

4.1 Green Roofs

A green roof (vegetated roof/eco roof/roof garden) is a system consisting of waterproofing material, growing medium and vegetation. A green roof can be used in place of a traditional roof as a way to limit impervious site area and manage storm water runoff. The green roof design should attempt to mimic pre-developed site hydrology, reducing post-developed peak runoff rates to near pre-developed rates. Green roofs also help mitigate runoff temperatures by keeping roofs cool and retaining much of the runoff from typical storm events. Although many green roofs consist of lightweight growing medium and low-growing succulent vegetation, other more heavily planted systems are possible; in either case the design should be self-sustaining.

The structural support must be sufficient to hold the additional weight of the green roof. Greater flexibility and options are available for new buildings than for reroofing existing buildings, however retrofits are possible. For retrofit projects, an architect, structural engineer, or roof consultant can determine the condition of the existing building structure and what might be needed to support a green roof. Alterations might include additional decking, roof trusses, joists, columns, and/or foundations. Generally, the building structure must be adequate to hold an additional 15 to 25 pounds per square-foot (psf) saturated weight, depending on the vegetation and growth medium that will be used (in addition to live load requirements). An existing rock ballast roof may be structurally sufficient to hold a 10-15 psf green roof (ballast typically weigh 10-15psf).

Two additional alternatives, to the traditional bituminous roofing material, are a single ply cool roof and reflective tiles. White single ply membranes are highly reflective, as compared to traditional bituminous roofing material, and can help reduce the urban heat island effect as well as save the building owner cooling costs. Reflective tiles are usually made of clay or concrete, and manufacturers have begun to develop pigments that reflect in the infrared. Special pigments allow roofing material to keep their traditional colors, such as brown, green, and terra cotta, while reflecting away up to 70% of the sun's energy. These products enable buyers to forego the perceived tradeoff between energy efficiency and the aesthetic concerns with a bright-white roof (EPA, 2007).



Key Elements:

- Green Roofs must be designed in accordance with applicable city, state, and federal building codes and a drainage system and overflow to an approved conveyance and discharge location must be designed in accordance to the Storm Water Design and Specification Manual.
- Internal drainage, including provisions to cover and protect deck drains, must anticipate the need to manage large rainfall events without inundating the cover.
- Green roofs with engineered growing medium of at least 3 inches in depth can be considered more pervious in storm water design calculations for the WQv sizing equation than a standard roof.
- Providing urban green space, aesthetically pleasing views, and habitat.
- May reduce utilities such as heating and cooling costs.
- Can extend roof life by two to three times.
- Improve air quality by filtering dust particles.
- LEED points.

Table 4.1.1: Green Roof Potential Application and Storm Water Regulation

Potential applications		Storm water regulations		
			Infiltration	No Infiltration
Residential				
Subdivision:	Yes	Water Quality Benefit	No	Yes
Commercial:	Yes	Volume Reduction	No	Yes
Ultra Urban:	Yes	Attenuation Benefit	No	Yes
Industrial:	Yes			
Retrofit:	Yes			
Highway Road:	No			

Acceptable forms of pre-treatment

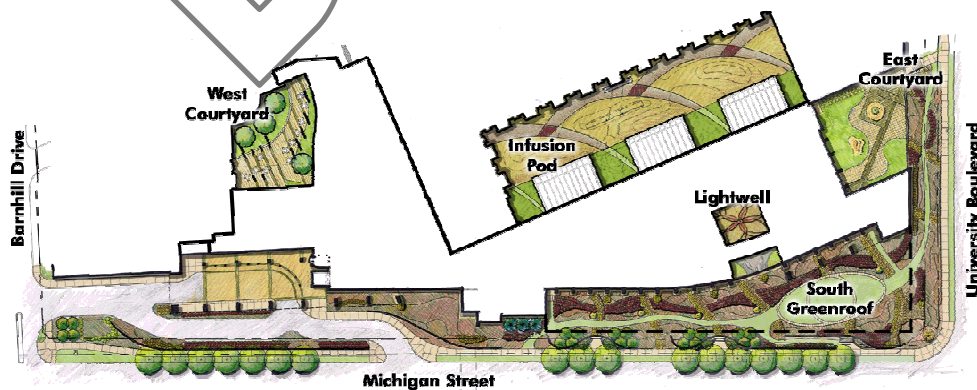
N/A

Green Roofs in the Urban Landscape

Unlike conventional roofing, green roofs promote retention and evapotranspiration of precipitation. This storm water management technique is very effective in reducing the volume and velocity of storm water runoff from roofs.

