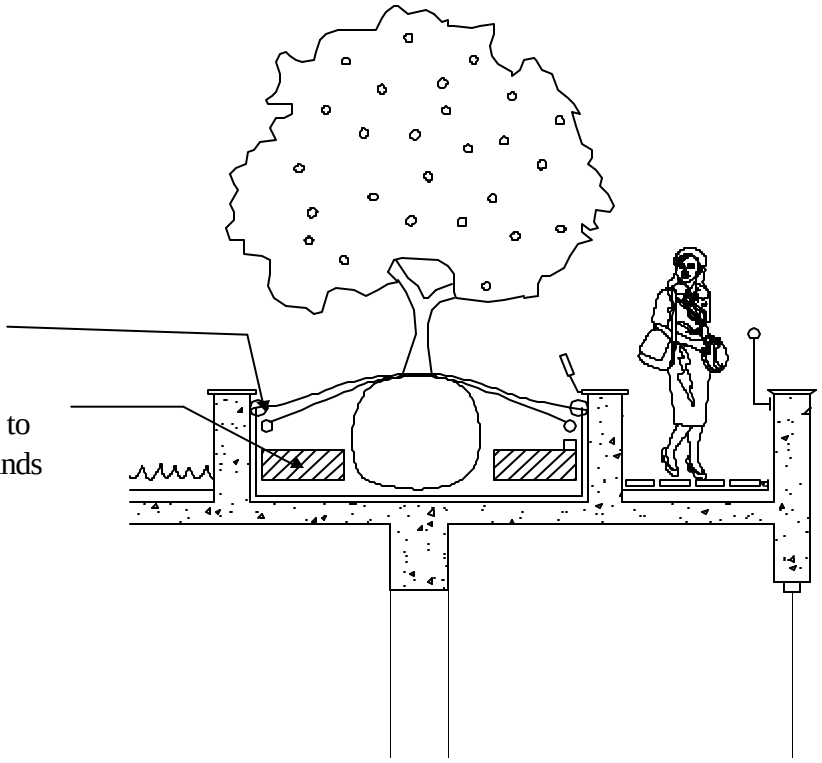


Drawing 4.1.1

4.1 ACCESSIBLE ROOFS "INTENSIVE"

As per Drawing 4.1.1

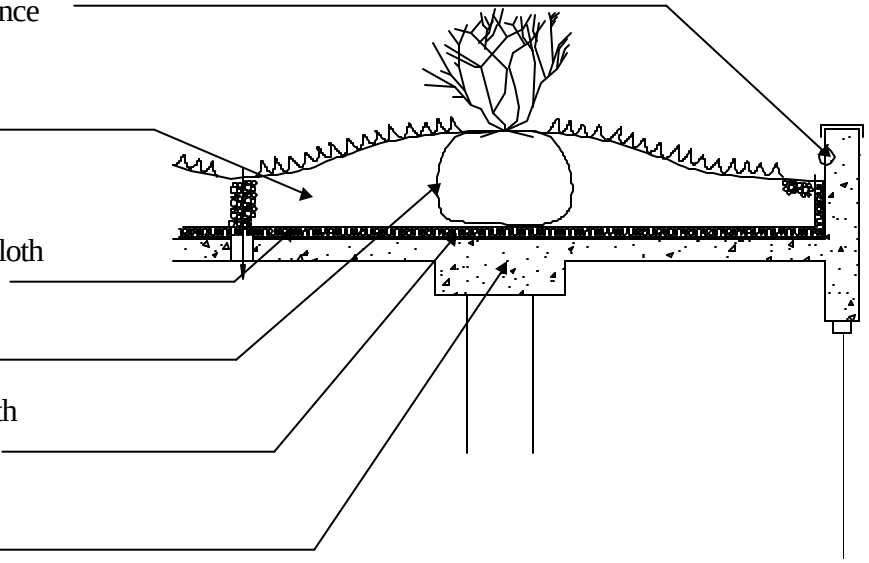
1. Anchoring rootballs
2. Add Styrofoam slabs to reduce weight at mounds



