

## A.6 VEGETATED (GREEN) ROOFS



Location: County of San Diego Operations Center, San Diego, California.

**Figure A.6-1. Vegetated (green) roof.**

### A.6.1 DESIGN

The design of a vegetated (green) roof can be broken down to a nine-step process. Table A.6-1 summarizes the basic design steps, which are described in more detail below. Additional design guidance can be consulted in the *Design Guidelines and Maintenance Manual for Green Roofs in the Semi-Arid and Arid West* (Tolderlund 2010).

**Table A.6-1. Vegetated (green) roof iterative design step process**

Design step		Design component/ consideration	General specification
1	<b>Determine Vegetated Roof Type</b> (A-64)	Extensive	Shallow growing media (4 to 6 inches), small drought tolerant vegetation, no irrigation needed.
		Intensive	Growing media more than 6 inches, regular irrigation required, deeper rooted vegetation. Contact qualified professional with experience designing intensive vegetated roofs.
2	<b>Determine Integrated Management Practice (IMP) Treatment Volume</b>	Runoff calculations	Per chapter 2 of the County SUSMP, the volume of the 24-hour 85th percentile storm is required for the water quality treatment method.
3	<b>Determine Structural Capacity of Roof</b> (A-65)	Underlying roof deck and building structure	Evaluate proposed or existing building and roof structure to determine additional dead and live load capacity available to accommodate green roof installation.
4	<b>Specify Impermeable Liner and Root Barrier</b> (A-65)	Roof liner	Select waterproof liner. Conventional roof waterproofing tar is typically sufficient but can be supplemented with waterproof geomembranes if desired.
		Root barrier	Select root barrier. Geomembranes used as waterproof liners can sometimes double as root barriers.
5	<b>Specify Drainage Layer</b> (A-65)	Aggregated	Minimum 2 inches of clean washed No. 8 stone or alternative lightweight, high-porosity, inorganic or synthetic aggregate. Geotextile fabric should be installed between the media and the aggregate.
		Manufactured	Select drainage layer specified for green roof applications that incorporates minimum of 0.75 inches of retention storage of rainfall. Geotextile fabric should be installed between the media and the drainage layer.
6	<b>Design Outlet Components</b> (A-66)	Roof drains	Provide roof drains or scuppers consistent with local building codes. Surround outlets with minimum of 12 inches of high-porosity drainage material (washed ASTM No. 57 stone or comparable).
7	<b>Specify Media</b> (A-66)	Depth	Minimum 4-inch depth (intensive vegetated roofs).
		Composition	Media should consist of well-drained, high-porosity mix of primarily lightweight aggregate. (Preferred media is site specific, but expanded mineral materials are typically specified for intensive vegetative roofs.)  pH = 6.5–8.0, cation exchange capacity greater than 10 milliequivalents per 100 grams (meq/100 g).
8	<b>Select Vegetation</b> (A-67)	Low growing, drought-tolerant species	See Plant Palette (Appendix E).
9	<b>Design for Multi-Use Benefits</b> (A-67)	Additional benefits	Include features to enhance habitat, aesthetics, public education, recreation opportunities, and energy savings.

### A.6.1.1 STEP 1. DETERMINE VEGETATED ROOF TYPE

Vegetated roofs can be categorized into two basic types; extensive and intensive. The following subsections describe each type of vegetated roof.

#### A.6.1.1.1 EXTENSIVE VEGETATED ROOF

An extensive vegetated roof typically has the following characteristics:

- Includes 6 inches of media or less.
- Has shallow rooting and xeric vegetation.
- Requires little to no irrigation. If irrigation is required, typically drip irrigation is used.
- Contributes minimal loads to the rooftop.

Figure A.6-2 shows an example of an extensive vegetated roof.



Location: Fallbrook Library, Fallbrook, California.

**Figure A.6-2. Extensive vegetated roof.**

#### A.6.1.1.2 INTENSIVE VEGETATED ROOF

An intensive vegetated roof typically has the following characteristics:

- Includes more than 6 inches of media.
- Uses deep-rooting plants.
- Irrigation likely needed. Native plants can minimize irrigation requirements.
- Contributes significant loads to the roof structure requiring significant structural strength and design.
- Acts as an amenity with park-like features.

#### A.6.1.2 STEP 2. DETERMINE IMP TREATMENT VOLUME

Vegetated roofs must be sized to fully capture the desired or required design storm volume. Relevant sizing regulatory requirements are presented in chapter 2 of the County SUSMP.

#### A.6.1.3 STEP 3. DETERMINE STRUCTURAL CAPACITY OF ROOF

A qualified structural engineer should be consulted to determine the structural capacity of the proposed vegetated roof that would be necessary to withstand the additional dead and live loadings resulting after installation. Typical dead weight loading of fully saturated systems for intensive and extensive installations are found in Table A.6-2.

