King County Green Roof Case Study Report

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Prepared for:

King County Department of Natural Resources & Parks

Prepared by:

Paladino & Company, Inc.

ACKNOWLEDGEMENTS

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Prepared by Paladino and Company, Inc.

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Green Roofs as a Sustainable Design Strategy

A green roof, also called an eco-roof, is a light-weight, vegetated roof over a protective root barrier and a roof membrane. Green roofs offer many features and benefits not present in a conventional membrane roof. First, the vegetation and soil layers protect the waterproof membrane from solar exposure, prolonging roof membrane life. Second, the soil provides additional insulation and shades the roof from solar heat gain. Third, green roofs create many environmental benefits, including stormwater filtration, heat island mitigation, improved air quality and increased wildlife habitat in urban spaces.

Green Roof Benefits

- *Mitigate Urban Heat Island Effect*
- *Reduce stormwater run-off*
- *Protect the roof membrane*
- *Added Roof Insulation*
- *Improved Air Quality*
- *Increases wild life habitat in urban spaces.*

Green roofs are a well established practice in Europe, but are still new in North America. The benefits of green roofs have not been fully explored and are not yet fully understood. Further study of green roof performance will facilitate the installation of green roofs as a viable sustainable design strategy.

Green Roofs in King County

In general, green roofs are applicable and feasible for commercial buildings in the Pacific Northwest. They are an emerging strategy with many local examples. However, this technology is highly interactive with other building systems and has created several design and maintenance challenges for the local design teams and building owners. To assist in successful application of the green roofs in King County, Paladino and Company has developed resources on cost and feasibility of green roofs in the past. However, detailed information on existing local projects was not available. Therefore this report looks at a set of green roof projects in and around the county to garner lessons for future projects.

Paladino and Company prepared a Green Roof Feasibility Review for King County in March 2004. The study investigated the feasibility of green roofs as a sustainable design strategy in King County and outlined green roof issues, benefits, costs and case studies for local, urban commercial projects. A copy of the study can be found at http://www.metrokc.gov/dnrp/swd/greenbuilding/documents/KCGreenRoofStudy_Final.pdf

Purpose & Scope

The purpose of this case study review is to assist King County in implementing green roofs on future projects. The recommendations in Section 3 of this report are based on the information obtained from the seven green roof projects studied, of which six are located in King County. Lessons learned and overall conclusions were incorporated into a set of design, installation and maintenance best practices.

Green Roof Case Studies

- ***Ballard Library***
- ***City Hall***
- ***Dexter Regulator Station***
- ***Henderson Regulator Station***
- ***Justice Center***
- ***King County International Airport***
- ***Seminar II, Evergreen State College***

This study provides detailed information on the green roof design, specifications, installation and maintenance procedures for each case study. Paladino researchers conducted site visits to evaluate the condition of existing green roofs and interviewed the design team and maintenance staff to get first-hand experience from other projects. This report includes the challenges faced by both successful and unsuccessful green roof projects. There are important lessons that each of these projects give for future green roof projects in King County.

This report is not intended as a comprehensive design guideline but as a set of practical recommendations based on local examples.

Ballard Public Library, *Seattle, WA*

Ballard Public Library

Paladino Site Visit in September '05 with the Architect and the Maintenance Staff

The plants after 6 months of installation

About the Project

The Ballard branch of the Seattle Public Library exhibits a number of sustainable design strategies such as daylighting, building integrated photovoltaics, operable windows and recycled materials. One of the key features is the 18, 000 sq.ft green roof planted with low-water use plants. Visitors can view the planted green roof from an interior stairwell.

Green Roof Design

The green roof system was installed to reduce stormwater runoff and includes the means to monitor quantity and quality of stormwater runoff. However, monitoring of run off water quality or quantity is not currently underway. A variety of drought-tolerant plants were established in random patterns. The concept was to mimic the natural process of seeds-spread by prevailing breezes. The plants that can adapt to the microclimate will survive and spreadout in other areas.

The roof structure is parabolic in shape and a drip irrigation system was installed only on the area of roof with southern exposure. The plants were selected such that some may go dormant during the summer but will rejuvenate with the winter rains. A biodegradable coconut fiber mat was installed on top of the 4-inch thick soil to prevent soil erosion.

Green Roof Characteristics

Existing Roof/ New Roof	New Roof
Green Roof Area	18,000 square feet
Green Roof Type	Extensive
Green Roof System	Garden Roof Assembly™
Accessibility	Maintenance only
Installation season	March
Establishment Period	Six months
Slope of existing Roof	Parabolic Roof
Green Roof Slope	varies
Soil Mix/ depth	4 inches
Plant Type	Drought tolerant plants
Irrigation	Yes
Structural Load	50 lbs/sqft

Current Status

The green roof was installed in March 2005, and is currently in the establishment phase. Different types of grasses and sedums have been planted in patches. Most plants have done well; the sedums are more hardy and are in the best condition. The irrigation system is

Green Roof Design Team

Architect
- *Bohlin Cywinski Jackson*

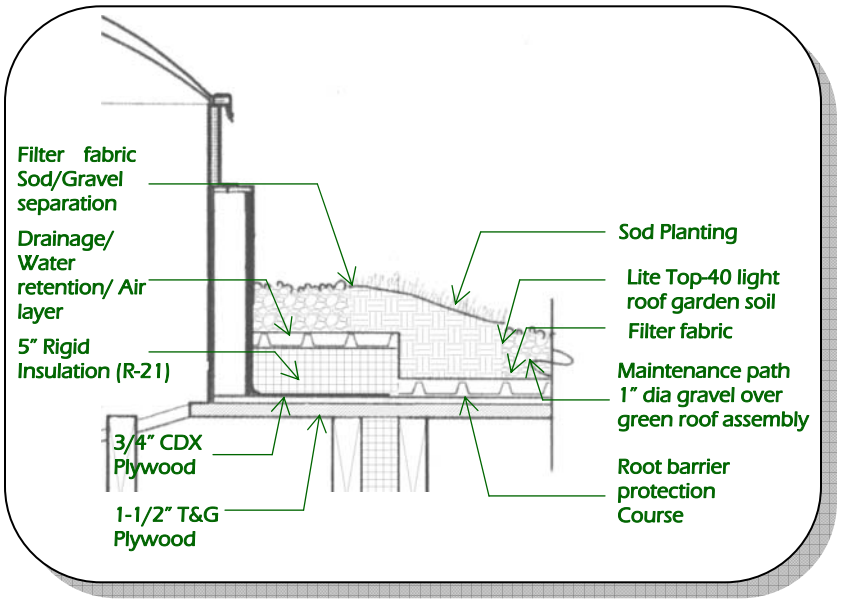
Landscape Architect
- *Swift & Co.*

Contractor
- *PCL Construction Services Inc.*

Green Roof Consultant
- *Hydrotech Inc.*

based on gravity flow and is inadequate at certain places resulting in drying in those patches. However, the roof overall appears to be on target for establishment.

