NYC Parks Green Roof

A living laboratory for innovative green roof design

A project of NYC Parks' Five Borough
Citywide Operations and Technical Services division

Randall's Island, NY

August 2013

Introduction

In the spring of 2007, the Five Borough Technical Services Division of the New York City Department of Parks and Recreation installed its first green roof system atop their headquarters, the Five Borough Complex on Randall's Island. Since then, the Technical Services division, in cooperation with the Parks' GreenApple Corps, has expanded the green roof program to encompass over 30 unique growing systems covering 30,000 square feet of our roof. As the fifth largest green roof in New York City, the 5-Borough project is not only a key component of the Parks' commitment to reducing its carbon footprint, but it also serves as a way to educate and inspire park staff and patrons, as well as supply a resource for peers in the field.

The 5-Borough green roof distinguishes itself from others, as it is the only known green roof in the country to feature distinct systems side by side. These systems vary by type of growing medium, depth of growing medium, and plant selection. By using a variety of planting systems and monitoring their progress, we are identifying the types of green roof systems that will thrive in the NYC urban environment.

Background

A green roof is a thin layer of vegetation installed on a traditional flat or pitched roof. Although the specifics of green roof design may vary, all green roofs have the same basic components (*Fig. 1* from the bottom up): waterproofing layer(s), a root barrier (to prevent the plantings' roots from growing through the roof), water retention/water drainage layer, growing medium, and plants.

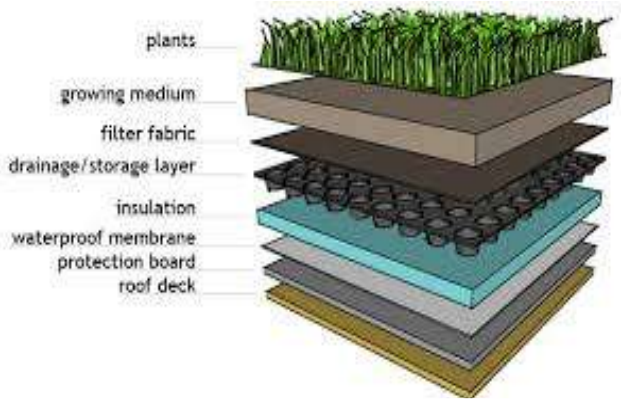


Fig. 1: Typical green roof profile

There are two types of green roofs: intensive and extensive. Intensive green roofs are greater than 6" deep and allow for a greater variety of plants including shrubs and even trees to be considered. They are similar to traditional rooftop gardens and often provide social and recreational uses. Intensive roofs can require more maintenance than extensive roofs and may also be more costly to install. By contrast, extensive green roofs are much shallower; their growing media are typically less than 6". They are lighter weight systems that provide primarily ecological and economic benefits. Plants likely to flourish on extensive green roofs are more specific and include sedums, succulents, alpine type plants, and some grasses. Extensive

green roofs contain fewer layers than those of intensive roofs and tend to require less maintenance.

Green roofs vary greatly in weight, depending on depth, material components and if they are wet or dry. The wet weight of a system, measured in pounds per square foot, is defined as the system's weight when it is supersaturated with water and cannot retain anymore. For each green roof system described in this report, the wet and dry weights are given.

