ECOROOF HANDBOOK 2009

ENVIRONMENTAL SERVICES
CITY OF PORTLAND
working for clean rivers

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working for clean rivers

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Cover image: Hamilton Apartments ecoroof next to an impervious surface roof

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introduction

Ecoroofs are living, breathing, vegetated roof systems that provide a sustainable alternative to conventional roofing. They are part of a growing worldwide effort to promote sustainable development and reduce negative impacts on air, water, energy and the earth. The City of Portland is at the leading edge of this exciting green building movement.

The city encourages the use of ecoroofs as part of its efforts to promote sustainable development. This handbook is a resource for the general public, developers, designers and anyone interested in ecoroofs. It is not a comprehensive design manual, but provides information needed to understand the feasibility, benefits, components, and process of designing, constructing, and maintaining an ecoroof.

This handbook contains information the city has gathered since 1996 through ecoroof research, construction, and monitoring. The information applies to Pacific Northwest conditions, mainly west of the Cascades and, more specifically, to the Portland area.

Ecoroofs are an evolving technology. As more ecoroofs sprout up, the city will continue to learn about them and make this emerging information available.

Portland's Ecoroof Program is a cooperative effort of the Bureau of Environmental Services, Bureau of Planning and Sustainability, Bureau of Development Services and other bureaus that own facilities with roofs. The program promotes ecoroofs by researching ecoroof technologies and providing information and technical assistance to the public.

Sustainable development uses practices that respect natural systems, do not impact the environment, and promote environmental, economic, and social health today, while protecting and sustaining the well-being of future generations.

what is an ecoroof

An ecoroof is a lightweight system of soil (growing media or substrate) and vegetation designed to be as self-sustaining as possible. A successful ecoroof is synergetic. The soil anchors the plant roots and supports plant growth. The plants protect the soil from erosion and heat gain. Roots and soil foster microorganisms that make the soil and plants healthier. Water and sun feed the soil and plants. Plants photosynthesize and produce food for other species, which produce waste matter that helps improve the soil. Ecoroofs are also known as living roofs, extensive greenroofs, or vegetated roofs.

Ecoroofs can be used on most types of commercial, multifamily, and industrial structures, as well as single-family homes, garages, and other facilities. They are suitable for both new construction and re-roofing of existing buildings, and can be located on both flat and pitched roofs.

Buildings are predominately made of wood, steel, brick, some form of concrete, or a combination of two or more of these materials. When properly designed, all of these materials are appropriate for ecoroof installations.

Portland Building ecoroof

why an ecoroof is beneficial

Based on documented experience and studies, ecoroofs offer a number of important benefits that conventional roofs do not. In fact, conventional roofs cause many of the problems that ecoroofs solve.

The City of Portland, in partnership with Portland State University and Oregon State University, is monitoring ecoroof performance in relation to energy, stormwater quantity and quality, and vegetation. This information will help quantify benefits and identify best design and maintenance practices.

Environmental Benefits

- Based on City of Portland monitoring data since 2002, ecoroofs typically capture and evaporate an average of 60 percent of the rain that falls on them. This reduces stormwater runoff volume and speed, helps prevent combined sewer overflows (CSOs), and protects rivers and streams.
- Ecoroofs lower stormwater runoff temperature which helps maintain the cool stream temperatures needed by fish.
- Ecoroofs improve air quality by decreasing air temperatures and capturing airborne pollutants.
- Ecoroofs increase vegetation and wildlife habitat on urban sites that are typically biologically dead spaces.
- Ecoroofs reduce urban heat island impacts.

Ecoroofs provide habitat for insects and other wildlife

Building Owner Benefits

- Ecoroofs can last twice as long as conventional roofs, saving replacement costs and materials.
- Ecoroofs insulate buildings and decrease cooling and heating costs.
- An ecoroof can reduce drainage fees by making a property eligible for Portland's stormwater discount program.
- An ecoroof qualifies as a stormwater management technique and reduces infrastructure costs.
- Ecoroofs provide visually attractive alternatives to conventional roofs and can often increase property value.

Portland residential ecoroof

when to consider an ecoroof

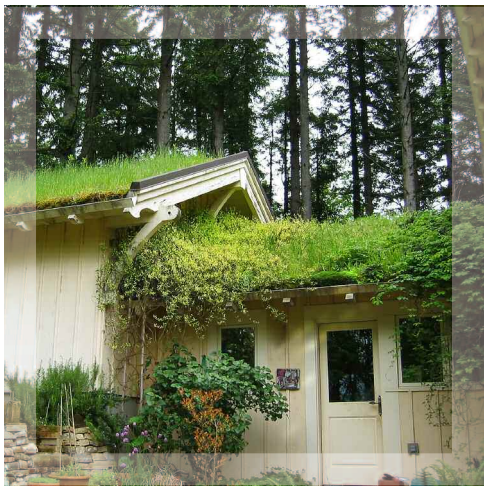
For a new building project, the best time to consider an ecoroof is during the initial concept/schematic design phases. Even though the ecoroof is on top of the building, many building design elements need to be considered. These design elements are discussed in the *Design, Construction and Maintenance* section of this handbook.

Many ecoroofs have also been installed on existing buildings throughout the city. The best time to consider an ecoroof for an existing building is when the roof needs repair or replacement, when considering seismic upgrades, or when considering building remodeling. Some building owners have installed ecoroofs on their existing roof membrane to extend the life span.