Drawing 4.1.2

4.2 INACCESSIBLE FLAT ROOFS "EXTENSIVE" and/or "INTENSIVE"

1. safety hooks for maintenance workers
2. lightweight growing medium
3. drainage layer with filter cloth
4. root barrier (optional)
5. waterproof membrane with protection board
6. structural slab

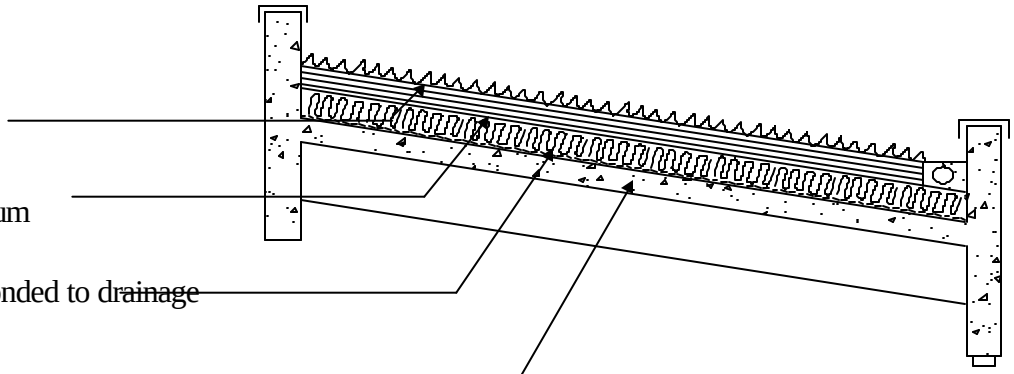


Drawing 4.2.1

Notes:

1. see notes for 4.1 accessible roofs also
2. maximize permeable surfaces
3. amount and location of insulation will vary by region and building

4.3 INACCESSIBLE SLOPED ROOFS



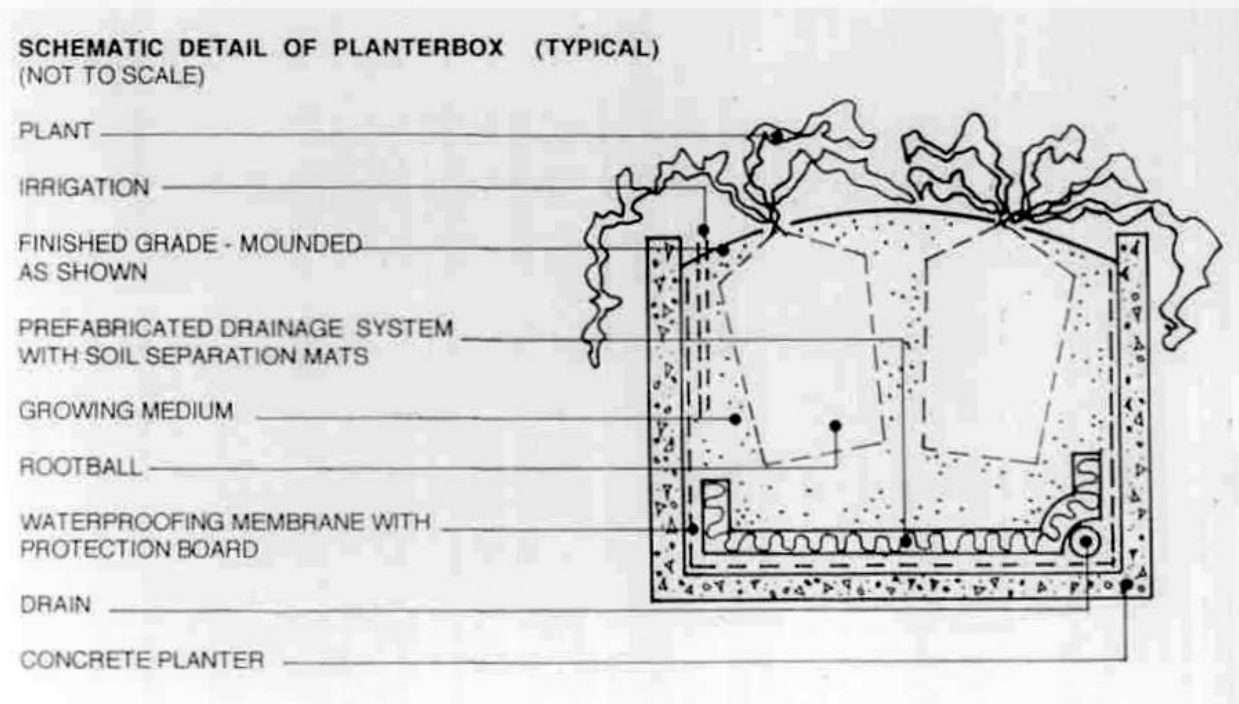
1. vegetation
2. growing medium
3. filter fabric bonded to drainage layer
4. waterproof membrane on structural slab