Green Roof Cross Section & Details



Membrane Base

100% solids, hot, fluid–applied, rubberized asphalt membrane, 5.5 mm (2.3 mm asphalt membrane, layer of spun-bounded polyester fabric reinforcing sheet, 3.2 mm of monolithic asphalt membrane) containing no PVC's and with inert clay filler for acid resistance.

Root barrier/ protection course

Fiberglass reinforced, rubberized asphalt sheet and polyethylene root barrier.

Rigid Insulation

STYROFOAM Plazamate brand plaza deck insulation that has a minimum compressive strength of 60psi, water absorption by volume 0.1%, insulation minimum of R-21 and CFC-free.

Drainage/water retention/air layer

The drainage and water retention layer is Floradrain FD 40- three dimensional, molded panels of recycled material with drainage channels top and bottom sides and water retention reservoirs top side. The air layer is composed of crush-proof core and non-woven filter fabric.

Filter fabric

Systemfilter SF non-woven, polymeric, geo-textile fabric

Plant List

Native Plants

- *Achillea tomentosa Hardiness Zones: 3 to 8/ Low growing mat*
- *Armeria Maritima Hardiness Zones: 4 to 8/ Tufts or clumps; rounded mat*
- *Carex inops Hardiness Zones: 6 to 9*
- *Festuca rubra - Hardiness Zones: 4 to 9/ Singular dense clumps*
- *Phlox subulata - Hardiness Zones: 3 to 9 /Dense, creeping carpet*
- *Sedum oreganum*
- *Sedum album Hardiness Zones: 4 to 9/ Form: Low mat*
- *Sedum spurium - Hardiness Zones: 3 to 8*
- *Thymus serphyllum - Hardiness Zones: 4 to 9/ Form: Low, dense mat; sprawls haphazardly*

Non-Native Plants

- *Eriphyllum lanatum*
- *Festuca idahoensis*
- *Saxifrage cespitosa*
- *Sisyrinchium idahoensis*
- *Triteleia hyacintha – hardiness 4*

Soil Mix

3/8" diameter mineral component: 45%, coarse sand: 15%, approved aged organic component: 40% plus fertilizers and amendments. Each component of the soil mix was specified in detail in the project specifications.

Plants & Nutrients

Low- to no-maintenance landscaping with plant varieties restricted to primarily sedums, mosses, herbs and grasses capable of withstanding harsh growing conditions.

Fertilizers

3 pounds gypsum/ 2 pounds iron sulphate/ 0.5 pound dry polymeric soil/ 1 pound ureaform/ 0.33 pounds potassium sulphate/ 0.33 single superphosphate per cubic yard of soil mix was specified. Although fertilizers were specified for this project, they are currently not being used. No fertilizers are being used as the City has strict rules about nitrogen going down the drains and requires regular testing of stormwater runoff if fertilizers are used. However, the plants may require some fertilization in the future.

Irrigation & Maintenance Procedures

The roof planting will be maintained at a height of 9 to 12". The roof will require some regular maintenance such as occasional trimming of plants andweeds removal.

The current irrigation schedule is 45 minutes of drip irrigation every other day on the southern side. The initial design intent was to let the plants go dormant during summers.

Challenges

- The initial establishment of the green roofs was a challenge because the vegetation attracted birds that pulled out the small plants. However, now the plants have stronger roots and birds are no longer a problem.
- Weeds are a persisting problem, especially creeping types which interweave with the coconut fiber bedding. To extract the weeds the netting has to be cut out and replaced.
- During the establishment period truckloads of weeds had to be removed. The initial maintenance required has been more than what was anticipated and it was a challenge to transfer the weeds from the roof for disposal.

Seattle City Hall, *Seattle, WA*

About the Project

City Hall Green Roof

City Hall Green Roof in September 2004

The Seattle City Hall achieved a Gold LEED™ rating from the US Green Building Council. The City Hall building is divided into two components: Council Chambers and Mayor/Council/Staff offices. The green roof on the building surrounds the Council Chamber portion of the building. Although it is not accessible, it can be viewed from the elevator lobbies of floors 3 through 7.

Seattle contains urban habitat of endangered wild salmon species, and so innovative stormwater management practices are considered to be a component of "salmon-friendly" design. The City Hall green roof was designed to decrease combined sewer overflows, decrease peak flows, and improve stormwater runoff water quality. Another ecological function of the green roof is the reduction of solar and heat reflection on the adjacent taller wall of the building's north portion.

Green Roof Design

The 13,200 sq.ft. roof is planted with 5,600 pots of sedums, including varieties such as Frosty Morn, John Creech, and Sedum reflexum and 8,400 pots of fescue and 8,400 pots of June Grass. The runoff from the roof goes into a 30,000 cubic foot rainwater collection cistern. This water is then used for toilet flushing and irrigation of other landscaping.