Green roofs can be installed on many types of roofs, from small slanting roofs to large commercial flat roofs. The maximum acceptable pitch for conventional green roofs is 25%, unless documentation is provided for runoff control on a steeper slope. Green roofs are an ideal option for new buildings that are taking long term cost savings and energy conservation into consideration. Many existing buildings can also be retrofitted with green roofs if structurally capable.

Although green roofs are more expensive than conventional roofs initially, they provide long term benefits and costs savings. A green roof's underlying waterproofing can extend the life of a roof two to three times by protecting the roof from mechanical damage, shielding the roof from UV radiation, and buffering temperature extremes. Green roofs also reduce energy costs by providing insulation and absorbing/reflecting excess heat and light. The roof slowly absorbs energy from the sun during the day and releases it as the air cools, thereby reducing heating and cooling costs. The benefits will be greatest during the summer months, and low buildings will see the greatest benefits. Green roofs also reduce the urban heat island effect by providing evaporative cooling and can improve air quality by filtering dust particles.

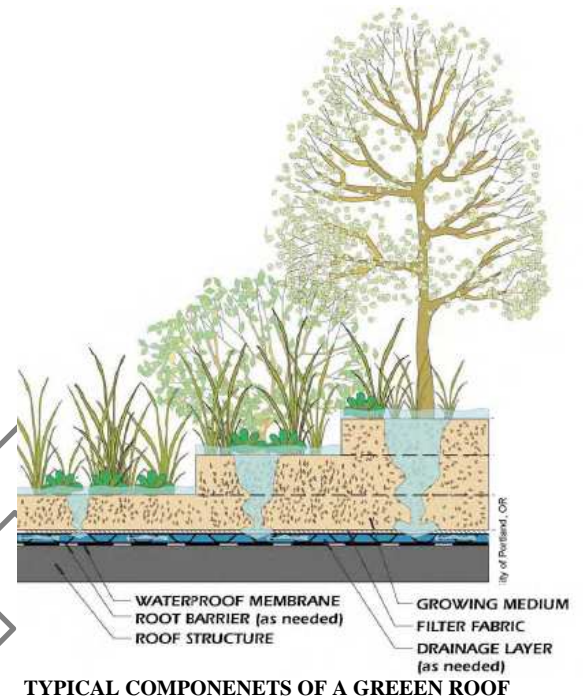


MICHIGAN STREET AND UNIVERSITY
BOULEVARD: INDIANAPOLIS
IU MELVIN BREN SIMON CANCER CENTER

Components of a Green Roof

There are three basic types of green roofs (GRHC, 2008). An extensive green roof system is 6 inches or less in depth, and has a water saturation weight of 10-35 lbs/ft². It usually has limited accessibility and is planted with drought-tolerant succulent plants and grasses. A semi-intensive green roof contains material 25% above or below 6 inches. It may be partially accessible, has a water saturation weight of up to 50 lbs/ft² and has potential for greater plant diversity than an extensive roof. An intensive green roof is deeper than 6 inches and typically has a water saturation weight between 50-300 lbs/ft². These roofs are usually accessible to others besides maintenance and allow for great plant diversity. Each green roof project is unique, given the purpose of the building, its architecture and the preferences of its owner and end user. However, green roof systems are typically comprised of the same components:

- Plant material
- Growing medium
- Filter fabric
- Drainage layer
- Insulation (optional)
- Waterproof membrane/root barrier
- Roof structure



In addition to the three primary green roof categories, there are two main approaches to installing green roofs; these are classified as Modular and Loose Laid. Each of these categories includes a variety of specific construction methods and system design approaches.