**Table A.6-2. Typical dead weight of fully saturated vegetated (green roof) systems**

Vegetated roof type	Typical dead loading
Intensive	15 to 55 pounds per square foot
Extensive	75 to 150 pounds per square foot

Source: Tolderlund 2010.

#### A.6.1.4 STEP 4. SPECIFY IMPERMEABLE LINER AND ROOT BARRIER

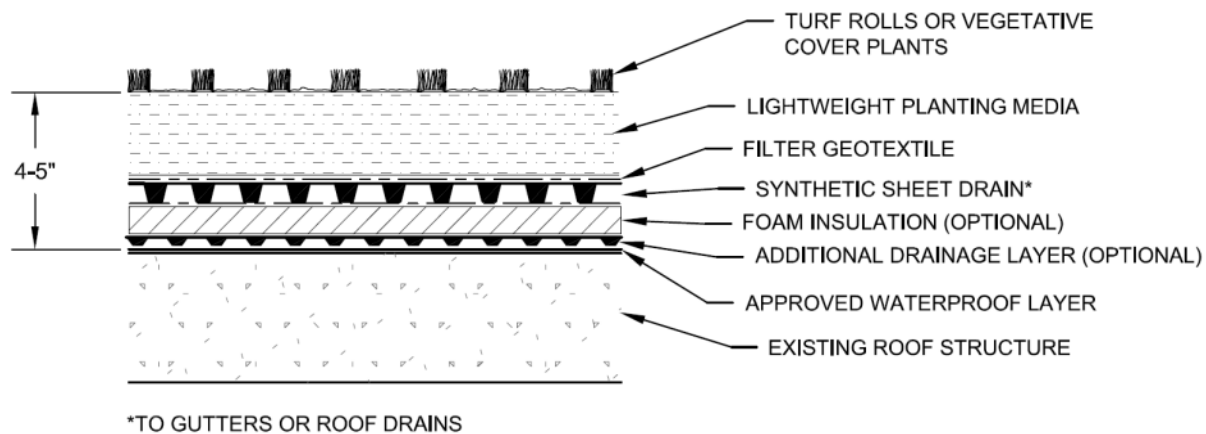
As with all roofs, a watertight barrier must be provided to prevent rainwater from infiltrating into the underlying structure. Watertight tar surfaces (conventionally used for roof sealing) are usually sufficient impermeable liners, but additional plastic or rubber membranes can be placed over the tar for added protection. The liner should be resistant to heat, desiccation, and ultraviolet radiation. A root barrier should be specified and placed directly above the impermeable liner or, alternatively, above an optional insulation layer that can be placed directly on the liner.

#### A.6.1.5 STEP 5. SPECIFY DRAINAGE LAYER

A drainage layer, also known as a *drainage net* or *sheet drain*, is necessary to convey excess rainwater to the roof drains. This layer will also maintain an aerobic root zone for plant health. Geotextile should be placed between the media and the drainage layer to prevent migration of media and act as a root barrier.



Geotextiles containing chemicals that prevent root penetration can be used to prevent root systems from infiltrating and clogging the drainage layer. Figure A.6-3 depicts a typical green roof cross section.



**Figure A.6-3. Typical extensive green roof profile.**

### A.6.1.6 STEP 6. DESIGN OUTLET COMPONENTS

As with all roofs, components must be incorporated in the roof structure to allow excess runoff to drain off the rooftop and away from the building. Outlet types for vegetated roofs include the following:

- Internal roof drains
- Roof scuppers along roof perimeters

Roof drain components should be designed to comply with local building codes. To prevent clogging and provide adequate conveyance, green roof vegetation and soil media should be set back a minimum of 12 inches from roof drains. A screen, gravel apron of washed No. 57 stone (or comparable), or other alternative high-porosity material, can be placed around the roof drain to discourage overflow flooding.

### A.6.1.7 STEP 7. SPECIFY MEDIA

Soil media for vegetated roofs should have the following characteristics:

- Well-drained and aerated
- High porosity
- High nutrient holding capacity (cation exchange capacity)
- Permanent (nonbiodegrading)
- Lightweight
- Windproof
- Stable (must support plants)

Several media types are available from green roof component suppliers, but generally expanded lightweight aggregates are preferred (e.g., expanded slate, expanded shale, expanded clay, terra cotta). For extensive green roofs, a minimum of 4 inches of media should be provided. The specifications Table A.6-3 provides are example parameters that should be specified on design plans. Intensive green roofs should also employ lightweight aggregate media, but structural capacity generally allows a wider range of soil materials.