People's Food Co-op ecoroof

Meriwether ecoroof

Portland Building ecoroof



residential ecoroof

design, construction, & maintenance

Ecoroof configurations vary, but typically include the elements shown in diagrams on page 9.

ecoroof with a diversity of species

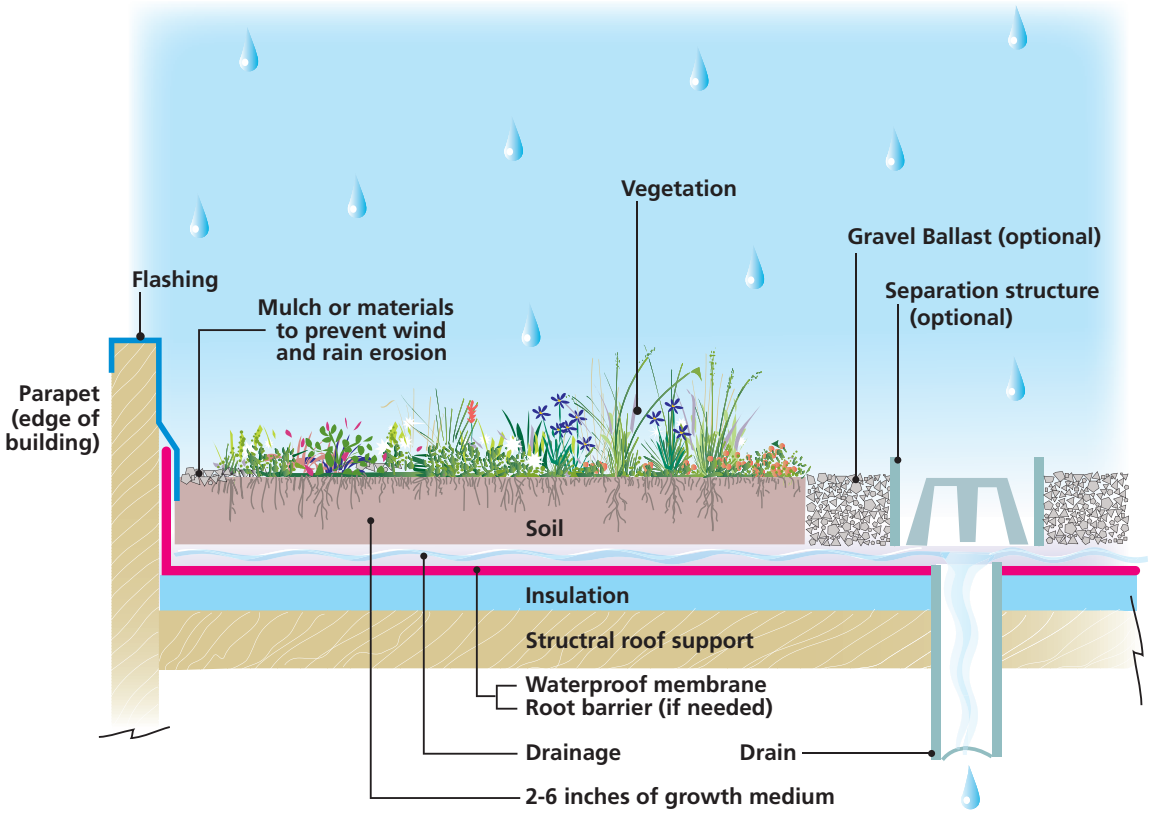
✔ Structural roof support
✔ Waterproof membrane
✔ Root barrier (if needed)
✔ Drainage (if needed)
✔ Growth medium (soil) 3-6 inches
✔ Vegetation (succulents, such as sedum)
✔ Gravel Ballast (optional)
✔ Drain
✔ Parapet (edge of building)
✔ Flashing
✔ Mulch or materials to prevent wind and rain erosion
✔ Separation structure (optional)

Ecoroof Design

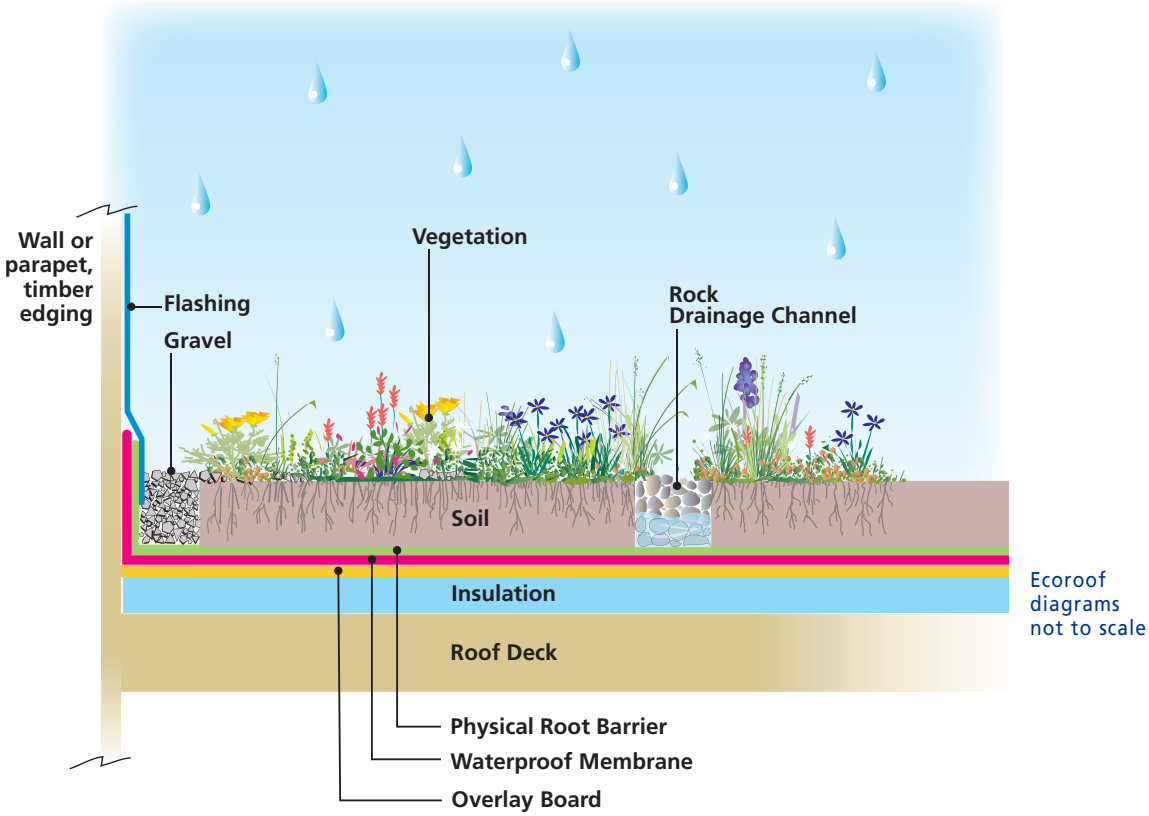
It is important to determine the basic design concept, including analysis of the building structure and anticipated level of operations and maintenance (O&M) required for the ecoroof before starting the design process. Ecoroofs afford many options depending on the purpose of the roof. Building owners and designers may want a relatively utilitarian ecoroof that provides stormwater management and building insulation, while others may want their ecoroof to provide habitat for greater biodiversity, aesthetics, access for human use, or some combination of any of these.