**MODULAR GREEN ROOF
SYSTEM INSTALLATION**



**DEARBORN, MI-FORD ROUGE CENTER COMPLEX-
10-AC GREEN ROOF –PART OF A 600-AC STORMWATER
MANAGEMENT SYSTEM AT A BROWNFIELD SITE**



PLANT MATERIAL

Plant Material

The plant material chosen for green roofs is designed to take up much of the water that falls on the roof during a storm event and be drought tolerant. Plant material also collects dust, creates oxygen, releases moisture, and provides evaporative cooling. Plant selection is very important to the sustainability of the roof. The extensive green roof should reach 90% growth coverage within two years. The following criteria should be taken into consideration when selecting vegetation for the green roof:

- Drought tolerant, requiring little or no irrigation after establishment
- Self-sustaining, without the need for fertilizers, pesticides, 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 resistant



SEDUM MIX

A mix of sedum/succulent plant communities is recommended because they possess many of these attributes. Herbs, forbs, grasses and other low groundcovers can also be used to provide additional benefits and aesthetics, however these plants may need more watering and maintenance to survive and keep their appearance. Refer to *Green Roof Plants* by Snodgrass and Snodgrass for a comprehensive list of plants suitable for green roofs.

Growing Medium

The growing medium is a critical element of storm water storage and detention on a green roof, and provides a buffer between the roof structure and vegetation for root development. Storage is provided by a green roof primarily through water held in tension in the growing medium pores.



**KENTUCKY SANITATION
DISTRICT1-DEMONSTRATION SITE**

The growing medium in an extensive green roof should be a lightweight mineral material with a minimum of organic material and should stand up to freeze/thaw cycles. Semi-intensive and intensive roofs may have organic material and/or sand added to the mineral material. Organic material should not contain peat, because of its nonrenewable nature and burning potential, nor animal waste, which can leach pollutants into storm water and may eventually leave the site. The engineered material should be FLL approved.



CROSS SECTION-GROWING MEDIUM

Filter Fabric

An engineered, non woven filter fabric prevents fine soil particles from passing into the drainage layer of the green roof system.

Drainage Layer

The drainage layer is a lightweight granular medium and/or plastic material resembling egg cartons set beneath the planting medium. The drainage layer needs to provide a balance between water retention and root aeration and is a critical component of the storm water retention function. An approved discharge location should be

identified for every green roof and drain(s) provided.

Waterproof Membrane/Root Barrier

To maintain structural integrity of the roof, a waterproof material is laid above the roof structure. Some waterproofing materials are inherently root resistant, whereas others require an additional root barrier. It is important that the membrane be of high quality as it will be labor intensive to replace once the green roof components are in place.

Roof Structure

The load capacity of a roof structure must be taken into account when considering the installation of a green roof. Extensive green roofs typically weigh between 15 and 25 psf and are compatible with wood or steel decks. Intensive green roof weigh more than 50 psf and typically require concrete supporting decks.

Recommended Design Procedure

- Early communication between the design team (developer, civil engineer, structural engineer, architect, landscape architect, planner, roofer etc) is extremely important in the design procedure.
- Investigate the feasibility of the installation of a green roof. A structural engineer should verify that the roof will support the weight of the green roof system. It is important to consider the saturated weight of the roof in the design calculations.
- Determine the portion of roof that will have a green roof. Typically 10% or less of the green roof is composed of non-vegetated components such as gravel ballast, pavers for maintenance access, etc.
- Extensive green roofs that have an engineered growing medium of at least 3 inches thick can be permitted as water quality volume reduction equal to the entire area of the green roof.
- Although green roofs are not considered as impervious surfaces when determining storm water management requirements, they are not zero discharge systems. The roof drainage system and the remainder of the site drainage system must safely convey roof runoff
- Develop a planting plan based on the thickness of the planting media.
- Complete construction plans and specifications.

Materials

Presently (2008), the only widely-accepted, established standards for green roof construction are those developed in Germany by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL). The FLL guidelines include industry standard tests for the weight, moisture, nutrient content, and grain-size distribution of growing media. FLL also certifies laboratories to conduct critical tests, such as the root penetration resistance of waterproofing membranes. These guidelines are available in English translation directly from FLL. There is also an American Standard Testing Methods (ASTM) task group that is developing comprehensive American standards for green roof installation.