Green Roof Design Team

Owner
- *City of Seattle*

Architect
- *Bohlin Cywinski Jackson & Bassetti Architects*

Landscape Architect
- *Gustafson Guthrie Nichols*

Contractor
- *Snyder Roofing, Northwest Landscape*

Structural Engineer
- *KPFF Consulting Engineers*

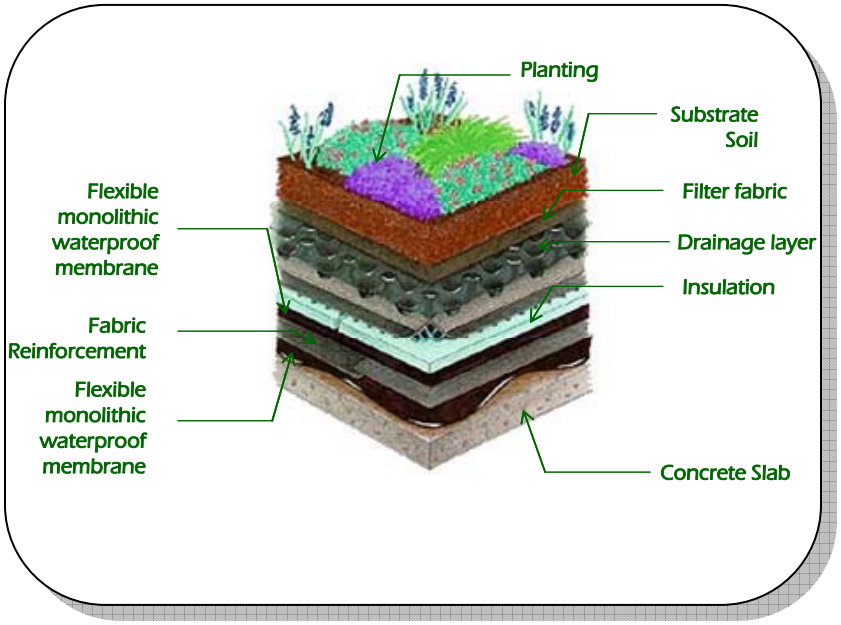
Green Roof Characteristics

Existing Roof/ New Roof	New Roof
Green Roof Area	13,200 square feet
Green Roof Type	Extensive
Green Roof System	American Hydrotech Inc.
Accessibility	Maintenance only
Installation season	Fall 2003
Establishment Period	Six months
Slope of existing Roof	Flat
Soil Mix/ depth	6 inches
Plant Type	Drought tolerant plants
Irrigation	Yes
Structural Load	50 lbs/sq.ft
Cost	$2/sqft

Current Status

The green roof was installed in July 2003 and has been successful since then. Weeds have been a persistent and have required a lot of maintenance staff time. However, it is expected that once the plants are established, the weeds will not have enough room to grow.

Green Roof Cross Section & Details



Plant List

- *Festuca brachyphylla / Pt. Joe Fescue*
- *Koeleria macranthe 'Barkol' / June Grass*
- *Sedum reflexum*
- *Sedum spectabile 'Frosty Morn'*
- *Sedum spurium 'John Creech'*
- *Sedum 'Vera Jamieson'*

Membrane Base

Hot fluid–applied rubberized asphalt membrane, layer of spun-bounded polyester fabric reinforcing sheet, 60 mm thick uncured neoprene flashing.

Root barrier/ protection course

A polyethylene sheet, Root Stop WSF40, was rolled out over the assembly as a root barrier. Over the root barrier, STYROFOAM closed cell, extruded polystyrene was applied to provide the required thermal value.

Rigid Insulation

Extruded polystyrene rigid foam insulation board, compressive strength of 60 psi max., water absorption by volume 0.1%, R-5 per inch and free of HCFC blowing agents.

Water Retention/Drainage Panel

Three-dimensional, 100% recycled polyethylene providing water storage, drainage, and aeration for soil substrate with non-woven polymeric geotextile fabric, minimum 0.40 gallons per square foot water containment.

Filter fabric

Systemfilter SF non-woven, polymeric, geotextile fabric

Soil mix

The engineered soil mix used for the City Hall garden roof included pumice, sand, compost and nutrients.

Irrigation & Maintenance Procedures

The current irrigation schedule is once a week for 45 minutes during summer. The irrigation system designed for the project landscape was not adequate to support the plants during the establishment period. This system was later supplemented with more sprinkler heads for adequate watering of plants.

The water from the green roof goes into a storage tank and is reused for toilet flushing. Therefore no fertilizers are being used in order to prevent water contamination.

Because of the large amount of weeds growing on the roof, regular maintenance is required. The weeds are wind blown or dropped by birds. Several weeds such as clover leaf, dandelion and black berries are pervasive on the roof. This summer 50 to 60% of the roof was covered with leaf clovers. Clovers can smother other plants causing them to rot and die.

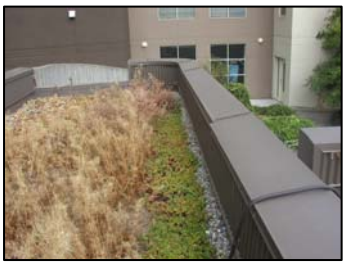
Challenges

- The maintenance staff had to pull out about 70 garbage bags of weeds this summer and spring.
- No operations and maintenance manual exists that describes the maintenance and irrigation requirements for the roof.
- The maintenance staff time varies from 12 to 15 hours a week for the green roof on this project.
- The intent was to irrigate the roof for just the first year. However, certain plant types, such as Blue Fescue, require irrigation in the summers or else they turn brown. These plants spring up again with the rain, however. The building visitors and users complain about the aesthetics of the roof if the roof is brown.
- Access to the roof is through a small room that has a vertical ladder and a hatch on top that opens onto the roof. It is very difficult for the maintenance staff to carry tools and weeds through this access. The gardener had to retrofit a pulley to take things up and down.
- The project was designed to collect rainwater from the roof and reuse it for flushing toilets. However, the water from the conventional roof and the green roof go to a single drain and the water is yellow in color because of the green roof soil. This discolored water resulted in a lot of complaints from the building occupants.

Dexter Regulator Station, Seattle, WA

Green Roof Establishment in June 2002

Green Roof in September 2002



Paladino site visit in Sept' 05

About the Project

The Dexter Regulator Station is an industrial facility that is part of King County's combined sewer overflow control system. The Wastewater Treatment Division has made significant efforts to educate project managers and support green building in their Division. When they replaced the existing Dexter Regulator Station roof in 2002, they chose a green roof.

Green Roof Design

The Project Manager at King County implemented a green roof strategy as an environmental strategy and to provide an acceptable view to the residents of the condominiums around the building.

Green Roof Characteristics

The green roof was constructed and planted in June 2002. The design, specification and construction supervision of the green roof was done by the King County Local Public Agency inspector.

Existing Roof/ New Roof	Existing Roof
Green Roof Area	128 sq.ft.
Green Roof Type	Extensive
Green Roof System	In-Situ, Design Build Project
Accessibility	Maintenance only
Installation season	June 2002
Establishment Period	Six months
Slope of existing Roof	Flat Roof
Soil Mix/ depth	5 inches
Plant Type	Sedums, Native Plants
Irrigation System	Yes, during establishment
Structural Load	40lbs/sqft

Current Status

The majority of plant material has died. Weeds are now more prevalent than the original species installed. The roof drain is completely clogged. Ivy from the adjoining structure has spread on the green roof damaging the metal flashing. One small area of plantings seems to be thriving. This area is a thin strip of sedums located near the edge of the parapet and is in shade. No fertilizer is used, but a combination of compost and pumice was included in the soil mixture.

The green roof thrived for a year before the plants died. During the establishment period the roof was regularly hand watered and the weeds were removed.