A successful ecoroof requires that all elements are well executed and work well together. These include design, construction, establishment, O&M plan, and O&M implementation. If any of these elements is poor, the project may fail.

- Most buildings require roof access for operations and maintenance of mechanical units, window washing, elevator repair, and other activities. Access requirements should be identified during the design phase, and access paths of gravel or other inert materials provided. Where access is needed only occasionally, paths may not be required because the vegetation can tolerate some foot traffic.
- The ecoroof design should include provisions for storage of maintenance equipment and materials, especially for large buildings.



A cross-section of an ecoroof with a drainage layer (above) and without (below)



Ecoroof diagrams not to scale

Function and Beauty

Solar panels integrated into the design of an ecoroof

Swan Island Pump Station ecoroof glows at sunset

Structural Roof Support

Many buildings already have the structural capacity to support rock ballast, which can often weigh as much as an ecoroof system

Ecoroofs weigh from 15 to 30 pounds per square foot (psf) saturated, depending on the vegetation and growth medium used. The building being considered for an ecoroof must be able to support this additional weight.

For new construction, the additional weight of the ecoroof may or may not require a more substantial structure. Design issues include the building's foundations, rafters, posts, beams, decking, and other structural elements.

For existing buildings, needed structural upgrades may include additional decking, roof trusses, joists, columns, or foundations. Many buildings already have a 15 psf gravel ballast roof and are usually structurally sufficient to hold an ecoroof.

The following table shows the typical weights of various materials.

Structural Loads for Materials per Cubic Foot

Material	***Weight*** *(lbs per cubic foot)*
Water	62.4
Pumice*	40
Silty loam (dry)	70-75
Silty loam (moist)	90-100
Silty loam (saturated)	100-120
Perlite (expanded)*	11
Concrete	150
Peat (dry)*	24
Peat (moist)	50
Peat (saturated)	70
Gravel (dry)	105
Gravel (wet)	125

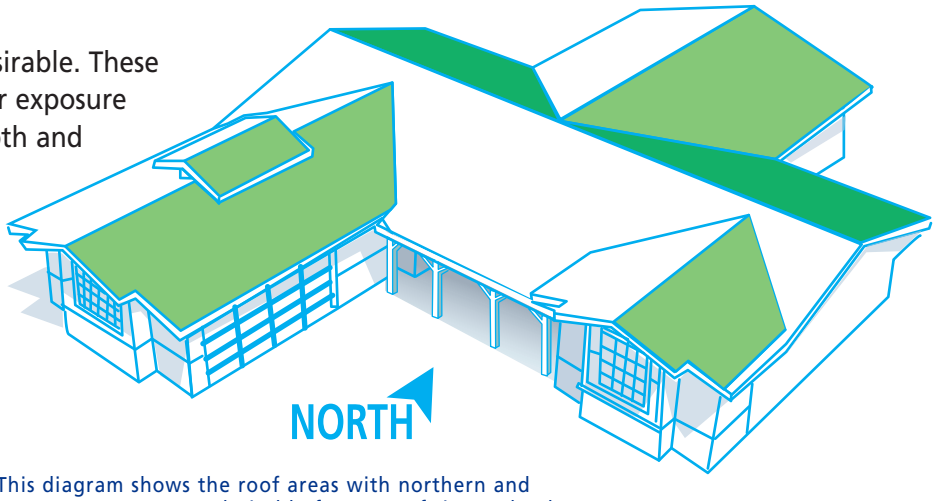
*When these materials are dry, they can float on water until completely saturated. If they are used in mixes, they will be subject to scour and blow-off. If a significant amount of these materials is used, gravel ballast (mulch) on top or vegetated mats should be considered in order to limit the scouring.

Aspect

Aspect is the compass direction the roof plane faces. An ideal ecoroof in Portland would have a north aspect. North is best to help reduce evaporation and solar exposure, which helps support the vegetation. A north-facing ecoroof may not require irrigation.

An east aspect is second best.

A south or west aspect is least desirable. These would have the most intense solar exposure and likely require greater soil depth and irrigation (unless there is shade).



This diagram shows the roof areas with northern and eastern aspects, most desirable for ecoroofs in Portland.

Slope

Slope is the angle of pitch of the roof plane. A 2 to 15 percent slope is good for north and east aspects, and a 2 percent or less slope is good for south and west aspects (because flat slopes have less sun exposure and less need for irrigation). In Portland, most ecoroofs are relatively flat, with slopes around 2 percent, although some are as steep as 40 percent.