Materials for green roofs will vary somewhat depending on the media thickness, intended uses, and desired appearance. The specifications provided below focus on those for a 3-inch extensive green roof system.

Plant Material

- Green roof plantings should be able to withstand heat, cold, and high winds. After establishment, the plants should be self-sustaining and tolerant of drought conditions.
- For extensive green roofs, about half of the plants should be varieties of sedums. To ensure diversity and viability, at least four different species of sedum should be used. For an extensive green roof, the remainder of the plants should be herbs, meadow grasses, or meadow flowers, depending on the desired appearance.
- *Sedum sarmentosum* also known as star sedum, gold moss, stringy stonecrop, or graveyard moss and *Sedum hispanico* are known to be invasive and should be avoided.
- Green roofs should include a significant percentage of evergreen plants to minimize erosion in winter months.
- When fully established, the selected plantings should thoroughly cover (90% or more), the growing medium.

Growing Medium

- Green roof growing medium should be a lightweight mineral material with a minimum of organic material and should meet the following standards
 - Non-Capillary Pore Space at Field Capacity, 0.333 bar: $\geq 15\%$ (vol)
 - Moisture Content at Field Capacity: $\geq 12\%$ (volume)
 - Maximum water retention: $\geq 30\%$ (volume)
- The nutrients shall be initially incorporated in the formulation of a suitable mix for the support of the specified plant materials.

Filter Fabric

Filter or separation fabric shall allow root penetration, but prevent the growth medium from passing through into the drainage layer. The fabric should be a non-woven polypropylene geotextile.

Drainage Layer

- Drainage layer shall be used to provide conveyance of excess water in the green roof system. The layer shall meet the following specifications:
 - Abrasion resistance (ASTM-C131-96): $\leq 25\%$ loss

- Soundness (ASTM-C88 or T103 or T103-91): $\leq 5\%$ loss
- Porosity (ASTM-C29): $\leq 25\%$ loss
- Grain size distribution (ASTM-C136)
 - Percent Passing US#18 sieve: $\leq 1\%$
 - Percent Passing $\frac{1}{4}$ -inch sieve: $\leq 30\%$
 - Percent Passing $\frac{3}{8}$ -inch sieve: $\leq 80\%$

Waterproof Membrane/Root Barrier

- PVC, EPDM, and thermal polyolefin (TPO) are inherently root resistant; other common waterproofing materials might require a root barrier between waterproofing and vegetative cover. PVC has been shown to release toxins in some situations and should be avoided if other alternatives are available.
- Avoid using herbicides to prevent root penetration of waterproofing.

Irrigation System

- It is recommended that extensive systems be designed to not require irrigation.
- When using an irrigation system pipes should not be placed directly on the waterproof membrane, but on a protection board or among the growing medium to avoid damage to the system from pressure and pipe movement.

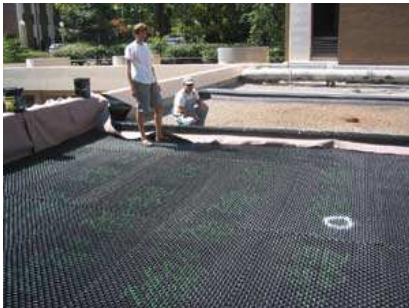
Roof Structure

- Typical roof structure should have structural stability inspected by a Structural Engineer.