Green Roof Design Team

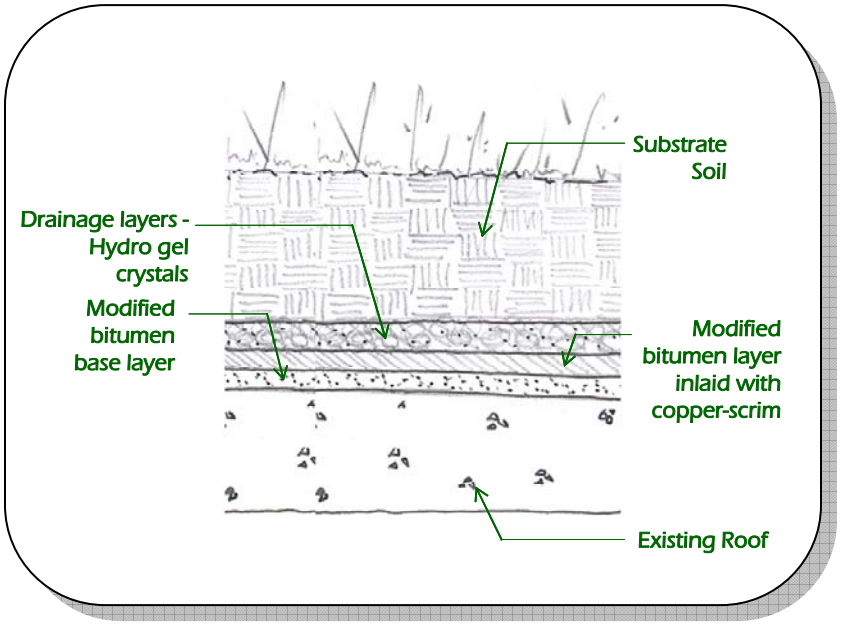
Project Manager

- ***Susan J. Michaud King County Wastewater Treatment Division , Local Public Agency Inspector***

Green Roof Cross Section & Details

Plant List

- *Sedum –Spurium Carneum – Z 5*
- *Middendorfflenum var. Diffusum/ - Z4*
- *Hispariam var. hisparicum – Z6*
- *Spath.ssp. pruinosum carnea – Z6*
- *Album Laconicum – Z4*
- *Sexangulare Z4*
- *Hybridum Immergrunchen Z4*
- *Album Z5*
- *Album France Z4*
- *Rupstre creetum – Z1*



Base Specifications

Base membrane ply: Torch-applied modified bitumen base layer (PIKA Ply GR-4) of 4mm thickness.

Top membrane ply: Torch-applied modified bitumen top layer (PIKA Ply GR/RC -4) inlayed with a non-woven polyester and copper scrim film for root resistance.

Water Retention & Drainage

Factory-adhered non-woven polyester fleece containing hydro gel crystals and adhered to the top membrane ply. The fleece is adhered to the membrane in a manner that forms a grid. Within each grid square lie hydro gel crystals. As the hydro-gel crystals expand, drainage channels form between the spaces.

Soil Mix/ Soil Depth

Soil depth of 5" with the weight of saturated, moderately compacted soil not more than 40 psf; the soil mixture consists of 30% Sandy Loam, 15% Compost – yard Debris, 20% Perlite – Coarse, 205 Pumice- Screened, 15% coir.

Irrigation & Maintenance Procedures

The roof was irrigated only during establishment by means of a water hose; no irrigation was provided after establishment.

Challenges

- Initially the project had staff available to perform regular maintenance procedures such as removing weeds and watering plants during the dry season. However, later no maintenance staff personnel were assigned the responsibility of regular maintenance required by green roofs. This resulted in the roof being unsuccessful.

Henderson Station, *Seattle, WA*

Green Roof at Henderson Pump Station

Paladino Site Visit in September 2005

3″ compacted depth of fine grade bark mulch

Green Roof Design Team

Architect
- *Streeter & Associates*

Landscape Architect
- *SvR Design Company*

About the Project

The King County Henderson Pump Station is located on the southwest corner of Seward Park Avenue South and South Henderson Street. In early 2002, a two-year construction effort was initiated to expand the pump station. Expansion, which occurred primarily underground, doubled the capacity of the original structure that was built in 1974. Several sustainable design strategies such as a green roof, recycling, pervious paving and recycled materials were incorporated as a part of the project.

Green Roof Design

The design intent of the green roof was to reduce runoff, and create an aesthetically pleasing roof that ties in with vegetation on the hillside. This project is one of the few projects in the region that have an intensive green roof. Plantings include small trees and shrubs. The Vine Maples will grow up to a 12′ height. Most of the shrubs will be 5′ high and some will be up to 3′ high.

Green Roof Characteristics

The green roof was constructed and planted in August, 2005.

Existing Roof/ New Roof	New Roof
Green Roof Area	1500 sq.ft.
Green Roof Type	Intensive
Green Roof System	In-Situ, Design Build Project
Accessibility	Accessible
Installation season	August 05
Establishment Period	Ongoing
Slope of existing Roof	Flat Roof
Soil Mix/ depth	24 inches
Plant Type	Shrubs
Irrigation System	Yes

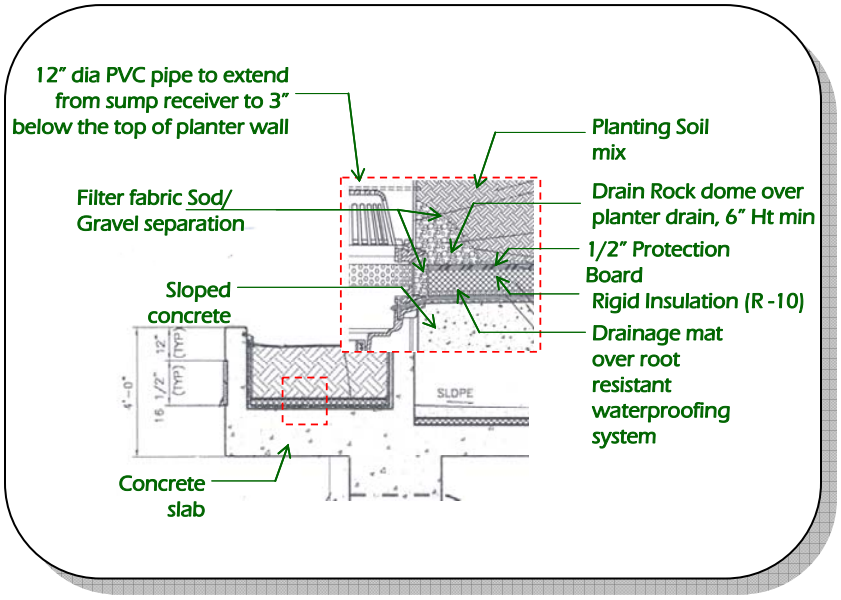
Current Status

The green roof is in the establishment phase. A permanent irrigation system is in place for watering the plants. The plants seem to be growing well. The landscape architect was not involved with the membrane selection and they elected to perform a 48-hour roof ponding test was done to confirm the absence of any leaks.