Slope affects the irrigation, plant material, and materials needed (e.g., lattice to prevent soil sloughing).

Portland residential ecoroof with 33 percent slope (left) under construction (right) plants established

Waterproof Membranes

Modified Asphalt Membranes

Modified asphalt, or bitumen, is generally asphalt material that has been improved with petroleum-based additives. It is a multi-layer system that comes in sheets, rolls, and liquid. Modified asphalt can be applied hot, cold, torched, or self-adhered. It can be laid loose or adhered to the roof deck.

Metro Building ecoroof modified asphalt membrane being applied

Thermoplastic Membranes

Thermoplastic membranes include:

- PVC (polyvinyl chloride)
- TPO (thermoplastic olefin or polyolefin)
- EPDM (ethylene propylene diene terpolymer)

These are all single-ply systems that come in rolls or large sheets. They can be laid loose or adhered to the roof deck.

Numerous companies manufacture waterproof membranes appropriate for ecoroofs.

A flood test will identify leaks in the membrane before the soil and plants are installed

Insulation

Building insulation is often associated with the ecoroof's waterproof membrane and is therefore important to consider at the early stage of design.

Insulation can be placed in one of three places; all have their pros and cons:

- Above the ceiling inside the building. This approach keeps the insulation out of the way of the ecoroof. The insulation is not affected by re-roofing.
- Above the roof deck, under the waterproof membrane. Insulation is often damaged during re-roofing.

Portland Building insulation on top of root barrier

Root Barrier (if Needed)

Root barriers prevent vegetation roots from penetrating the membrane and causing leaks. The need for a root barrier depends on the waterproof membrane selected. Consult the membrane manufacturer to determine if a root barrier is required for a particular product.

The two types of root barriers are physical and chemical.

Physical root barriers are made of dense plastic. The material is overlaid on the membrane and overlapped at the seams by 5 feet or more. PVC, EPDM, and TPO membranes act as the physical root barrier themselves.

Chemical root barriers are not allowed in Portland. Vendors have been asked to provide information that addresses the following concerns: (to date none have provided information)

- Possible leaching of chemicals into the ecoroof runoff can add pollutants to receiving waters.
- The long-term effectiveness of a chemical product that comes into frequent contact with water diminishes over time.
- Chemicals or impregnated metals such as copper can be dissolved by water and eventually lose their ability to resist the roots.
- The chemicals' potential negative impacts on the vegetation.

Columbia Boulevard Wastewater Treatment Plant test ecoroof with a moderate slope

Drainage

Roof Slope

The steeper the slope, the faster water drains. A slope of 2 percent or more will facilitate drainage off the roof and will minimize standing water, even with surface irregularities. At slopes greater than 20 percent, soil stabilization methods are needed.

Gravel or Sub-rock Layer

This is perhaps the oldest drainage method for roof gardens and vegetative roofs. Since the advent of many plastic drainage products, gravel has been used on ecoroofs less often. Some ecoroof designers, however, are finding that gravel is sometimes still a preferred option.

Drainage Channels

This approach uses a narrow gravel channel that runs along a contour of the slope and facilitates the flow of water to the drain. It is not a sub-layer; it can stand alone or be used in conjunction with a gravel sub-layer. Since most ecoroof soils are relatively porous, the channel helps relieve water buildup during heavy rains.

Metro building ecoroof with crisscrossed drainage channels

Drainage Mats

Drainage mats are also used for building foundation drainage. They have two layers of material with an air gap between them. One issue is whether dry summer air negatively affects plant roots in the air space, which may necessitate more summer irrigation. This is one reason for the growing interest in using drainage channels.

Vertical Drainage

As with a conventional roof, an ecoroof must safely drain runoff from the roof. Ecoroofs with any aspect or slope can have either conventional drains or drainage to rainwater harvesting systems (such as rain barrels or cisterns) or other stormwater facilities (such as planters and swales). Interior drains require ductile steel pipe, which is more expensive than exterior downspouts. During winter, interior drains also facilitate building heat loss up the pipe. Exterior drains are recommended whenever practical.

Portland Building drainage mat over insulation

Porous Soil

Porous soil allows horizontal flow through the soil during storm events, and no other drainage material is used. When the soil is saturated, the stormwater flows across the surface to the vertical drain. To date, this approach has been used in Portland on small and medium size projects. The negative side of these soils is that stormwater management may not be optimum and summer irrigation needs may be higher. It should be noted that some ecoroofs with river gravel support sedums without any irrigation. It is anticipated that stormwater management would be less; however these ecoroofs have not been monitored yet, in Portland.

Growth Medium (Soil)

The growth medium is one of the most important components affecting the success of an ecoroof, but there is no clear answer about the best soils to use. The city monitors numerous ecoroofs in Portland with a variety of soil mixes and depths. The results show that ecoroof plants can grow in many soils and conditions and that different soils provide different levels of stormwater management. Most soils are prone to wind erosion when exposed. It is important to ensure good plant coverage or mulch.

To determine the suitability of a soil mix for an ecoroof project, obtain information about the following product characteristics:

- **Irrigation needs**
- **Stormwater management capabilities**
- **Vegetation support**
- **Weight**
- **Porosity**
- **Susceptibility to wind and water erosion**

Soil Mixes

Soil mixes used for Portland ecoroofs vary. Recent projects have used a mixture of 75 percent mineral and 25 percent compost/organic. Most of the mineral used has been pumice, which is plentiful in the Pacific Northwest.

Soil formulated specifically for ecoroofs is available in Portland, and hopefully soil companies will continue to research and develop the most sustainable blends. The city will continue to monitor performance and at some point will determine a minimum specification to ensure ecoroofs are performing adequately.