Benefits of green roofs

- **Improving water quality**: Green roofs reduce the amount of storm water run-off by 50 to 90 percent and reduce the peak flow rate of run-off. During a 1" rainfall, 100% water retention is achievable. Green roofs filter out 95% of the cadmium, copper, and lead and 30% of the nitrogen and phosphorous in storm water. In addition, storm water retention is enhanced by the storm water tanks which store water until it is needed to water the plants.
- **Mitigating the heat island effect**: Green roofs cool the surrounding air and thereby reduce the temperature of the mass of hot air that hovers over cities during the summer. When the temperature outside is 90°F, a conventional black roof's surface temperature is over 150°F, while a green roof's temperature will vary from 90-95ºF.
- **Extending the service life of roofs**: Green roofs can double or even triple the usable lifetime of roofs. By and reducing temperature variations on a roof (which can cause thermal expansion and contraction stresses) and preventing harmful ultra-violet rays from reaching roofing materials, green roofs may extend the life of a roof by 40-60 years..
- **Conserving energy**: Green roofs reduce the energy required for heating and cooling. In the winter, green roofs insulate the upper floors of buildings and in the summer they cool buildings through shading and the process of evapotranspiration by plants.
- **Removing carbon dioxide from the atmosphere**: The plants on a green roof convert atmospheric carbon dioxide, a greenhouse gas, into organic compound by using energy from sunlight.
- **Reducing air pollutants**: Green roofs filter airborne particles that can cause respiratory diseases.
- **Reducing sound transmission and reflection**: Green roofs reduce the transmission of noise by 5 to 45 decibels and the reflected sound by up to 30 decibels.
- **Creating wildlife habitats**: Green roofs create biodiversity by attracting other types of vegetation, animals and insects including butterflies, bees and birds.

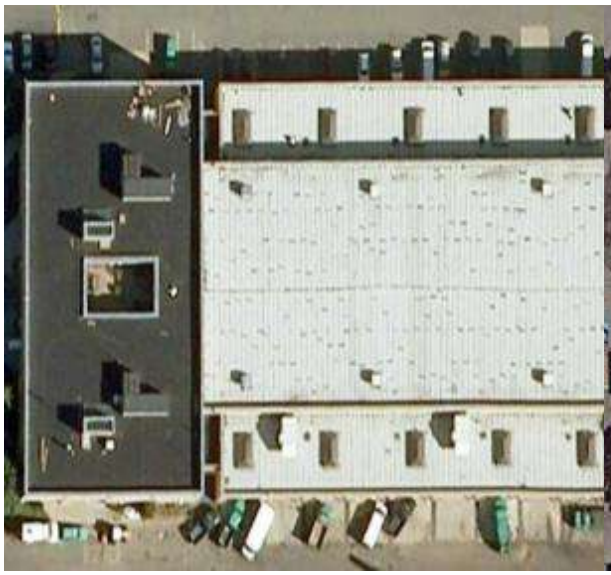
- **Improving carbon dioxide/oxygen exchange**: Sixteen square feet of vegetation on a green roof produces enough oxygen per year to satisfy the oxygen requirements of one person.
- **Improving aesthetics**: Green roofs can add to the beauty of residential and commercial buildings.
- **Sequestering carbon**: Green roofs take out carbon from the carbon cycle. For example, one square foot of green roof sequesters thirty-four grams of carbon.
- **Adjacent Solar Arrays:** Green roofs cool air around Solar Units, increasing efficiency.
- **Create Green space:** Green roofs create recreational areas and green space where there was once no green area.
- **Create an education venue:** All of the related benefits of a green roof should be monitored, creating opportunities to educate the public about the benefits of green roofs.

Progress of NYC Parks Green Roof Systems

Before (2007)

After (2013)

Aerial Views



Our first installation atop the 5-Borough complex was in the spring of 2007. The system chosen was based on an extensive green roof design provided by Barrett Roofs, a 12" deep monolithic layered system measuring 20' x 40' (800 square feet). The most prominent feature of this system is its 6” layer of growing medium, **GaiaSoil™**, a low density mixture of compost and recycled expanded polystyrene foam coated with pectin for water absorption. Above the growing medium, a layer of jute mesh was installed to prevent erosion because GaiaSoil™ is structurally unstable and can easily become windborne. The nine species of plants in this system are all native to the New York City metropolitan area and purchased from the Greenbelt Native Plant Center on Staten Island, a division of NYC Parks. Even at an overall depth of 12", this green roof system has a dry weight of only 14 pounds per square foot and a wet weight of 25 pounds per square foot. The estimated cost of this roof is between $25 and $30 per square foot.