Green Roof Cross Section & Details

Plant List

- *Pyrus calleryana redspire/ redspire pear – Zone 5 to 8*
- *Acer circinatum/ vine maple – Zone 6a to 9b*
- *Pseudotsuga menziesii/ Douglas fir – Zone 4 to 6*
- *Thuja plicata/ western red cedar – Zone 5 to 9*
- *Cornus stolonfera/ red-osier dogwood – Zone 2 to 7*
- *Cotoneaster microphyllus/ rockspray cotoneaster –Zone 6 to 8*
- *Polystichum munitum/ sword fern – Zone 3*
- *Ribes sanguineum/ red flowering currant – Zone 5 to 8*
- *Mahonia aquifolium/ Oregon grape – Zone 4 to 8*
- *Vaccinium ovatum/ evergreen huckleberry – Zone 7 to 9*
- *Arctostaphylos uva-ursi/ kinnikinnick – Zone 2b*
- *Gaultheria shallon/ salal – Zone 6 to 8*



Base Specifications
Water proof membrane: 328 mils, two layer torch-applied modified bitumen assembly.
Torch-applied modified bitumen base layer: 160mil, Eco-base-4, APAO modified bitumen sheet, W.P. Hickman Systems Inc.
Torch-applied modified bitumen top layer: EcoPly C-4, APAO root resistant modified bitumen sheet, inlaid with a non-woven polyester and copper film, W.P. Hickman Systems Inc., Solon, OH.

Water Retention & Drainage
Prefabricated drainage panels designed to retain soil while allowing water to collect and pass through its core.

Rigid Insulation
Extruded polystyrene board

Protection Board
½ inch asphalt-impregnated Celotex Insulation board.

Soil Mix/ Soil Depth
Specified by Garland Inc. (proprietary information)

Irrigation and Maintenance Procedures

A permanent irrigation system is in place for this roof. The roof will be irrigated in July, August and the first half of September for 12 minutes a day, 5 days a week.

Challenges

- One eighth of the plants died during the establishment period. The majority of these plants was Evergreen huckleberry and had to be replaced by the contractor. The reasons for the plants not working well was not determined by the design team.

Justice Center, *Seattle, WA*

Justice Center Green Roof

About the Project

The Seattle Justice Center achieved a Silver LEED™ rating from the U.S. Green Building Council. The Seattle Justice Center has two major components: the Police Headquarters, and the Municipal Courts. The green roof is located on the top floor of the Municipal Courts portion of the building, adjacent to the Jury waiting rooms. This accessible roof garden provides a welcome respite for citizens serving jury duty, and includes a partially covered roof deck. The runoff overflow from the Justice Center green roof is collected in the stormwater retention system. This system has been oversized to perform both stormwater management and to store water for irrigation of landscaping in the plaza on the entry level of the building.

Green Roof Design

The landscape concept for the Justice Center green roof complements the water-themed design concept incorporated into the new three-block downtown civic campus plaza. The landscape design for the Justice Center garden roof is naturalistic, with varying textures in the groundcover and accents of sheep fescue.

Green Roof Characteristics

Existing Roof/ New Roof	New Roof
Green Roof Area	7,300 square feet
Green Roof Type	Extensive
Green Roof System	American Hydrotech Inc.
Accessibility	Visitors
Installation season	Jul-04
Establishment Period	One Year
Green Roof Slope	Flat
Soil Mix/ depth	6 inches
Plant Type	mostly native plants
Irrigation	Yes, establishment only
Structural Load	50 lbs/sq.ft, saturated
Cost	$19.25 per sq.ft.

Current Status

The green roof was installed in mid-summer 2004. The roof is green and the plants are thriving. About one third of the plants had to be replaced in the establishment period. The initial design intent was to irrigate the plants during the establishment period only. However, the system was retrofitted later for ongoing summer irrigation.

Green Roof Design Team

Owner
- *City of Seattle*

Architect
- *NBBJ Architects*

Landscape Architect
- *SvR Design Company*

General Contractor
- *Hoffman Construction*

Roofing Contractor
- *Synder Roofing, Krueger Sheet Metal and Roofing*

Structural Engineer
- *Magnusson Klemencic Engineer*

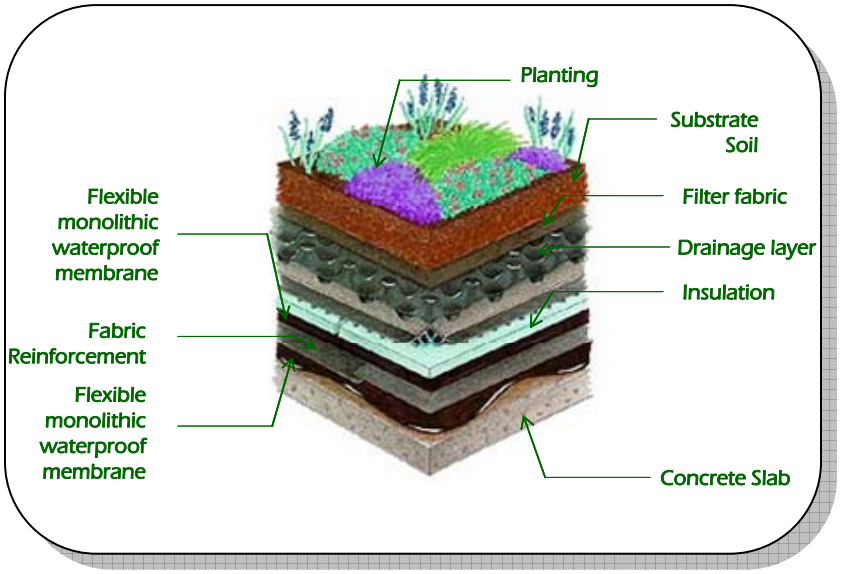
Green Roof Consultant
- *SvR Design Company*