Central Wine Warehouse growing media, a mixture of mineral and organic content

Soil Depth

Deeper soils allow for greater moisture retention, building insulation, and vegetation support. For ecoroofs on new buildings, a depth of 4 to 6 inches appears to work well. For ecoroofs on existing buildings, soil depth can be 3 to 6 inches depending on the structural capacity of the building.

Fertility

The long-term fertility of ecoroofs in the Pacific Northwest is not well understood. An ecoroof may possibly need fertilization over the many decades of its expected life. The oldest ecoroof in Portland to date (13 years) has not been fertilized and is rarely irrigated. One 9-year old ecoroof has also never been fertilized.

Mulch

A rock covering over ecoroof soil can retard evaporation caused by solar exposure and dry air from building vents. Sedums appear to prefer gravelly soils. Bark or wood mulch has the potential to blow off, burn, or decompose over time. Rock mulch has proven to be most effective in protecting soil and plants. River rock and large aggregate red cinder are options available in Portland.

Wind

Wind scour and uplift often relate to the roofing system that is used and the potential for wind problems from the site and building design. In Portland, many projects have not added more

structural support to address uplift and secure the ecoroof. These ecoroofs are designed to code and are functioning quite well. Other projects have incorporated stabilization measures such as cable tie downs. More information is needed about what seems to be an inconsistent approach to this issue.

Air vents and other mechanical systems that create warm or cold air flow across ecoroof vegetation may create conditions that harm the plants and cause soil scouring. Soil selection, mulch and planting design can help address this problem. However, the building design stage is an opportunity to avoid creating the problem in the first place. For example, air vents can be designed to direct air away from the plants.

Vegetation

Ecoroof vegetation should have the following attributes:

- Drought-tolerant, requiring little or no irrigation after establishment
- A growth pattern that allows the plant to thoroughly cover the soil
- Self-sustaining, without the need for fertilizers, insecticides, or herbicides
- Able to withstand heat, cold, and high winds
- Very low-maintenance, needing little or no mowing or trimming
- Perennial or self-sowing
- Fire resistance

Autumn Joy sedum at Buckman Ecoroof

Grass at Buckman ecoroof

Iceplant at Hamilton ecoroof

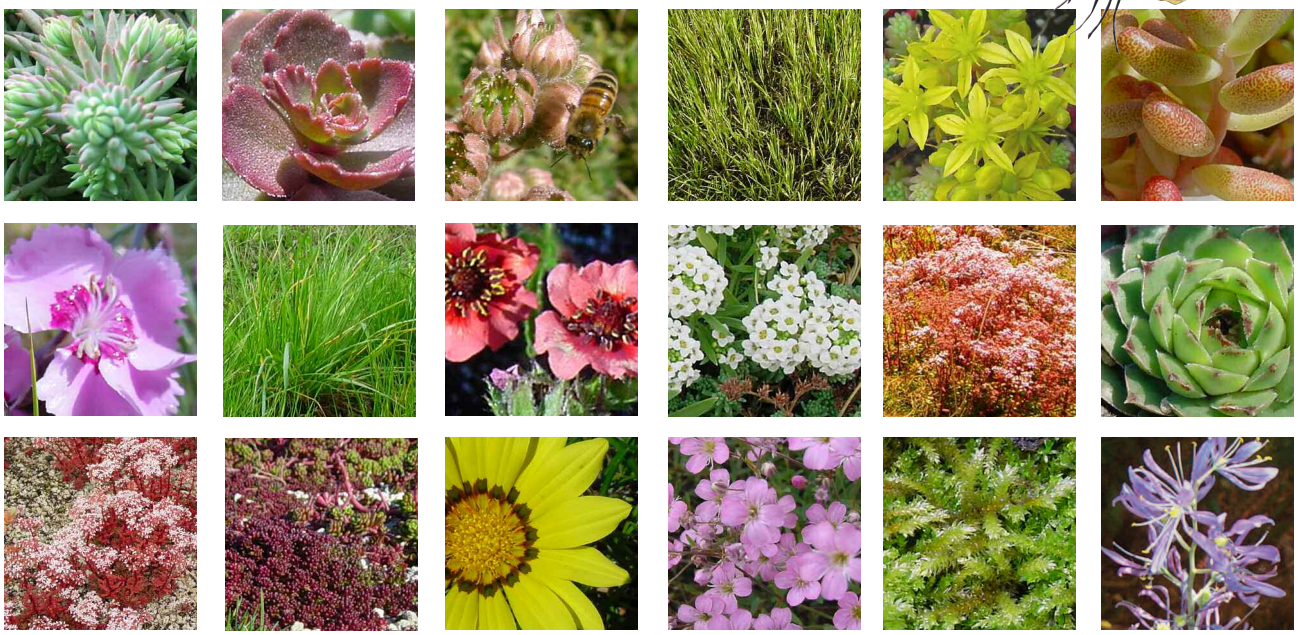
A mix of sedum, or succulent plants, is recommended because they possess many of these attributes. Herbs, forbs, grasses, and other low groundcovers can also provide additional benefits and aesthetics; however, these plants may need more watering and maintenance to survive and keep their appearance. Drought tolerant plants in the garden or natural areas may survive because they have deep tap roots. This depth of soil does not exist on an ecoroof. Other than the plants recommended here, the use of other plants should be limited until they have been tested and proven.

Ecoroofs are generally more aesthetically pleasing than conventional roofs. Foliage and flowers provide beauty, especially in spring and summer. Many sedums have beautiful fall colors, and some change color throughout the years, turning from red to yellow to green. Evergreen species provide year-round interest.

The following plants are working well in Portland with little or no irrigation. This is based on monitoring more than 14 existing Portland ecoroofs that are 3 to 12 years old. For more details about these plants and ecoroofs see the Portland Ecoroof Plant Report September 2008.