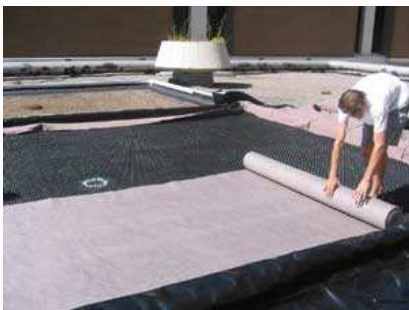
Construction Guidelines



FLOOD TEST



DRAINAGE LAYER



DRAINAGE MAT

- A safety program is one of the most important considerations for anyone that will be building a green roof. All governmental fall and safety protection regulations must be followed.
- Pre construction meeting/training for all trades involved in the installation of a green roof is critical to the success of a green roof due to the number of trades involved.
- Contractors should be trained for green roof installation and have a thorough understanding of the overall system that they are installing. Contractors must be aware of the roof access points, load bearing points, material storage requirements, mode of transportation of materials to the jobsite, and scheduling of materials.
- Apply waterproof membrane and inspect for any irregularities that would interfere with its elemental function within the green roof system.
- The waterproof membrane should be protected when exposed to increased moisture levels from construction and in work traffic zones. Membrane protection should be a mandatory requirement of installation for the period of time it is exposed during staging and installation of overburden, i.e. all layers above the membrane. All membrane layers should have enough strength to cope with the weight of construction equipment. The following are membrane protection techniques:
 - Restrictions of traffic on membrane
 - Physical protection
 - Phased construction
- When the waterproofing membrane is installed it must be tested to ensure that there are no leaks, after which it should be continuously protected.
- The design professional is responsible for deciding the best method to test the integrity of the waterproofing membrane. The most common method used is flood testing. A flood test typically involves the following steps:
 - Temporary blockage of drain system
 - Area covered with 2" water for 24 to 48 hours
 - Inspection of the underside of test area for water infiltration
 - Careful removal of water from the site so as not to stress the drainage system.
- Install drainage layer, taking care to protect the waterproof membrane from damage.
- Test the drainage system.
- Install the filter fabric or separation layer over entire drainage layer.

- Install growing medium component as specified.



GROWING MEDIUM

- Establish vegetation in the spring for best results, sedums can be established from fresh cutting that are broadcast onto the growing medium.
- In May/June or September/October, sedum plugs can be established by planting them 1 foot on center.
- Perennials can be seeded, except during summer months.
- A biodegradable or photodegradable wind barrier or hydromulch may be used to prevent erosion during the establishment period. It generally takes about two growing seasons for full establishment.



PLANTING

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Maintenance Guidelines

All facility components, including plant material, growing medium, filter fabric, drainage layer, waterproof membranes, and roof structure should be inspected for proper operations, integrity of the waterproofing, and structural stability throughout the life of the green roof.

Table 4.1.2: Green Roof Maintenance Guidelines

Activity	Schedule
<ul style="list-style-type: none">▪ Drain inlet pipe should be cleared when soil substrate, vegetation, debris or other materials clog the drain inlet. Sources of sediment and debris may be identified and corrected.▪ Plant material should be maintained to provide 90% plant cover. Weeding should be manual with no herbicides or pesticides used. Weeds should be removed regularly and not allowed to accumulate.▪ Irrigation, although not recommended, can be accomplished either through hand watering or automatic sprinkler systems if necessary during the establishment period.	As needed
<ul style="list-style-type: none">▪ Growing medium should be inspected for evidence of erosion from wind or water. If erosion channels are evident, they can be stabilized with additional growth medium similar to the original material.	Quarterly
<ul style="list-style-type: none">▪ Inspect drain inlet pipe and containment system.	Once per year

- Fertilization is not necessary and fertilizers should not be applied, unless there is a documented need. If it is determined that fertilization is required to restore function of the green roof vegetation, the exact fertilization requirements should be determined, and the minimum quantity of fertilizer should be applied to restore function. Fertilizers containing phosphorus should not be used.
- During the plant establishment period, maintenance staff should conduct 3-4 visits to conduct basic weeding, fertilization, and in-fill planting. Thereafter, only two annual visits for inspection and light weeding should be required (irrigated assemblies will require more intensive maintenance).
- Spill prevention measures from mechanical systems located on roofs should be exercised when handling substances that can contaminate storm water.
- If the structure/property where the green roof exists is likely to change hands, a plaque or similar element should be placed on and/or near the roof stating the manufacturer of the green roof elements so warranty details and other information best relayed by the manufacturer are easily obtained.

Note:

Design of green roof systems are not limited to the examples shown within this text. Successful storm water management plans will combine appropriate materials and designs specific to each site.

Maintenance guidelines vary for semi-intensive and intensive green roofs from what is presented here.