Drawing 4.3.1

Notes:

1. 10% to 20% slope preferred in most locations.
2. 30% maximum slope, add battens or anti-erosion devices
3. structure should always be designed for saturated conditions

4.4 PLANTER BOX



Schematic Detail Drawing 4.4.1

Planter box, Canadian Chancery, Washington D.C. 1989, C.H.O. L. Arch.

5. SAMPLE SPECIFICATIONS

The accompanying sample specifications are being developed in accordance with ***MasterFormat*** ©[1] and the National Master Specifications (NMS) of Canada for release in Version 2 of this document. The estimated date of completion of this task is February 2003.

[1] *MasterFormat*© is a North American construction industry formatting document jointly owned and published by Construction Specifications Canada (CSC) and the Construction Specifications Institute (CSI) in the United States.

6. SUPPLIERS INVESTIGATED

For Green Roofs

6.1 Drains and Drainage Materials

American Hydrotech, Inc.
303 East Ohio Street
Chicago, Illinois 60611 3387 U.S.A.
Telephone: 1 800 877-6125

Eljen Corporation
125 McKee Street
East Hartford, CT, 06108 U.S.A.
Telephone: 1 800 444-1359

Koro Drain
Mansonville Plastics Ltd.
19402 56 Avenue, Surrey, B.C.
Telephone 604 534-8626

Lightweight drain layer made from styrofoam. Should be used in conjunction with a non-woven filter fabric.

Nilex Inc.
Canadian Head Office
3448 93 Street
Edmonton, Alberta T6E 6A4
Telephone: 1 800 667-4811

An excellent line of prefabricated drainage composites: a high flow dimpled drainage core with a bonded layer of non woven filter fabric. A lightweight, long life drainage solution for green roofs.

Soprema
800 Saint-Vallier Street West
Quebec City, Quebec G1N 1C9
Telephone: 1 800 463-2382. Call for local representative.

TC Mirafi
Armtec
245 10451 Shellbridge Way
Richmond, B.C. V6X 2W8
www.armtec.com

6.2 Roof Garden Systems

At present these systems seem to be quite restricted in the types of plant material that can be used, for example they do not allow for the planting of large shrubs and trees.

American Hydrotech, Inc.
303 East Ohio Street
Chicago, Illinois 60611 3387 U.S.A.
Telephone: 1 800 877-6125
Mr. Charles Cronenweth, Western Sales Manager
Telephone: 206 441-6125 Email: cronenweth@uswest.net

Garland Canada
1290 Martin Grove
Toronto, Ontario M9W 4X3
Telephone: 416 747-7995 or 1 800 387-5991
Call for your local representative.