- Sedum acre
- Sedum album
- Sedum divergens
- Sedum hispanicum
- Sedum kamschaticum
- Sedum oreganum
- Sedum rupestre
- Sedum sexangulare
- Sedum spathulifolium
- Sedum spurium
- Sedum telephium 'Autumn Joy'
- Sempervivum tectorum
- Camassia quamash
- Delosperma cooperi
- Delosperma nubigenum
- Festuca glauca
- Muscari spp.
- Polypodium glycyrrhiza
- Many native herbaceous annuals and perennials

Wildlife, especially insects, love ecoroofs. Honeybees, bumblebees, dragonflies, damselflies, beetles, and ladybugs are often found on ecoroofs, even though this may not have been the designer's intent. Numerous birds feed on insects and gather nesting materials from ecoroofs. Designing specifically for biodiversity is just beginning in Portland, and much is still to be learned.



Installation Methods

Seeds: Seeds can be used for many species considered to be appropriate for an ecoroof. Wildflower seeds are most often planted after the sedum plants. Careful attention to irrigation is required to ensure the seeds germinate and grow.

Cuttings/sprigs: These are small pieces of sedum and other succulents thrown evenly across the top of the soil. Cuttings usually require frequent light irrigation for 3 to 6 months to accelerate establishment.

Bulbs: Bulbous plants have been installed successfully on many Portland ecoroofs. They include daffodils, onions, bluebells, muscari, and tulips. Bulbs are simply pushed 2 to 3 inches into the soil.

Plugs: Plugs are small plants in 2-inch or smaller pots or sometimes in large trays. The plants are individually removed and planted with 12-inch spacing.

Pots: These plants are grown in 4-inch or larger pots. They are removed from the pot and planted with 12-inch or greater spacing.

Container plant installation on the Multnomah County ecoroof

Hydro-seed/mulch: Hydro-seeding has been done on a couple of projects, with some successes and some problems. Part of the Hamilton ecoroof was successfully hydro-seeded with dianthus, marigolds, and clover. However, the inclusion of sedum cuttings has not always worked.

Vegetated Mats: Vegetated mats are a sod-like approach to vegetation on ecoroofs. Plants are grown in relatively thin soils that have been spread over a fabric-type material. Some mats are grown similarly to turf sod and have only soil, not fabric.

Sedum mix on the Portland Building ecoroof

Trays: A tray is a shallow container that contains soil and plants. It is usually rectangular or square, from 2 to 6 inches deep and 12 to 48 inches wide or long. Most trays are made of plastic; some are aluminum and some are bio-trays of coir fabric.

Other Considerations

Heat that reflects off building surfaces can damage vegetation. Solar exposure (related to aspect and slope) is also very important to consider when designing an ecoroof.

Gravel Ballast

Gravel ballast is often placed along the perimeter of the roof and at air vents or other vertical elements. The need for ballast depends on operational and structural design issues. It is sometimes used to provide maintenance access, especially to vertical elements that require periodic maintenance. In many cases, very little, if any, ballast is needed.

If a root barrier is used, it must extend under the gravel ballast and growth medium and up the side of the vertical elements.

Gravel ballast on the Portland Building

Materials

Many materials used on a conventional roof or an ecoroof can be dissolved by rain and other water sources on the roof. Metals such as galvanized steel, copper, zinc and lead are examples. It is recommended that designers consider more benign materials such as stainless steel, aluminum, rock, brick or recycled plastic products.

Edging is sometimes used to separate the soil and vegetation from the gravel ballast areas around parapets and penetrations. Edging materials include lumber, galvanized steel, stainless steel, aluminum, plastic, concrete, brick, and others. These materials are subject to wear and tear and break down over time. Chemicals used to extend the life of the material break down and leach into the ecoroof, harming or killing vegetation and discharging into drainage. These materials also add to the cost of the ecoroof. Edging is usually not necessary, since no problems are caused if vegetation grows into the gravel. In general, it is advisable to minimize the use of unnecessary or potentially harmful materials.

Irrigation

Irrigation will probably be needed during the vegetation establishment period. Several ecoroofs in Portland are not irrigated at all. These ecoroofs are not intended for aesthetic purposes and may look a little dry, but are still alive and well, especially when fall rains begin. The goal is to minimize irrigation needs and potable water use by paying close attention to plant selection, soil, and building and roof characteristics.

Water Sources

The following are potential sources of water to be considered at the design stage:

Precipitation: The ideal choice would be an ecoroof without need of water other than the precipitation that lands on it.

Shade (natural and applied): Many native and non-native plants can survive without irrigation if some shade is present. Shade can be provided by taller buildings that shade a lower roof, roofs with a north aspect, trees that cast shadows, parapets, and photovoltaics and other mechanical equipment. Rock mulch may also retard evaporation.

Non-potable Water (Condensate): Many buildings have air conditioning equipment that discharges water condensate. One Portland ecoroof project is designed to capture condensate and rainwater, with potable water as a backup.

Potable Water: Although potable water is readily available, it is desirable to limit or eliminate use.

System Design

Many types of irrigation systems, both manual and automatic, are being used on ecoroofs. These include hand watering, back-yard sprinklers, commercial spray or stream heads on risers and pop-ups, large rotary heads, and various drip systems.

Irrigation systems may not last for the life of an ecoroof and may require replacement or major repair over time. This is another reason to keep them simple and minimize their use.

Irrigation Considerations

To minimize water needs, early autumn is the best planting season.

Contractors have often over-watered ecoroofs, especially during the plant establishment period. This can damage succulents and other plants.

The city's recommendation for watering is:

- From May through October, no more than 1/2 inch of water per 10 days during the first 2 years
- No more than 1/4 inch of water per 10 days thereafter

Portland's climate has two different dry periods:

- The moderately dry months of May, early June, late September and early October
- The very dry months of late June, July, August and early September

Irrigation controllers that can be set for both periods should be considered to avoid over-watering or under-watering.