**Table A.6-3. Example green roof media specifications**

Parameter	Specification
Noncapillary pore space at field capacity	15% (vol)
Moisture content at field capacity	12% (vol)
Maximum media water retention	30% (vol)
Alkalinity, CaCO <sub>3</sub> equivalents	2.5%
Total organic matter by wet combustion	3–15% (dry wt.)
pH	6.5–8.0
Soluble salts	6 mmhos/cm
Cation exchange capacity	10 meq/100g
Saturated hydraulic conductivity for single media assemblies	0.05 in/min
Clay fraction (2 micron)	0
Pct. passing US#200 sieve (i.e., silt fraction)	5%
Pct. passing US#60 sieve	10%
Pct. passing US#18 sieve	5%–50%
Pct. passing 1/8-inch sieve	20%–70%
Pct. passing 3/8-inch sieve	75%–100%

Source: based on East Baton Rouge Parish 2007.

### A.6.1.8 STEP 8. SELECT VEGETATION

Green roof vegetation should consist of low-growing, highly drought-tolerant species that can survive in the harsh environment of a rooftop. Common vegetation types include grasses and succulents.

Appendix E includes a full plant list.

### A.6.1.9 STEP 9. DESIGN FOR MULTI-USE BENEFITS

In addition to enhancing biodiversity and beautifying the urban environment with native vegetation, the following components can be incorporated into vegetated roofs to promote multi-use benefits:

- Simple signage or information kiosks can educate the public about the benefits of watershed protection measures or provide a guide for native plant and wildlife identification.
- Bird and butterfly feeders can be used to attract wildlife to the vegetated roof.

- Sculptures and other art can be installed on the vegetated roof; outlet structures can be painted lively colors.
- Intensive vegetated roofs can be equipped with pedestrian cross-paths or benches for wildlife viewing.
- Vegetation with canopy cover can provide shade, localized cooling, and noise dissipation.
- Vegetated roofs can reduce energy use and the heat island effect.

## A.6.2 CRITICAL CONSTRUCTION CONSIDERATIONS

Green roofs' unique nature requires construction considerations that are not applicable to landscape-based integrated management practices (IMPs). Examples include:

- Providing access for installation, inspection, and maintenance
- Considering supplemental irrigation during plant establishment
- Ensuring visitor safety

## A.6.3 OPERATIONS AND MAINTENANCE

Vegetated roofs require regular plant, soil, and drainage layer maintenance to ensure optimum filtration, storage, and pollutant removal capabilities. Table A.6-4 provides a detailed list of maintenance activities.

**Table A.6-4. Inspection and maintenance activities for vegetated roofs**

Task	Frequency	Indicator maintenance is needed	Maintenance notes
<b>Media Inspection</b>	Two times per year	Internal erosion of media from runoff or wind scour, exposed underlayment components	Replace eroded media and vegetation. Adopt additional erosion prevention practices as appropriate.
<b>Liner Inspection</b>	One time per year	Liner is exposed or tenants have experienced leaks	Evaluate liner for cause of leaks. Repair or replace as necessary.
<b>Outlet Inspection</b>	Two times per year	Accumulation of litter and debris around the roof drain or scupper or standing water in adjacent areas	Litter, leaves, and debris should be removed to reduce the risk of outlet clogging. If sediment has accumulated in the gravel drain buffers, remove and replace the gravel.
<b>Vegetation Inspection</b>	One time per year	Dead plants or excessive open areas on green roof	Within the first year, 10 percent of plants can die. Survival rates increase with time.
<b>Invasive Vegetation</b>	Two times per year	Presence of unwanted or undesirable species	Remove undesired vegetation. Evaluate green roof for signs of excessive water retention.
<b>Temporary Watering</b>	One time every 2 to 3 days for first 1 to 2 months	Until established and during severe drought	Watering after the first year might be required.

## A.6.4 REFERENCES

County of San Diego. 2012. *County of San Diego SUSMP: Standard Urban Stormwater Mitigation Plan Requirements for Development Applications*.

[http://www.sdcountry.ca.gov/dpw/watersheds/susmp/susmppdf/susmp\\_manual\\_2012.pdf](http://www.sdcountry.ca.gov/dpw/watersheds/susmp/susmppdf/susmp_manual_2012.pdf).

East Baton Rouge Parish. 2007. Chapter 7. *East Baton Rouge Parish Stormwater BMP Manual*. Accessed January 7, 2013. <http://brgov.com/dept/planning/WWS/pdf/bmp7.pdf>.

Tolderlund, Leila. 2010. *Design Guidelines and Maintenance Manual for Green Roofs in the Semi-Arid and Arid West*. University of Colorado, Denver, CO.