Soprema
800 Saint-Vallier Street West
Quebec City, Quebec G1N 1C9
Telephone: 1 800 463-2382. Call for local representative

6.3 Pedestal Paving

Westcon Pavers
19675 98th Avenue
Langley, B.C. V1M 2X5
Telephone: 1 888 816-2111

Appian Way System has adjustable height pedestals.

6.4 Planter boxes

Benz & Fischer Alulines
Handelsgesellschaft mbH
Neuer Weg 32
D-71711 Murr, Germany
Telephone: 07144 8050 0

Elegant, light weight aluminum planterboxes, arbours, mesh screening.

6.5 Light Weight Growing Medium

Check local suppliers in yellow pages

Answer Garden Products
A Division of Envirowaste Consolidated
27715 Huntingdon Avenue, Abbotsford, B.C.
Telephone 604 856-6221

Supplied the light weight growing to landscape architect specifications for Vancouver Public Library Roof.

Fraser Richmond Bio-Cycle Ltd.
12630 Woolridge Road
Pitt Meadows, BC V3Y 1Z1
Telephone 604 465-3506 Fax 604 465-6254

Range of composted soil products.

Great Pacific Pumice Inc.
790 Millbank, Vancouver, BC V5Z 3Z3
Telephone 604 250-2750 Fax 604 879-6411

Red River Soils, A Division of Envirowaste Consolidated
2427 Waverley Street
Winnipeg, Manitoba R3T 2E7
Telephone: 204 275-7980
Fax: 204 269-0167
Mr. Victor Lesser

6.6 Drip Irrigation

The Toro Company
Canadian Representative – Mr. Peter Laverne
Telephone 416 699-5495 Fax 416 699-5469

Rainbird Technical Services Canada
Telephone: 1 800 247-3782

6.7 Nurseries

Bluestem Nursery, Jim Brockmeyer
1946 Fife Road, Chistina Lake, BC, V0H 1E3
Telephone/Fax: 250 447-6363

A wonderful selection of ornamental grasses and willows.

Bunchberry Nurseries
Box 210, Clementsport, NS B0S 1E0
Telephone: 902-532-7777 Fax: 902-532-7588
Jamie Ellison & Jill Covill

An impressive list of Sempervivums and Saxifrages.

Free Spirit Nursery Inc.
Lambert & Marjanne Vrijmoed
20405 32 Avenue
Langley, B.C. V2Z 2C7
Telephone 604 533-7373 Fax 604 530-3776
Web: www.plantlovers.com

Humber Nurseries, Frans Peters
8386 Hwy. #50, RR#8, Brampton, Ontario L6T 3Y7,
Telephone: 416-798-8733 from Toronto, or
905-794-0555, fax: 905-794-1311
Web: http://www.gardencentre.com

JEA Perennials, Janet Anderson
24640 Melbourne Rd., RR#3, Strathroy, Ontario N7G 3H5
Telephone: 519-245-4039, or 1 877 500-6162
Fax: 519-245-1267.

Linnaea Nurseries Ltd.
Mr. John Folkerts, General Manager
3666 224th Street
Langley, B.C. V2Z 2G7
Telephone 604 533-8281 Fax 604 533-8246
Toll free: 1 888-327-7705
Email: linnaea@telus.net

Pacific Rim Native Plants Ltd.
Paige & Pat Woodward
44305 Old Orchard Road, Chilliwack, BC V2R 1A9
Telephone: 604 792-9279 Fax: 604 792-1891
Telelphone: 1 888 751-7427
Email: pwoodwar@dowco.com

Sheridan Nurseries Ltd.
Bill and Karl Stensson.
RR#4, 12302 10th Line Georgetown, Ontario L7G 4S7
Telephone: 416-798-7970 Fax: 905-873-2478,

Specimen Trees
18598 Advent Road, Pitt Meadows, BC V3Y 2G8
Telephone: 604 465-7122 Fax: 604 465-8100
Telephone: 1 800 471-4448
Email: inquiry@specimentrees.com
Web: www.specimentrees.com