The second year was a time of major expansion on the 5-Borough rooftop. We installed four extensive green roof systems and five intensive and/or atypical systems in 2008 alone. Two of the systems utilized 2' x 2' trays made from 0.032 gauge aluminum that were fabricated in Technical Services’ own Citywide Shops. The individual trays in this modular system can be temporarily removed, providing easy access to the roof below in case of needed inspections or repairs. **Tray Systems I and II** each measure 20' x 40' (800 square feet) and use Rooflite™ growing medium, a mixture of heat-treated clay and organic materials. Tray System I is 4” deep and is planted with 440 sedum plugs and 2,000 square feet of sedum cuttings. It has a dry weight of 14 pounds per square foot and a wet weight of 25 pounds per square foot. Tray System II has a depth of 6”, and is planted with 1,520 sedum plugs. It has a dry weight of 22 pounds per square foot and a wet weight of 34 pounds per square foot. The seven sedum species used in both systems were selected for their robustness, contrasting color and texture, and winter interest. A comparison of these two systems over time should provide

an indication of the effect of growing medium depth on the viability of sedum green roofs. The estimated cost to furnish and install Tray System I was calculated to be $16 to $18 per square foot and the cost for Tray System II is $18 to $20 per square foot.

Green Paks™ modular system was also installed in 2008. Manufactured by Green Roof Blocks of Florissant, Missouri, Green Paks™ are weaved bags made of high density polyethylene measuring 20" x 32" x 4" deep. They are pre-filled with a proprietary growing medium consisting of 80% expanded shale and 20% organic composted pine bark. Green Apple Corps members cut six evenly spaced holes in the polyethylene bags and inserted sedum plugs in to each hole. The 800 square foot Green Paks™ system lies atop a root barrier and drainage mat, and costs about $22 per square foot to furnish and install. Its dry weight is 12 pounds per square foot and its wet weight is 18 pounds per square foot.

The fourth modular green roof system installed in 2008 was **BIOtrays™**, by Green Roof Solutions. These trays are made of coconut husk fiber and measure 17" x 17" x 2". They were purchased empty, filled with mineral soil and planted with three varieties of sedum. Eventually,

the BIOtrays™ break down to form a monolithic system and their decaying components will nourish the mineral soil by providing additional organic matter. The BIOtrays™ cover an area of 200 square feet and the approximate cost to furnish and install this system is $10 per square foot. When dry, the BIOtrays™ system weighs 12 pounds per square foot and when saturated it weighs 14 pounds per square foot.


Cedar Planters, Trellis System and Parapet Walls

Several atypical planters were added to our green roof in the summer of 2008 in order to add some variety of plant species and display different growing heights. There are twenty **cedar planter boxes** measuring 3' x 3' x 2.3' high filled with Metro-Mix 510 growing medium, and planted with 3-gallon size Mugo Pine, Sedum Sieboldiana and Sedum. **Elevated planters** were also installed, some used to sprout extra plant material for green roof system replacements, and some provide a community garden for the office staff. Other atypical systems on the 5-Borough green roof include: an **overhead trellis** with a surface area of 650 square feet and a roof foot print of only 90 square feet; a **wood parapet system** along the atrium parapet wall; and a **metal parapet wall** along the west wing's perimeter.


In our third year, nine new systems were added to the 5-Borough green roof. The first was another GaiaSoil™ system, dubbed **Layered System II**. This system's overall depth is 7", 5" shallower than the original GaiaSoil™ system installed in 2007. Like its predecessor, Layered System II is monolithic and covers a 20' x 40' area. Planted with 825 native plants of 10 different species. Layered System II is very light, weighing only 8 pounds per dry square foot and 13 pounds per square foot when saturated. The estimated cost to furnish and install this system is $15 per square foot.

An extremely simple system, known as the **6" Container Growing System**, was also installed in the spring of 2009. Five 10' x 12' x 5" deep wood-framed plots were constructed on top of an EPDM roof protection layer and covered with Metro-Mix 510 growing medium—a medium usually used in container gardening. Over time, this system should provide an indication of how well a green roof can function without a drainage layer and whether one can flourish in a medium not specifically designed for green roofs. Planted with 3 species of native plants, the Container Growing System's dry weight is 11 pounds per square foot and its wet weight is 25 pounds per square foot. The system costs about $7 per square foot to furnish and install.