Designers should specify:

- Exactly how the controller should be set, and not assume the contractor knows
- Installation of a flow meter so maintenance staff can monitor water applications to help minimize water use
- When and how to winterize the irrigation system

Irrigating a backyard shed by hand

Simple impact sprinkler on an ecoroof

Portland Building irrigation flow meter

Whitaker Ponds ecoroof, which is not irrigated, supports a healthy sedum community

Operations and Maintenance

Similar to conventional roofs, ecoroofs require care to maintain optimum function. The desired Operations and Maintenance (O&M) costs should be determined at the beginning of the design stage, and the project designed to them. The goal is to balance the soil, plantings, and water so the ecoroof is almost self-sustaining, with minimal O&M needs and equipment.

A successful ecoroof requires that all elements are well executed and work well together. These include design, construction, establishment, O&M plan, and O&M implementation. If any of these elements is poor, the entire project can fail.

O&M Plan

An O&M plan should be prepared by the designer. It should include:

- Plant care (pruning, etc.)
- Weed control (no herbicides)
- Pest control (no pesticides)
- Irrigation timing, frequency, and quantity of water (including winterization)
- Schedules for inspections and work

O&M staff should get a copy of the O&M plan, including the as-built drawings of how the project was installed.

The designer, not the contractor, should develop project specifications for vegetation establishment, including irrigation frequency and volume of water to be applied. The designer and contractor should collaborate to ensure the specifications are well understood and to identify any needed improvements.

O&M Implementation

Plant Care

The ideal ecoroof does not require any trimming, edging, fertilization, or other typical garden care techniques. O&M involves periodically checking the health and coverage of the vegetation. Some plant replacement or in-filling may be needed.

If plants are unhealthy, causes may include pests, too much or too little water, fertilization, damage by air vent flows, HVAC condensate, or people. Most problems are usually associated with too much irrigation and fertilization.

The importance of aesthetics influences the amount and frequency of care needed. Some plants may "brown out" or almost disappear from sight, but they are still viable and will revive in the rainy season.

Weed Control

Depending on the planting method, weeding and mulching may be needed during the establishment period and periodically thereafter over the life of the ecoroof.

Plants that are weeds on an ecoroof are:

- Plants with roots that will penetrate the membrane, usually trees
- Plants that grow in abundance and dry out and become a fire hazard (e.g., grasses and herbaceous species)
- Plants that invade and crowd out desired species (e.g., English ivy, blackberry)

Plants that are not weeds and can be allowed to be part of the ecoroof are:

- Plants that were not originally planted, have colonized the ecoroof, but do no harm and are not invasive

Uninvited volunteer plants on the Portland Building ecoroof

The best approach is to be patient, watch the plants first, and then decide what to do. Checking for undesirable weeds and trees should be done in late May or early June. Most summers will be dry enough to inhibit weeds, unless the ecoroof is over-watered. In wet summers, weeds may come back after removal, requiring a second weeding.

Weeding can be done by:

- Manual pulling (pull and bag or pull and drop).
- Cutting, using a weed whacker, mower, hoe, or clippers (cut and bag or cut and drop)

Pulling causes more disturbance to the ecoroof, and soil is often removed. It also removes the diversity of weed roots and microorganisms. Cutting disturbs the soil less and may allow many weeds to return from the base. If not watered, the base of many weeds die and can break down in soil.

No herbicides are allowed on an ecoroof that received a floor-area ratio (FAR) bonus or that was installed to comply with the City of Portland's Stormwater Management Manual.

Learn more about invasive plant species at www.portlandonline.com/bes/invasive

Travelers Joy, *Clematis vitalba*, an invasive vine, found on the Portland Building ecoroof

Pests

Pests are insects that destroy plants or impair soil. Disease and typical garden pests have been found on ecoroof plants, but so far nature has kept things under control. To date, no widespread problems are known. If pests are found it may be possible to use beneficial insects to solve the problem.

Fire Safety

All roofing materials must meet fire resistance requirements. The ecoroof soil and other components on top of the membrane lessen its vulnerability to fire. In addition, the soil acts as a fire retardant.

Sedum and other succulents are naturally fire resistant. Other types of vegetation could be of concern and need to be watered, mowed, and maintained to prevent fire. Depending on the seasonal rains in Portland, it is best to mow a dry grass roof before July 4th.

Debris

Debris, such as trash or excessive leaf litter, should be removed as needed (once or twice a year) to keep vegetation healthy.

Litter on an ecoroof

Drains

Periodic inspection (at least twice a year) is needed for any type of roof to ensure drain inlets are not blocked. Drains should be cleared at least annually.

Erosion

The ecoroof should be inspected for erosion, and problems should be corrected with gravel mulch and sedum cuttings.

Membrane

Once the membrane is covered with the ecoroof, it is protected from sun, wind, rain, and human activities and should be free of maintenance needs for up to 40 years. The ecoroof must be maintained to ensure the membrane is protected, but it is important to cover even small areas, since any exposed membrane may experience detrimental effects.

An example of an interior drain

Leaks

An ecoroof is less likely to leak than a conventional roof because the membrane is protected. If a leak does occur, it may be more difficult to pinpoint the leak on an ecoroof than a traditional roof. Because ecoroofs are thin, however, they can be removed and replaced in small sections as needed. Penetrations such as vents are often the cause of leaks. The standard rule for both conventional roofs and ecoroofs is that the more the roof is penetrated, the more potential there is for leaks.

Ecoroof Replacement

The typical lifespan for an ecoroof is about 40 years, significantly longer than a conventional roof.

