Green Roofs

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Green roofs are vegetated roof systems that consist of a waterproof membrane, an optional drainage layer, an engineered growing medium or soil, and a layer of plants. In addition to minimizing impervious area and stormwater runoff, they are an attractive alternative to conventional roofs and provide several benefits, including attracting wildlife by creating habitat, establishing green/open space for social or aesthetic purposes, moderating indoor building temperatures in the summer and reducing cooling bills (Gaffin et al. 2007), minimizing the effects of urban heat islands, reducing noise, and improving air quality.

Derek Godwin

Sequential Biofuels in Eugene.

Green roofs have proven successful in European countries and have outlasted traditional roofs by as much as 30 years. Several green roofs have already been installed in Portland, Oregon, and the city has a master plan that calls for 43 acres of green roofs by 2013.

Green roofs manage stormwater by holding rainfall in the pores of the growing medium, in the drainage layer underneath the medium (if used), and in the plants themselves. Evaporation from the growing medium and evapotranspiration from the plants releases some of the moisture back into the atmosphere. Evaporation is an important element of the hydrologic cycle and contributes to regulation of the regional climate.

There are two kinds of green roofs, "extensive" and "intensive." Extensive roofs are accessed only for maintenance and are generally lightweight, thin roofs with shallow-rooting plants. Intensive roofs often serve as additional parks or areas of enjoyment (thus, they are used intensively). They can support growing-medium thicknesses of up to three feet to grow trees and other deep-rooted plants.

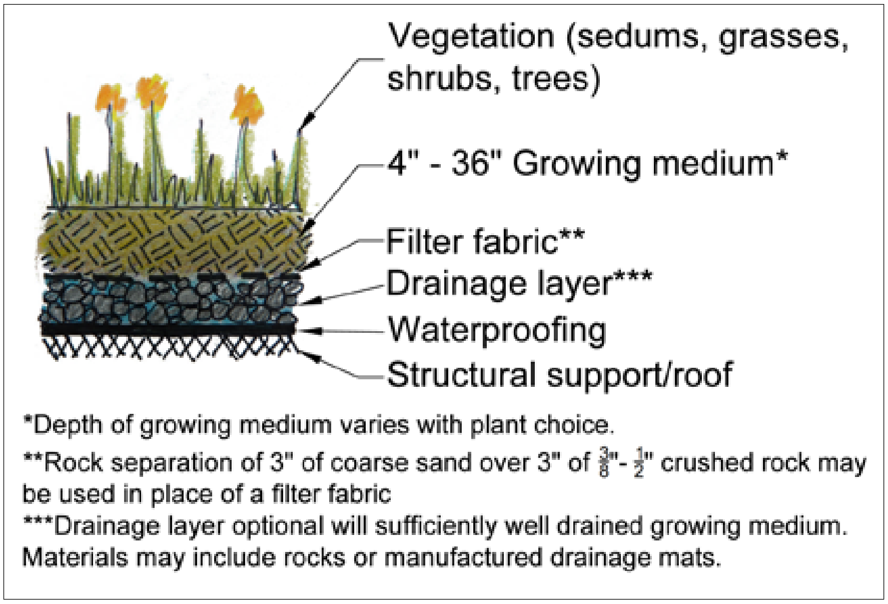
Design

The following descriptions are general guidelines. The structural capacity details of your green roof will be determined by state and local building codes, along with your architect, landscape architect, and structural engineer. *Check your local planning, engineering, or development services department for specific design requirements for your area.*

Growing-medium depth depends on roof space and water-retention goals (BES 2006a). Studies in Portland and Seattle indicate that green roofs can reduce annual runoff volumes by 40 to 60%. Even though green roofs still generate runoff, Portland has

Oregon Sea Grant
Corvallis, Oregon
ORESU-G-11-007

created incentives for green roofs by allowing a developer or builder to replace a building's impervious area with a green roof that meets specific requirements (that is, replacement at a maximum 1:1 area ratio) (BES 2008a). Green roofs can be installed on flat or sloped roofs. Those with slopes greater than 20 degrees require a system that prevents the growing medium and vegetation from slumping. The maximum slope is a function of the frictional coefficient between the different components. When friction can't be relied upon, steep slopes can be mitigated through horizontal strapping, laths, battens, or grids. Maximum weight loads of vegetation and medium are 35 pounds per square foot, not including snow loads (NCDWQ 2007).