4.1.1 Green Roof Designer/Reviewer Checklist

Item	Yes	No	N/A	Notes
Load and structural capacity analyzed?				
Waterproofing layer and protection adequate?				
Leak protection system provided?				
Internal drainage capacity for large storms provided?				
Appropriate growing medium?				
Appropriate drainage media and/or layer?				
Geotextile/filter fabric specified?				
Good detailing (flashings, penetrations, drains, gravel edges, etc.)?				
Slope stability provided, if necessary?				
Appropriate vegetation selected?				
Appropriate drainage location provided?				
Plant establishment (temporary irrigation/fertilization) procedures provided?				
Erosion control / wind protection provided?				

4.1.2 Green Roof Maintenance Inspection Checklist

Green Roof - O & M Manual

Address of Property

BMP Narrative:

Regular inspection and maintenance is critical to the effectiveness of a green roof. It is the responsibility of the property owner to maintain all storm water facilities in accordance with the minimum design standards required by the City of Fort Wayne and this Operations & Maintenance Manual. All facility components, including plant material, growing medium, filter fabric, drainage layer, waterproof membranes, and roof structure should be inspected for proper operations, integrity of the waterproofing, and structural stability throughout the life of the green roof. The local jurisdiction has the authority to impose additional maintenance required where deemed necessary. The city has the right to inspect the system and to require replacement if it fails or is a threat to public safety. If maintenance does not correct the problem, full or partial replacement may be required.

Green Roofs shall be in accordance with the following inspection and maintenance criteria:

Inspection Activities	Suggested Frequency
<ul style="list-style-type: none"> Inspect to ensure that the green roof was installed and working properly. Inspect areas for potential erosion or damage to vegetation. 	Post-construction
<ul style="list-style-type: none"> Inspect foundation for any leaks and structural deficiencies. Inspect overflow devices (pipes and inlets) for obstructions or debris that would prevent proper drainage when filtration capacity is exceeded. 	Annually and after large storm events
<ul style="list-style-type: none"> Inspect for ponding. Inspect for dead or stressed vegetation. Inspect for tall or sun scorched grass. Inspect for weeds. Inspect mechanical equipment for leaks and spills. 	As needed
Maintenance Activities	Suggested Frequency
<ul style="list-style-type: none"> Repair any leaks or structural deficiencies. Contact manufacturer for repair or replacement of membrane. Remove any sediment and plant debris from clogged outlets. 	Post-construction
<ul style="list-style-type: none"> Drain inlet pipe should be cleared when soil substrate, vegetation, debris or other materials clog the drain inlet. Plant material should be maintained to provide 90% coverage. Weeds should be pulled manually, and removed regularly and not allowed to accumulate. If necessary during the establishment period (initial 18 months), irrigation can be provided by hand watering or automatic sprinkler system. Report any mechanical equipment leaks and spills, proper spill prevention should be exercised. 	as needed
<ul style="list-style-type: none"> Growing medium should be inspected for evidence of erosion from wind or water. If erosion channels are evident, they can be stabilized with additional growth medium must be similar to the original 	Quarterly

specified material.	
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Address of property

Inspector:
Date:
Time:
Weather: Rainfall over previous 2-3 days?
Site conditions:
Owner change since last inspection?: Y N

Mark items in the table below using the following key:

- X** Needs immediate attention
- Not Applicable
- ✓ Okay
- ? Clarification Required

Green Roof Components:

Items Inspected	Checked		Maintenance Needed		Inspection Frequency
	Y	N	Y	N	
STRUCTURAL COMPONENTS:					A
1. Foundation checks (e.g. are there any leaks or structural deficiencies)?					
2. Tears or perforation of membrane (contact manufacturer for repair or replacement)?					
3. Clogged outlets (remove any sediment and plant debris if necessary)?					
4. Standing water present (all facilities shall drain within 24 to 48 hours. Record time/date, weather, and site conditions when ponding occurs)?					
VEGETATION: (plant material shall cover 90% of the facility)					M, AMS
5. Dead or stressed vegetation?					
6. Tall or sun scorched grass?					
7. Weeds?					
GROWING/FILTER MEDIUM:					M, AMS
8. Exposed soils?					
9. Gullies?					
10. Ponding?					
OTHER					A
11. Are mechanical units free of leaks and spills?					
12. Is there any threat to Public Health? (e.g mosquito larvae or rats)					
13. Other (describe)?					

Inspection Frequency Key A= Annual, M= Monthly, AMS= After Major Storm

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March 2010

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