Valleybrook Gardens / Heritage Perennials. John Valleau
961 Line 4 Rd., R.R. #6
Niagara-on-the-Lake, Ontario L0S 1J0
Telephone: 905 468-4210 Fax: 905 468-4220
Web: www.perennials.com

Valleybrook Gardens / Heritage Perennials. (Head Office)
1831 Peardonville Road, RR#1
Abbotsford, B.C. V4X 2M3
Telephone: 604 855-1177 fax: 604 850-1383
Telephone: 1 800 824-1120

7. RESOURCES

7.1 Bibliography

Brown, R.D. and T.J. Gillespie, 1995.
Microclimate Landscape Design: Creating Thermal Comfort and Energy Efficiency,
John Wiley & Sons, New York.

Presents the basic principles of microclimatology – how objects in the landscape affect climate to create microclimates. Explains how to use landscape design to modify microclimate, including radiation, wind, temperature, humidity and precipitation.

City of Fort Collins (March 1999)
Xeriscape: a New Kind of Landscaping

http://www.ci.fort-collins.co.us/water/xeriscape.php

A summary of environmentally responsive landscaping resources, including a list of very low, low and moderate water

Daniels, Elizabeth.
'Green' Buildings' DJC. COM (September 15, 2000).
See: www.djc.com/news/environ/11113857.html

Dramstad, W.E., J.D. Olson, and R.T.Forman, 1996.
Landscape Ecology Principles in Landscape Architecture and Land-Use Planning,
Harvard University Graduate School of Design, Cambridge.

Presents and explains the principles of landscape ecology and provides numerous examples of how those principles can be applied in specific situations.

Immen, Wallace.
'***Gardens in the sky help ward off warming'***
The Globe and Mail, Saturday, February 16, 2002.

Jeavons, J. 1982.
How to Grow More Vegetables.
Tenspeed Press, Berkeley, CA

A concise discussion on how to maximize vegetable production in small, contained gardens.

Johnston, J. and Newton, J., 1996.
Building Green, A Guide for Using Plants on Roofs, Walls and Pavements.
The London Ecology Unit, London.

Kourik, R. 1992.
Drip Irrigation for Every Landscape and All Climates.
Metamorphic Press, Santa Rosa, CA
One of the most thorough books available on design and construction of drip irrigation systems.

Liesecke, Hans-Joachim, Bernd Krupka, Gilbert Losken, Hilke Bruggemann. 1989.
Grundlagen der Dach begrunung.
Berlin and Hannover: Patzer Verlag.
Excellent discussion of primarily inaccessible and sod roofs with details and examples and lots of technical information. In German.

Loken, S., W.Spurling and C.Price, 1994
GREBE (Guide to Resource Efficient Building Elements).
Center for Resourceful Building Technology, Missoula, MT.
The original resource book on green building materials, and still one of the best (in USA). Updated regularly.

Marcus, Clare Cooper and Marni Barnes. 1999.
Healing Gardens: Therapeutic Benefits and Design Recommendations.
John Wiley & Sons, New York.
A 600 page comprehensive guide with site plans, design guidelines and case studies of out door spaces for medical settings. Many of the gardens are on roof tops.

Marsh, W.M., 1991.
Landscape Planning: Environmental Applications.
John Wiley & Sons, New York.
A definitive reference for landscape architects, planners and designers on the definition and application of environmental design principles to landscape and site planning.

Moffat, A.S. and M. Schiler, 1993.
Energy- Efficient and Environmental Landscaping.
Appropriate Solutions Press, South Newfane, VT.
Good discussion on specific landscape approaches for enhancing the energy efficiency of buildings.

Netafim Irrigation Inc., 1998.
Techline Design Manual.
Netafim Irrigation, Inc. Landscape Division, Fresno, CA.
A technical primer for designing drip irrigation systems. A note of environmental interest: Netafim provides free recycling of plastic pipe to greenhouse growers in California.

Oberlander, Cornelia Hahn, 1990.
The New Canadian Chancery
Landscape Architectural Review, Vol. 11, No. 4.