Typical vegetated roof detail showing depths for both intensive and extensive roofs.

EXTENSIVE GREEN ROOF OR "ECOROOF" (MINIMAL LOADING/SYSTEM WEIGHT)

These facilities have a thin layer of growing medium or soil, ranging in depth from 4 to 12 inches. Monitoring results from the City of Portland and Washington's King County found 4 inches to be the optimal depth to support plant life and manage stormwater. Extensive green roofs (or "ecoroofs" as the City of Portland calls them) are often used in retrofit situations, because a thin soil profile weighs less, and supporting more weight (that is, a thicker soil profile) requires greater structural integrity of the building (NCDWQ 2007). Extensive roofs are not meant to be accessed other than for maintenance, so there is minimal foot traffic (BES 2006a, NCDWQ 2007). In some cases, it may be possible to remove the 15-pounds-per-square-foot gravel ballast roof on existing buildings and replace it with an ecoroof without additional structural support. When retrofitting a building for a green roof, a structural engineer should be consulted as well as a landscape architect.

INTENSIVE ROOF GARDEN (INCREASED LOADING/SYSTEM WEIGHT)

In this design, the thicker growing medium (12 inches or more) will support a greater diversity of plants and plant sizes (BES 2006a). A more weight-resistant structure is required, so it is generally appropriate only for new construction (NCDWQ 2007).

ROUTING

Depending on the frequency and size of a storm event and the season, green roofs may not retain the entire volume of stormwater. Because of this, all green roofs should include an overflow drain to deliver excess runoff to an approved disposal point (BES 2006a). Portland and other cities also allow overflow to be directed to their public piping system. Facilities such as rain gardens and infiltration planters can be used to infiltrate runoff at the ground level, but care should be taken to avoid designing facilities that may trigger permitting requirements with the Oregon Department of Environmental Quality's Underground Injection Control permitting process. *See other fact sheets in this series for guidance.*

GROWING MEDIUM

The growing medium or soil helps manage peak runoff volumes from roofs. Physical properties to consider are porosity, moisture content at field capacity, moisture content at the wilting point, and saturated hydraulic conductivity (NCDWQ 2007). Growing medium must be deep enough to contain adequate water and nutrients to support the chosen plants, but as thin as possible to reduce weight loads—generally 3 to 6 inches deep (SEMCOG 2008, NCDWQ 2007). For extensive roofs, approximately 4 inches of growing medium is optimal (BES 2008a).

Intensive green roofs require deeper growing medium than extensive green roofs to support a larger range of plant species. Several options are available for growing mediums. Using soils on green roofs isn't recommended because soils can have pollutants, be heavier, contribute fewer nutrients, and lack adequate drainage. To avoid confusion, the industry usually calls the engineered mixes "growing medium" instead of "soil." There are several suppliers of premixed growing medium in Oregon. The City of Portland recommends a mix of 70% porous material, 20% organic material, and 10% digested fiber or alternative mix approved by the Bureau of Environmental Services (BES 2008a). Suggested water-retention rates are 40% by weight or greater. Suggested bulk dry densities are 35 to 50 pounds per cubic foot (NCDWQ 2007).

VEGETATION

Plantings are a key component of green roof functioning. It is best to consult a horticulturalist with a background of working with green roofs (NCDWQ 2007, SEMCOG 2008). Green roofs can have semi-acidic, poor growing medium, which drains rapidly, so it's best to select plants with a high resistance to difficult conditions. When locating plants, consider that the growing medium is likely to drain more rapidly at peaks and remain saturated longer near gutters or drains. As with any stormwater-management facility, seeds, rhizomes, and clippings can easily be transported downstream during overflows to impact the habitat of natural drainageways downstream. For this reason, we recommend selecting native species first and noninvasive species next. Never choose plants on Oregon's Noxious Weed List (ODA 2007).

Selected plants should be

- sun, heat, wind tolerant;
- successful colonizers, perennial, or self-sowing;
- easy to maintain (such as those that outcompete weeds and don't require mowing or trimming);
- self-sustaining (no need for fertilizers or pesticides);
- fire-resistant; and
- appropriate for the depth of soil selected (BES 2008a, NCDWQ 2007).