Replacing an ecoroof involves:

- Removing and stockpiling the vegetation, growth medium, irrigation pipes, and other components. (It may be possible to simply move these materials to one side, rather than removing them entirely.)
- Removing and replacing the waterproof membrane.
- Reinstalling the stockpiled growth medium, vegetation, and other components.

Building Construction Sequencing

The sequencing of building construction can influence the choice of materials and other decisions. Sequencing should be planned well in advance and even considered at the early design stages.

The ecoroof vegetation, soil, and irrigation should be the last components of the building construction on the roof, or the vegetation and irrigation could be damaged and soils compacted. If a membrane is applied to provide weather protection and staging areas during building construction, however, it must be protected. Membrane manufacturers can provide the pros and cons of their products for this purpose.

Soil being hoisted to the roof of the Portland Building

Permit Requirements

Commercial Projects

All commercial ecoroof projects (on both new and existing buildings) require a commercial building permit, available from the Bureau of Development Services' permit center. Plans of the complete scope of work and structural engineering calculations are required.

Residential Projects

New residential ecoroofs are part of the house plans. The plans are the typical submittal package required for residential structures and include all work that is required to support the ecoroof. Structural engineering is required to demonstrate that the structure can support the weight of the ecoroof.

A permit is not required for re-roofing a house if:

- The roofing does not exceed 30 percent of the required live load; and
- The roof is not required to be fire-resistant; and
- The house is not in a wildfire hazard area.

For loads greater than 30% structural engineering calculations are required.

For the Portland area, the roof live load is 25 psf (snow load). Thirty percent of 25 psf = 7.5 psf. Therefore, a permit is required if the ecoroof system weighs more than 7.5 psf.

A permit is not required if the structure is non-habitable, less than 200 sf and at least 3 feet from the property line.

construction costs

Ecoroof costs vary and depend on several factors. Installation of an ecoroof costs from $10 to $40 per square foot (sf). This includes materials, labor, and structural upgrades. A conventional roof installation ranges from $3 to $35 per sf. As the ecoroof market develops, costs are likely to become more affordable.

	Ecoroof (cost per square foot)	Conventional Roof (cost per square foot)
New construction (includes structural support)	$10 to $20	$3 to $15
Re-roofing	$6 to $40	$10 to $35

Source: Bureau of Environmental Services estimates based on City of Portland demonstration projects, and information obtained from roof contractors.

Although ecoroofs initially cost more than conventional roofs, they are competitive on a life-cycle basis because of reduced maintenance and replacement costs. The typical lifespan for an ecoroof is about 40 years, significantly longer than a conventional roof. Visit www.portlandonline.com/bes/ecoroof to see the BES Cost Benefit Evaluation of Ecoroofs report.

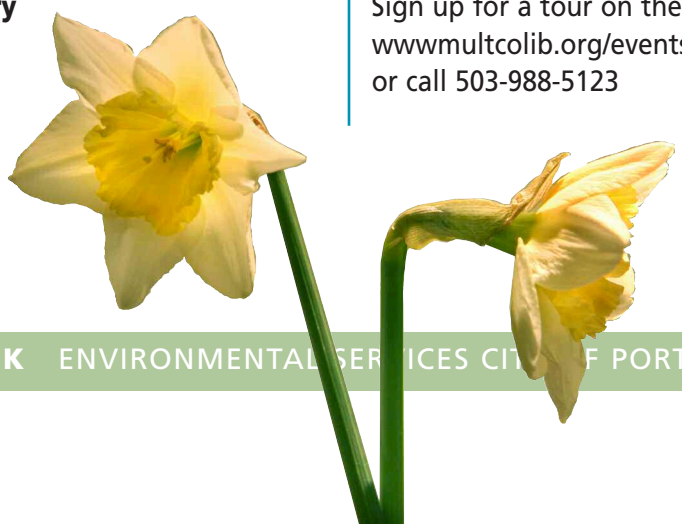
Louisa ecoroof

where you can see ecoroofs

There are ecoroofs throughout Portland.

The following list identifies some that can be viewed.

Property:	Contact:
Hamilton Apartments Building SW 12th and Clay	Ecoroof Program 503-823-7378
Buckman Terrace Apartments NE 16th and Sandy	Ecoroof Program 503-823-7378
Jean Vollum Natural Capital Center NW 10th and Irving	Ecotrust: 503-227-6225
Native American Student and Community Center 710 SW Jackson Street	Access during business hours Portland State University
Columbia Boulevard Wastewater Treatment Plant 5001 N Columbia Boulevard	Check in at Main Desk: 503-823-2400
Multnomah County Building 501 SE Hawthorne Boulevard	Open to public 8:30 am - 5:00 pm Check with security on the main floor.
Hawthorne Hostel 3031 SE Hawthorne Boulevard	Viewable from sidewalk
People's Food Co-op 3039 SE 21st Avenue	Viewable from sidewalk
Metro Regional Center 600 NE Grand Avenue	Check in with security at the front desk.
Multnomah County Library 801 SW 10th	Sign up for a tour on their website wwwmultcolib.org/events/ecoroof or call 503-988-5123



information and assistance

Ecoroof Program

Bureau of Environmental Services: 503-823-7378
www.portlandonline.com/bes/ecoroof

Materials available on the ecoroof website:

- Virtual Tour of Ecoroofs
- Ecoroof Grant program information
- Ecoroof seminar Power Point presentations
- Video of a residential ecoroof construction project
- Case studies
- Monitoring results
- Incentive information
- Cost Benefits Evaluation of Ecoroofs 2008
- Ecoroof Plant Report 2008
- Resources Guide

Green building approaches

Bureau of Planning and Sustainability: 503-823-7222
www.sustainableportland.org

Building code, permitting and zoning information

Bureau of Development Services:
503-823-7310 (for building code information)
503-823-7526 (for zoning information)
www.portlandonline.com/bds