Oberlander, Cornelia Hahn, 1981.
An Oasis in the City
Landscape Architectural Review, Vol. 2, No. 2. Toronto
A description of the Provincial Government Complex, Robson Square, Vancouver.

Osmundson, Theodore. 1999
Roof Gardens: History, Design and Construction.
W.W. Norton & Company, New York..
A comprehensive study of roof gardens showing plans, sections and photographs of individual projects. Discussions on wind, safety, loads, maintenance and other site considerations. A useful appendix with weights of building materials, plants, growing mediums. 318 pages.

Peck, Steven and Chris Callaghan., 1999.
Greenbacks from Green Roofs: Forging a New Industry in Canada.
CMHC Canada.

Pereira-Bron, Kathleen. 2001.
"Up on the Roof: Rooftop Landscaping Remains an Untapped Market in Canada".
Turf & Recreation, Canada's Turf and Grounds Maintenance Authority. January/February 200l, Volume 14, Number 1.

Scholz-Barth, Katrin. 2001.
'***Green Roofs: Stormwater Management From the Top Down'.***
Environmental Design + Construction. www.edcmag.com
Katrin Scholz-Barth is the Director of Sustainable Design for the HOK Planning Group and is an expert on green roof technology. Telephone: 202 339-8728

Sheltair Scientific Ltd. - Theaker, I. and Cole, R., Connery, K., Rousseau, D. April 1999
Green Building Design & Construction Guidelines.
City of Santa Monica

Terres, J.K., 1994
Songbirds in Your Garden.
Algonquin Books, Capel Hill, NC
Brief but information-filled guide to enhancing wild bird habitat with urban landscaping design.

Thompson, William. May 1998.
"Grass-Roofs Movement"
Landscape Architecture, Vol. 88, No. 6, pp.47 - 51.

ZinCo International.
'***Landscaped Roofs in Their Most Attractive Form'***. March, 1998.
Promotional 50 page brochure in English with case studies, detail, etc. www.zinco.de/ausland/englisch/ehome.htm

7.2 Information on Plant Material

Plant Hardiness Zones

Canadian Forest Service website:
http://www.nrcan-rncan.gc.ca/cfs-scf/index_e.html

Or Agriculture Canada at
http://sis.agr.gc.ca/cansis/nsdb/climate/hardiness/intro.html

Plant Resource Books

Plants of Coastal B.C.
Plants of the Western Boreal Forest & Aspen Parkland
Trees and Shrubs of Alberta
Trees of Ontario.
Lone Pine Publishing

Excellent plant guides with complete plant descriptions, photographs and diagrams for identification. For complete list of books see catalogue at web:
www.lonepinepublishing.com

7.3 Weights of Common Building Materials

(from Roof Gardens by T. Osmundson unless noted)
Where possible use Re-used or Re-cycled Materials
from as local a source as possible

Material	**kg/m^3**
Lt. Wt. Concrete	1298-1622
Precast Concrete	2108
Reinf. Concrete	2433
Gravel	1946
Timber	
Hardwood (average)	730
Solftwood (average)	568
Sand (dry)	1460-1784
Sand (wet)	1784-2108
Water	1013
Lt. Wt. Growing Med.* (in moist condition)	884-1121

Plant Material
Weights vary considerably depending on soil type and moisture content . (from Piroche Plant catalogue)

Size	**kg/m^3**
5 cm pot	150 grams
10 cm pot	850 grams
#1 pot	2 kg
#5 pot	12 kg
45 cm shrub pot	30 kg
6 cm caliper	150 kg

* from: The Answer Garden Products on weight of 'Library Mix' (see bibliography)

7.4 Other Canadian Resources

Canada Mortgage and Housing Corporation
Ms. Susan Fisher, Researcher
Sustainable Planning and Regulation
National Office, 700 Montreal Road
Ottawa, Ontario K1A 0P7
Telephone: 1 800 668-2642
Email: sfisher@cmhc-schl.gc.ca
Web: www.cmhc-schl.gc.ca

Canadian Nursery Landscape Association
R.R.#4, Station Main, 7856 Fifth Street, Milton, Ontario,
Canada L9T 2X8 · Fax: (905) 875-1840
Telephone: (905) 875-1399 or 1-(888) 446-3499
www.canadanursery.com
A web connection to all nursery associations in Canada and through them listings of local nurseries and resources.