For extensive roofs where planting options are almost limitless, adhering to these suggestions is more crucial than with intensive roofs (SEMCOG 2008). A variety of trees, shrubs, herbs, succulents, and grasses are applicable to green roofs, so long as they are resistant to conditions (BES 2006a). Succulents have proven highly successful with these facilities (NCDWQ 2007). These plantings should cover 90% of the area in a 2-year span. The City of

Green Girl LDS

Sedums are well adapted to the harsh conditions of green roofs.

Portland suggests a 50% evergreen cover, and no more than 10% of non-vegetation, such as access pavers or ballasts (BES 2008a).

IRRIGATION SYSTEMS

Long-term irrigation is controversial. Depending on how irrigation is triggered (for instance, whether there are automatic weather sensors for just the hot days or if it is based on a regular schedule), watering can reduce the effectiveness of the green roof by saturating soils just before they are needed to absorb rainfall. Others say that a single 100-degree day can kill every plant on the roof, requiring that the plants be replaced. Often the choice of irrigation systems for establishment is a matter of convenience and access, and will vary from client to client.

Irrigation systems on green roofs must also be chosen to withstand the harsh elements of a rooftop. Traditional irrigation systems are installed underground, where soil can protect plastic from harmful UV light and temperature swings, but green roofs may not have enough growing medium to provide long-term protection (BES 2008b). For this reason, you may choose to hand-water during the initial 2- to 3-year establishment period, and occasionally beyond the establishment period during exceedingly hot or dry summers. In addition, you may choose to minimize irrigation needs through the use of mulch by choosing native plants, or by shading the roof with buildings, solar water heaters, or trees.

If irrigation must be installed, install a controller that will adjust the amount of irrigation based on the season or actual rainfall data. Provide this guidance to the contractor, as he or she may not be familiar with green roofs. In the first 2 years, Portland limits irrigation to a maximum of ½ inch per 10 days from May to October, and a maximum of ¼ inch per 10 days at other times. Also, consider if the system needs to be winterized. Green roofs larger than 5,000 square feet may benefit from an irrigation flow meter (BES 2008a).

ROOF ASPECT

Roof aspect is the direction a sloped roof is facing. North- and east-facing directions are considered excellent aspects for ecoroofs because they have reduced exposure to the sun and require less (or no) irrigation. South- and west-facing directions may require increased growing-medium depths and more irrigation to support plant life. Don't forget to consider shading from nearby vegetation and structures (BES 2008b).

Bureau of Environmental Services

The Hamilton West Apartments ecoroof in Portland, Oregon, is carefully monitored by the City of Portland.

MEMBRANES/ LINERS

Several liners are required for proper roof protection. The base layer of a green roof should be a waterproof membrane

(SEMCOG 2008, BES 2008a, NCDWQ 2007) such as asphalt (modified to protect against breakdown of the asphalt by microbial activity), synthetic rubber, or reinforced thermal plastics (BES 2008a). Often times, this layer can include a root-barrier fabric as well. If not, a separate root-barrier layer may be included to prevent root penetration, which could damage the building's roof. However, a root barrier is not always necessary. For instance, an ecoroof planted with grasses and flowers would experience damage from aggressive roots only if trees and shrubs volunteer on the roof and are not weeded. If you do install a root barrier, it should be manufactured without pesticides or chemicals that have the potential to kill plants or pollute stormwater (BES 2008a). The root barrier and/or waterproof membrane can also serve to capture nutrients and precipitation for plant use (SEMCOG 2008). For specifics on requirements and selection, please consult a reference manual or a professional.