Plant Supplier
- *Northwest Landscaping*

Plants

- *Ajuga reptans 'Purpurea' / Carpet Bugle*
- *Cotoneaster dammeri / Bearberry Cotoneaster*
- *Potentilla Verna 'Nana' / Potentilla*
- *Arctostaphylos uva-ursi 'Pt. Reyes' / Pt. Reyes Creeper*
- *Waldsteinia fragarioides / Barren Strawberry*
- *Festuca ovina 'Glauca' / Sheep Fescue*
- *Thymus pseudolanuginosus / Woolly Thyme*
- *Thymus praecox 'Articus' / Creeping Thyme*
- *Sedum album / Stonecrop*
- *Delosperma nubigenus / Ice Plant*
- *Hebe "Quicksilver' / Quicksilver Hebe*
- *Sedum lydium / Stonecrop*
- *Thymus citriodorus / Lemon Thyme*

Green Roof Cross Section & Details



Base Specifications

Water proof membrane: 328 mils, two layer torch-applied modified bitumen assembly.
Torch-applied modified bitumen base layer: 160mil, Eco-base-4, APAO modified bitumen sheet, W.P. Hickman Systems Inc.
Torch-applied modified bitumen top layer: EcoPly C-4, APAO root resistant modified bitumen sheet, inlaid with a non-woven polyester and copper film, W.P. Hickman Systems Inc., Solon, OH.

Soil Mix/ Soil Depth

Custom mixture of nitrolized pine bark, sand, pumice, nutrients and peat

Water Retention / Drainage

Floradrain 40, lightweight panels made of 100% recycled polyethylene molded into specially designed retention cups and drainage channels

Filter Fabric

A geotextile filter sheet, Systemfilter SF, was unrolled over the entire drainage/water storage/aeration layer. The filter sheet, made of non-woven polypropylene fibers, helps prevent the loss of soil, mulch and plant debris while allowing for the flow of moisture.

Plants & Nutrients

Many of the plants used for the Justice Center roof are native to the area, such as Point Reyes Creeper and Barren Strawberry. Fertilizer use was specified only during installation.

Irrigation & Maintenance Procedures

Currently the irrigation schedule is two times a week for 20 to 30 minutes during summer. No fertilizers are being used now. Weeds are a problem but as the plants become more established the weeds have fewer places for growing. According to the maintenance staff this roof appears to have fewer weeds than usual. It may be that the elevation of the roof and location of adjacent buildings minimizes weed dispersal by the birds and winds. Some of the staff maintenance time required for this roof goes to pulling weeds.

Challenges

- The plants were scheduled to be planted in May 2002 initially. However, there were delays in the construction schedule and the roof was installed in September. The plants were off-site during this time and the delay made them root bound. After these root bound plants are planted on the Justice Center roof, it was easy for the birds to pull out the plants because their roots were not spread out when they were installed.
- The soil mix contained bark. Bark should usually be used only as mulch and not mixed into the soil because the bark breaks down with time and uses up the nitrogen in the soil, competing with plant roots for existing nutrients. To correct this problem 2 to 3 inches (15 cubic yards) of compost was added on top of the soil to enrich it.
- Inadequate irrigation and soil mix composition resulted in replanting of about one third of the 5,000 to 6,000 existing plants on the roof.
- The original design intent was to have no permanent irrigation system and to have a temporary system of hose bibs that would irrigate from the bottom. However, the summer after the roof was installed was very dry and plants needed to be watered. Several plants did not survive and therefore the hose bibs were retrofitted in shallow trenches to allow automatic irrigation. Later a pop-up irrigation system that operates on a timer was installed.

King County International Airport, *Seattle, WA*

King County International Airport

Paladino site visit in June 05

Soil depth less than an inch

About the Project

The historic Main Passenger Terminal Building at King County International Airport reopened after restoration in July 2003. Renovation of the 1930 brick structure included restoring the historic art deco building, meeting new security standards; complying with the Americans with Disabilities Act (ADA), completing a seismic retrofit, installing a state-of-the-art fire alarm system, and increasing energy efficiency with new mechanical, electrical and lighting systems. A unique feature of the renovation is the new green roof atop the existing terminal building.

Green Roof Design

During renovation of the Main Terminal Building at the King County Airport in 2003 a green roof was installed above the existing roof structure as one of the sustainability measures for the building. It was projected that the green roof would provide multiple benefits: extend the life of the roofing membrane, reduce stormwater runoff, increase insulation, reduce sound transmission and reduce the heat island effect (heat absorption and re-radiation).

Green Roof Characteristics

Existing Roof/ New Roof	Existing Roof
Green Roof Area	8,000 sqft.
Green Roof Type	Extensive
Green Roof System	In-Situ
Accessibility	Maintenance only
Installation season	September
Establishment Period	Six months
Slope of existing Roof	Flat Roof
Green Roof Slope	1/4″ per foot
Soil Mix/ depth	1.5 inches
Plant Type	Rye grass/ Lawn
Irrigation System	No

Current Status

The green roof was a design-build project planted in September, 2003. Most of the green roof plantings have died; some weeds are alive in patches; some areas show limited growth. One small area of plantings seems to be thriving. This area is a thin strip of grasses located underneath an existing HVAC pipe (2″ diameter) that apparently is dripping condensation onto the ground and supporting the plant growth.

Green Roof Design Team

Architect
- *SERA Architects Inc.*

Landscape Architect
- *Northwest Landscape Co.*

Contractor
- *Berschauer Phillips Construction Company*

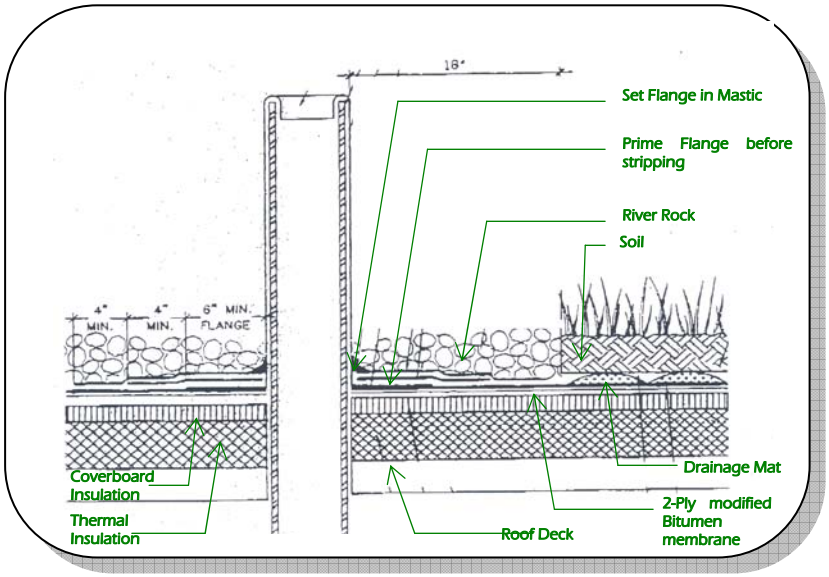
Green Roof covered with weeds and moss

Plants

- ***Low-Grow Barclay: Lawn***

The plant failure happened several months after the roof was installed. The plants died in circular patches that grew larger until all plantings died. Currently, no remediation measures are being implemented and the majority of plants are dead.