Environment Canada
Mr. Brad Bass
33 Willcocks Street
Toronto, Ontario M5S 3E8
Telephone: 416 978-6285 Fax: 416 978-3884
Email: brad.bass@ec.gc.ca

Greater Vancouver Regional District
4330 Kingsway, Burnaby, B.C.
GVRD home page http://www.gvrd.bc.ca
Mr. Thomas Mueller – publications, applications
Telephone: 604 436-6818
Ms. Marian Kim – research, technology aspects
Telephone: 604 436-6828
Mr. Robert Hicks – roof stormwater management
Telephone: 604 451-6165

Green Roofs for Healthy Cities – Canadian Eco-Industrial Network
1560 Bayview Avenue, Suite 305, Toronto M4G 3B7
Telephone: 416 971-4494 Fax: 416 971-9844
http://www.cardinalgroup.ca/grhcc/index.html

Invasive Plant Species
B.C. Ministry of Agriculture, Food & Fisheries
Telephone 888-221-7141
For a list of invasive plants in B.C. see:
http://www.agf.gov.bc.ca/cropprot/invasiveplant.htm

LEED – Leadership in Energy & Environmental Design
U.S. Green Building Council
1015 18th Street NW, Suite 805, Washington, DC 20036
Telephone: 202 828-7422
leedinfo@usgbc.org

National Research Council of Canada
Dr. Karen Liu, Research Officer
Institute for Research in Construction
Building Envelope and Structure Program
1500 Montreal Road, Building M20
Ottawa, OntarioK1A 0R6
Telephone: 613 993-4584 Fax 613 954-5984
Email: karen.liu@nrc.ca

Pest Management Publications
Ministry of Water, Lands and Air Protection
PO Box 9342, Station Provincial Government
Victoria, B.C. V8W 9M1
http://www.gov.bc.ca/wlap

Rooftop Gardens Resource Group
C/o Monica Kuhn, Architect
14 Sackville Place, Toronto, Ontario M4X 1A4
Telephone: 416 923-9034

The Toronto and Region Conservation Authority
5 Shoreham Drive, Downsview, Ontario M3N 1S4
Ms. Angela Jonkman, Engineer Stormwater Management
Telephone: 416 661-6600
Email: info@trca.on.ca
Web site: http://www.trca.on.ca

8. HISTORY

Man's longing for nature is built into our genes."
E. O. Wilson

8.1 Ancient Roof Gardens

From time immemorial man has dreamt of the Garden of Eden and built gardens on the ground and on roofs. Roof gardens are known to have existed in ancient times. Records tell us of ziggurats planted with trees at every landing in the 2nd Century B.C.E. in Mesopotamia. The best known gardens are the hanging gardens of Babylon built by King Sennacherib of Assyria in the City of Ur about 700 B.C.E. They tell us of a most intricate system of mechanical irrigation, loading over columns and exotic plants for the enjoyment of all.

The art of roof gardens flourished in ancient Rome and the tradition continued in the Renaissance as evidenced by the terraced roof gardens designed by the of Count Borromeo III at Isola Bella in Lake Maggiore. This roof garden features plants on various terraces with fruit trees, flowers and clipped box hedges and it is still in existence today.

8.2 Early Modern Roof Gardens

Inspired by the past, roof gardens were developed in the 19th and 20th Century, such as:

Ralph Hancock & A. M. Vanden Hock, Landscape Architects.
Raymond Hood Architect 1933.
Rockefeller Center, New York.
Roof gardens on buildings along 5th Avenue.