DRAINAGE LAYER

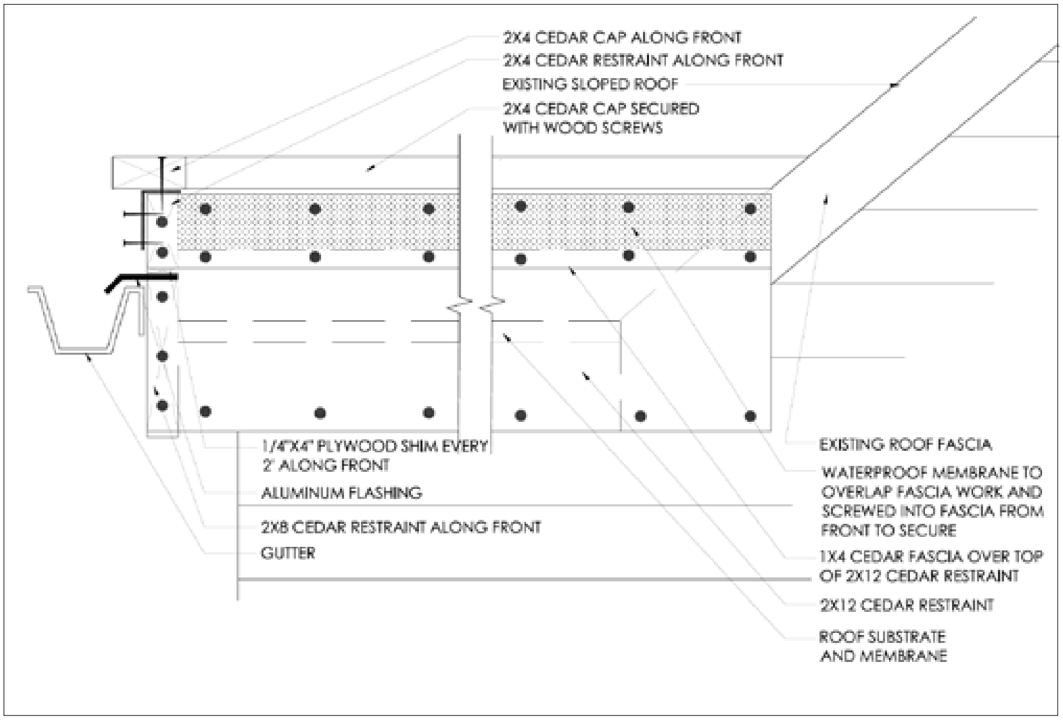
A drainage layer is often installed above the waterproof membrane and root barrier. This layer collects excess runoff from the growing medium and directs it to downspouts or gutters. If desired, the layer can be used to increase water-storage capacity, provide additional aeration space, and increase the root-zone area. Regardless of its use, it should be lightweight material, such as rubber or plastic, but gravel, lava, and expanded clay are occasionally acceptable (SEMCOG 2008). If the growing medium is sufficiently well drained, this layer may not be needed.

FILTER FABRIC

Finally, a filter fabric (usually geotextile) protects the drainage layer from the growing medium. This layer will catch fine particles that can clog underlying layers and also make the particles available for plants (SEMCOG 2008).

Access

Be sure to consider how access will be provided for operations and maintenance. This may require getting people and their maintenance equipment up to the roof.



BioMimickry

Residential ecoroof retrofit detail. Thinking ahead can save time during construction.

Pollutant Removal

Green roofs can remove airborne pollutants, such as acid rain and particulates (Berghage et al. 2007), in addition to mitigating flow rates, volumes, and temperatures of waters reaching the ground through downspouts (NCDWQ 2007, BES 2006a). Based on published research, the Center for Watershed Protection (CWP) estimated the total amount of phosphorus and nitrogen removed to be equivalent to the 45 to 60% of annual runoff reduction (CWP & CSN 2008), although nitrogen and phosphorus are highly resoluble and can also leach back out of a green roof. Pollutant-removal levels are a direct result of the runoff reduction achieved through evaporation. Without evaporation, the CWP has found that the event mean concentration pollutant removal rates for both phosphorus and nitrogen are 0.0% (2008).

Construction

During construction, protection boards can be used and building design elements such as skylights, mechanical systems, vents, and parapets should be well protected (NCDWQ 2007, BES 2008a).

The waterproof membrane is crucial to protecting the building underneath from water intrusion. To protect the membrane from punctures and the rest of the roof assembly from possible abuse, the ecoroof installers should be the last people on the roof. Before adding other materials, the roof should be flooded to check for leaks. Follow the installation guidelines of individual manufacturers carefully, since requirements vary for each type of material.