Green Roof Cross Section & Details



Base Specifications
Membrane base ply: Ecobase-4, APAO modified bitumen sheet (160 mils)
Membrane top ply: Ecoply RC-4, root-resistant, APAP modified bitumen sheet with moisture retaining gel pack.

Soil Mix/ Soil Depth
Pacific Topsoils, 3-way Topsoil composition: 60% Loam Soil, 20-30% Composted Mulch, 10-15% peat. Soil depth was limited to 2" to keep deadweight on roof within the specified 12 lbs/ sq.ft.

Drainage
1.5" drain rock around (not under) the green roof areas.

Plants & Nutrients
70% Barclay perennial Ryegrass, 20% Illahee Red Fescue, 10% Hard Fescue

Fertilizers
The fertilizer package: limestone flour, dolomite lime, ferrous sulfate, potassium nitrate, boron, copper, iron, molybdenum, zinc.

Irrigation & Maintenance Procedures

Plants were manually watered every day during warm weather. The initial intent was that no irrigation would be required after the establishment period. However, the plants selected required regular watering. Mowing was required when the green roof was thriving. The grass has died and the roof is covered with weeds and moss and is not being maintained.

Challenges

Many conditions at the King County Airport combined to make this a challenging green roof installation.

- It was an existing building with a minimal roof slope that could accommodate relatively low additional weight for the soil substrate and plantings (12 lb/sq.ft. combined).
- The inspection on May 25, 2005, indicated a settled depth of 1-1.5". The existing 1-1.5" of soil is minimal for supporting plant growth while providing good drainage and not drying out during summer months. Many installers recommend a minimum of 2" settled depth.
- The FAA was required to approve the planting mix because of concerns about attracting birds adjacent to the airstrip. This left the design team with limited options. The plants chosen from the approved list required regular watering and were not compatible with the soil mix specified. The approved list included low water use plants. However, it was a public project with a limited budget and the plant selection was driven by this.
- When the green roof failed several lab tests were done and the test reports recommended:
    - Avoid excess nitrogen and water
    - Provide adequate drainage or use soil mix containing 50-60% sand.
    - Increase oxygen levels in the root zone by coring and closely monitoring irrigation
    - Conduct a nutrient analysis of soil to identify correct fertilizer
    - Treat the area with disease by applying fungicides OR Remove soil and replace with soils that have been certified free of these pathogens And/Or
    - Replace plants with plantings that are not susceptible to the se pathogens (e.g. Sedums)

However, measures recommended in the test reports were not implemented.

- The owner wanted low maintenance and low growth planting that could thrive in full sun and partial shade. However, the Barclay Perennial Ryegrass was selected as it was the cheaper alternative to install.

Seminar II, Evergreen State College, *Olympia, WA*

About the Project

Seminar II Green Roof

Seminar II Green Roof

Evergreen State College is a post-secondary educational institution in Olympia, Washington. Seminar II is the first major academic building to be constructed on the campus that is designed specifically around the college's interdisciplinary teaching philosophy and commitment to environmental advocacy.

The project demonstrates several green building technologies and is a learning and demonstration tool for the faculty and students. Sustainability measures included in the project are waterless urinals, low-flow toilets, native plants, natural ventilation, daylighting and local materials. Exterior sunshades coupled with operable windows, fan-assisted night flushing, and exposed interior concrete mass have been incorporated to achieve summer cooling.

Green Roof Design

The project features an impressive 20,443 square foot green roof built on 13 separate roof areas. It was designed to encourage student interaction and be a visual representation of the sustainable approach to designing and building the entire facility. This green roof project was designed to integrate with the operation of the building and its occupants.

The green roof was intended to increase the life of the roof and reduce the size of stormwater retention ponds required for this project. All rainwater that filters through the green roof system will overflow into a 20,000 gallon reservoir tank designed to slowly release water back to the environment.

Plants were specifically chosen for the full sun and partial shade exposures of different sections of roof.

Green Roof Design Team

Owner
- *Evergreen State College*

Architect
- *Mahlum Architects*

Landscape Architect
- *Murase Associates*

General Contractor
- *DPR Construction*

Roofing Contractor
- *Wayne's Roofing*

Landscape Contractor
- *Magnusson Klemencic Engineer*

Green Roof Consultant
- *Northwest Landscape*

Plant Supplier
- *The Garland Co., Inc.*

Green Roof Characteristics

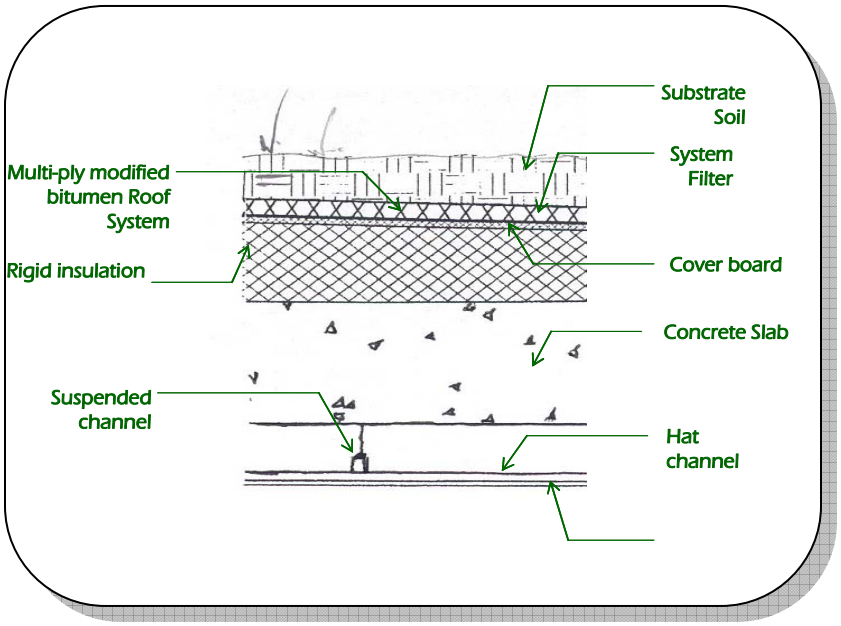
The project was completed in November 2003.