Ralph Hancock Landscape Architect. 1938.
Derry and Toms, London.
One acre garden with mature horse chestnuts, walnuts, palms and maples.

Timothy Pflueger, 1942.
Redesign of the open space, April Philips & Michael Fotheringham, 2000.
Union Square, San Francisco.
The first plaza built over a parking garage.

8.3 Roof Gardens from 1950's to present

Osmundson & Staley, Landscape Architect, Welton Becket & Assoc., Architect 1960.
Kaiser Center, Oakland

1.2 hectare park over above ground parking with a large pond and plantings of magnolias, olives and maples.

Lawrence Halprin & Assoc., Landscape Architect, 1970.
Freeway Park, Seattle.

2.2 hectare inter-city park built over Interstate 5 physically and visually linking the neighbourhoods. Fountains mask the noise of the traffic

Cornelia Hahn Oberlander Landscape Architect, Arthur Erickson Architects. 1983 - 1989
Canadian Chancery, Washington, D.C.

Roof garden and hanging gardens

Raymond Moriyama Landscape Architect with Shunmyo Masuno, 1960.
Canadian Embassy in Tokyo, Canada.

Garden on 4th Level

8.4 Roof Gardens in Canada

Sasaki Dawson Demay, Boston & Arcop Architectural Group, Montreal. 1960's.
Renovated 1990's by Arbour, Berthiaume & Beauregard
Bonaventure Hilton International Hotel, Montreal.

I.M. Pei & Arcop Architectural Group. 1967.
Renovated 1990 by Sandra Donaldson, John MacLeod.
Place Ville Marie

Plaza over shopping mall and subway station.

Cornelia Hahn Oberlander Landscape Architect, Arthur Erickson Architects 1974 - 1982
Robson Square, Vancouver, B.C. The Provincial Government Complex.

An urban park atop a 3-block government building complex.

Theodore Osmundson and Assoc Landscape Architect, Architect: Rhone and Iredale, 1979
Kaiser Resources, Vancouver, B.C.
A roof garden on the 18th floor of a 20 storey building.

Cornelia Hahn Oberlander Landscape Architect, Downs/Archambault, Musson Cattell and Partners, Zeidler Roberts Partnership Architects, 1986
Canada Place, Canadian Pavilion, Expo 86
Roof planting based on plants recorded by Capt. George Vancouver.

Williams Asselin Ackaoui & Associates. 1986.
Place de la Cathedrale
Park located over underground garage.

Parent Latrelle & Associates. 1980's.
Maison Alcan
Alcan International headquarters roof garden.

Don Vaughn Ltd. Landscape Architect with Shunmyo Masuno, Douglas Cardinal Architect, 1995.
Canadian Museum of Civilization, Hull, Quebec
Traditional Japanese Zen Garden on Public Terrace Rooftop.

Cornelia Hahn Oberlander Landscape Architect. 1995.
Library Square, Vancouver.
www.greenroofs.com/north_american_cases.html

Terry McGlade and David Lieberman 2000.
Cresford Development Lofts, Toronto
The largest green roof on a multi-residential building in Canada, includes marshlands and prairie meadows.

City of Toronto/Green Roofs for Healthy Cities. 2001.
Toronto City Hall Green Roof Infrastructure Demonstration Project.
www.peck.ca/grhcc/overviewdemo.htm.

Center for Indigenous Environmental Resources Inc., Winnipeg. 2001.
Study on the Environmental and Stormwater Management Benefits of Green Roof Technologies.

Arbour, Berthiaume & Beauregard. 1997.
Centre Molson, Montreal.
Terraces built to incorporate the recycled Windsor train station at the new home of the Montreal Canadiens.

Cornelia Hahn Oberlander Landscape Architect. 2002
Vancouver General Hospital, Burn & Plastics Unit.
Therapeutic Roof Garden for patients, visitors and staff.