Growing medium can be brought up to the roof manually (wheelbarrow, bucket, shovel) or via a crane, conveyor, or blower. Plants can be installed by hydroseeding, using cuttings (for sedum, especially), and planting plugs. Potted plants are often discouraged because they become established in nursery soil and often don't transition well to a growing medium with so much less organic matter. There are also several proprietary vegetated mats and tray systems that can be used to establish plants very quickly. If the ecoroof will be exposed to wind velocities that may carry the soil off, an erosion-control fabric like jute mat should be laid over the soil during plant establishment. After establishment, maintaining proper vegetative coverage, at least 75% (BESa), will hold the soil in place.

Derek Godwin

Pringle Creek Community in Salem, Oregon.

Maintenance

Maintenance of green roofs is relatively low, and is most demanding during plant establishment when weekly inspection is suggested (BES 2006a, NCDWQ 2007). Beyond plant establishment, 2- to 3-year inspection intervals are recommended, along with inspection after large storm events (NCDWQ 2007). Tasks include hand weeding and mulching, and removal of cut grasses and vegetation (BES 2006a). Be sure to specify in your operations and maintenance manual which plants are considered to be weeds, including plants with deep roots (such as trees) that might damage the membrane, plants that could become a fire hazard, and plants on the Oregon Noxious Weed List (ODA 2007). In western Oregon, checking for weeds in late May or early June may limit the necessary weeding to once a year, but wet summers or overirrigation may encourage weed growth.

Fertilizers are not encouraged, but if they are necessary, they should be nonchemical. Pesticides and herbicides are prohibited and generally have been unnecessary. The City of Portland's 2004 *Stormwater Management Manual* provides a table of potential maintenance issues and suggested solutions (BES 2004).

Inspect the irrigation system at least once a year. If plants are struggling, the causes may include too much or too little water, pests, condensate from the HVAC system, or chemical spills from rooftop equipment maintenance.

Permits

Check with local plumbing and piping codes to ensure proper construction of both retrofit and new projects. The engineering department may review the stormwater-management aspects of green roofs, and depending on location of the facility, residential or commercial permits may be required (BES 2008a, BES 2006a). Consult with your local engineering or development services department during the early planning phase of the project to find out what is required for permitting in your jurisdiction.

Other

Green roofs conserve space and, in some cases, can receive credits for stormwater fees. They cannot, however, receive nutrient reduction credit. Because construction takes place on elevated structures, safety for construction workers is a concern. Consider how air vents and other mechanical equipment can affect the plants, and the detailing of a waterproof membrane where it must intersect with roof penetrations. Many green roofs have been installed in Portland and no excessive wind issues have been found, but wind erosion could be a problem for green roofs in other areas of Oregon. Consult a design professional when constructing a green roof (NCDWQ 2007).

Cost

These are one of the most expensive LID facilities, but long-term cost savings can be gained from decreasing costs of cooling energy and a long roof lifespan (in a number of German facilities, the lifespan easily exceeds 50 years). Cost will also vary with the structural demand needed to support vegetation (NCDWQ 2007, BES 2006a). If additional structural support is not (or only minimally) required, costs can range from $0 to $5[1] per square foot (BES 2008b). If significant structural upgrades are needed, the cost of a green roof can increase depending on how much additional weight-bearing capacity must be added: "Costs range from $10 to $15 per square foot for new construction and $15 to $25 per square foot for reroofing" (BES 2006b)."

Other factors can greatly affect costs, including how the growing medium is transported to the roof, the height of the building, project location and accessibility (remoteness), size of facility, and assembly choices. For instance, hydroseeding is expensive, while spreading sedum clippings can be very cost-effective. For short buildings, manual delivery via buckets and wheelbarrows will be cheapest, but for tall buildings, material will often need to be pumped or craned up to the roof. Equipment mobilizing costs can also be significant.

1 Values are in 2010 dollars.

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Editing and layout by Rick Cooper; template design by Patricia Andersson.

This report was prepared by Oregon Sea Grant under award number NA06OAR4170010 (project number A/ESG-07) from the National Oceanic and Atmospheric Administration's National Sea Grant College Program, U.S. Department of Commerce, and by appropriations made by the Oregon State legislature. The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of these funders.