Existing Roof/ New Roof	New Roof
Green Roof Area	20,443 square feet
Green Roof Type	Extensive
Green Roof System	Garland Inc.
Accessibility	Building Occupants
Installation season	Fall 2004
Green Roof Slope	Flat
Soil Mix/ depth	4 to 6 inches
Plant Type	sedums & flowering species
Irrigation	Yes, establishment only
Structural Load	22.5 lbs/sq.ft, saturated
Cost	$18 per sq.ft.

Current Status

Although a site visit was not possible at the time of this report, the green roof appears to be performing as intended.

Green Roof Cross Section & Details



Base Specifications

Membrane base ply: Root barrier - Bitumen Compatible, Construction Grade 8 mil – thick polyethylene; Drainage and Filter Top ply: Akzo Nobel – engineered geo-textile drainage fabric with integrated filtration membrane.

Soil Mix/ Soil Depth

Custom-mixed soil less substrate of coarse aggregate material and organic components (15% – 20%); A soil depth of 6" was provided to keep the deadweight on roof within the specified 45 pounds/cu.ft.

Plants & Nutrients

10% native grass, 30% sedums and 60% annuals/perennials; 70% were grown on transplantable mats (cultivated as 1 X 1 m square mats) and 30% were transplanted individually. For color in winter, some evergreen semi-green species were included. A maximum of five species for each genus were specified.

Irrigation & Maintenance Procedures

A soaker hose irrigation system was provided, for use during the first three months and for extreme drought conditions. During the establishment period the roof was irrigated for 30 minutes, twice a

day. Currently the roof is irrigated 30 minutes every day during summer months and alternate days in September and October.

Custom-blend fertilizer from Garland Company was applied for the first three months. The vegetation on the roof is maintained at 1″ to 12″ height. The gardener has to pull out weeds once every month for maintenance.

Challenges

Evergreen maintenance staff were unavailable at the time of this study, however it appears that regular maintenance (monthly weed removal) is required.

Recommendations for King County Green Roofs

The case study examples documented in Section 2 provide useful insights for the design and installation of green roofs. The green roof projects studied varied in size, function, roof type and construction; however the composite of all the projects creates a bigger picture from which some initial conclusions can be drawn. The lessons learned from these case studies have been incorporated in to the following categories:

- Design Recommendations
- Installation Recommendations
- Maintenance Recommendations

Design Recommendations

Feasibility Study

A structural feasibility study should be done to ensure that a green roof strategy can be implemented on an existing building roof that may have structural load limitations. The roof structure must be capable of accommodating the industry recommended minimum soil depth of 2" (saturated weight).

Coordination of Design Team Members

Design of green roofs requires coordination of several design team members such as the architect, roofing contractor, landscape designer, horticulture specialist and/or product manufacturer. The successfully implemented green roof case studies demonstrate input from several members of the design team.

Prior Experience on Green Roof Projects

It is recommended that the design team include at least one member with prior experience with green roof projects so that well-informed decisions are made. The most successful green roof case study projects documented in this report had design team members who had prior experience on green roof projects.

Aesthetics & Dormant Cycling

Often these eco-roofs are designed such that no irrigation should be required after the establishment period. However, there may be some plants specified that become dormant during the summer season and spring up again later. It is important to educate the building occupants as well as the maintenance staff about the benefits of the green roof that are not compromised by a temporary dormancy of some plant species or select for year-round aesthetics for projects where this is a concern.

Compatibility of Green Roof Components

Successful implementation of green roofs require that the building structure can support the green roof, plants selected should be suitable to the climate type, the soil mix specified is compatible with the plants selected and the irrigation system provided is adequate to water the plants. The case studies indicate that the common challenges that required remediation measures for green roofs included inappropriate plant selection, inadequate irrigation or compatibility issues between the soil mix and plants specified.

Accessibility for Maintenance

Easy access for maintenance of green roofs should be provided in the building. The maintenance staff often encounters difficulty in maintaining the roofs especially when the roofs are not designed for building occupant access. Weeds are a persistent problem, especially during the establishment period. It is a problem to dispose of the weeds if the roof does not have an easy access.

Irrigation System

Most of the green roof case studies had provided an irrigation system for use during the establishment period only. However, in almost all of the case studies it was found that the plants specified required more water than what the irrigation system was designed for. Also, continued irrigation of plants is being done on most projects during the summer months. It is important to specify plants that are drought-tolerant if the project intends no irrigation of the green roof after the establishment period.

Installation Recommendations

Plant Establishment

The initial establishment of the green roofs was a challenge for two out of seven case studies because the vegetation attracted birds that pulled out the small plants. This problem is usually eliminated as plants grow and the roots become stronger. Another option can be to transplant established plants from the nursery to the green roof. However, transplant must occur before plants became 'root bound'. Sometimes the roots of well established potted plants become bound to each other as if they are still in a pot and do not hold to the ground well. This makes them a susceptible target to the birds in spite of being bigger in size than smaller potted plants. This problem can also be addressed by spreading the roots manually when they are planted.

Roof Slope & Drainage

Adequate roof slope is necessary to promote drainage, avoid ponding of water, and promote healthy root growth.

Maintenance Recommendations

Operations & Maintenance Manual

Maintenance is one of the most important elements of a successful green roof. An Operations & Maintenance manual should be created before the installation of a green roof project and maintenance procedures should be followed.

Information about the irrigation system and the design intent should be conveyed to the maintenance staff through an Operations and Maintenance Manual. On one case study the maintenance staff was not fully aware that the plants were specified such that some may go dormant during the summers without irrigation. The maintenance staff was irrigating these species to keep them green and was not aware of the fact that the irrigation system was not designed to irrigate that area of the roof where such species were planted.

It is important to update maintenance procedures after the establishment period because often green roof projects encounter than the maintenance efforts required for tasks such as removing weeds and watering plants during the establishment period are different than what was anticipated.

Removing Weeds

It is necessary to remove weeds because their roots may penetrate deep and damage the roof membrane. Also, mono-culture planting may not always work for green roofs because if the plant species is affected by a disease the entire roof dies. A greater diversity of plants increases the possibility of a successful green roof. Weeds need to be pulled early in establishment so that the plants can thrive. Once plants are thriving, weeds are less of a problem.