Xero Flor, a 2" deep, ultra-extensive system developed in Germany, added 6,350 square feet of green space to the 5-Borough roof. Comprised of a pre-vegetated sedum mat, water retention fleece, a drainage layer, and a root barrier, this extremely light system spans and has a dry weight of only 8 pounds per square foot (while the wet weight is 4 pounds more). Its installation cost is $10-$12 per square foot.

5-Borough's first **walk-able green roof system** was also installed in the spring of 2009. Located on a lower level so that it may be accessed easily from the 2nd floor offices, this roof is a popular lunch spot for staff during warmer months. Plants selected for this space are able to tolerate fluctuating amounts of sun and shade, and regular foot traffic. The planted species include creeping myrtle, red wing phlox, candy stripe phlox and tall fescue. 5-Borough's walk-able green roof is 4" deep and covers nearly 800 square feet.

In June 2009, Technical Services installed 800 square feet of its first pre-vegetated modular system. **GreenGrid® modules** can be delivered pre-planted with sedum and each module contains its own built-in root barrier and drainage/water retention features. We decided to incorporate salvaged rubber safety surfacing mats with this system for an additional design element and to provide a pathway for entering and servicing the system. Its dry weight is 10 pounds per square foot and its wet weight is 14 pounds per square foot. Installation costs were $26 per square foot.

That same month, 5-Borough installed a **green wall system,** another first for Technical Services and NYC Parks. Like a green roof system, a green wall has many of the same attributes, except for its vertical appearance. Upon purchasing the raw materials—20" x 20" x 2" plastic grid trays, mineral soil and three different varieties of sedum—the 12 wall panels were constructed at the Citywide Nursery in the Bronx's Van Cortlandt Park. These units were purchased from ELT Easy Green www.eltlivingwalls.com at a cost of $70 each. The total cost for the system including plants, plugs and mineral soil was $27 per square foot.

5-Borough introduced 650 square feet of another very light weight system planted with wild flower seeds. This wildflower system features a growing medium developed by Five Borough which consists of 80% Metro-Mix 510 (a conventional container growing medium) and 20% perlite (heated-expanded volcanic material). Unlike all other systems on the Five Borough roof, this **native wildflower system** was planted from seed and covered with jute mesh to prevent wind erosion. The dry weight of this system is 15 pounds per square foot and the wet weight is 29 pounds per square foot.

In October of 2009, a custom designed 400 square foot **Multi-depth Mineral Soil system** was installed with sedum plants and sedum clippings. This system shows how sedum at different depths of mineral soil in a bed fosters different growing rates. This system's average weight is 35 pounds per square foot and it costs $10 per square foot.


In 2010, we installed a second large scale system and three additional smaller systems. Our largest installation was a 6,350 square foot **3” Xero Flor** system, similar to the 2” deep Xero Flor we installed in 2009 but with an additional 1" of mineral soil placed below the pre-vegetated sedum mat. The mat and soil sit on a water retention fleece, a drainage layer, and a root barrier, altogether weighing 12 pounds per dry square foot and increasing to 18 pounds at full saturation.


In May of 2010, **Columbia University** students helped install a 400 square foot **8” Gaia Soil system** for research purposes. Filled with native plants and grasses (American Dittany, Blackeyed Susan, Wavy Hair grass, Globe Flatsedge, Virginia Wild Rye, Slender Goldentop and Switchgrass), this bed started out thin with plant material and has since become densely flourished. Similar systems exist on the tops of ten NYC Parks recreation facilities and are being studied comparatively by Columbia University. This system weighs about 16 pounds per square foot and costs about $10 per square foot.


During April and May of 2010, a 4000 square foot **vegetable/herb farm** was installed on top of 5 Borough in the form of ten 50' x 6' wide planting beds. This system has an average depth of 7.5” and its growth medium is composed of 1/3 mineral soil, 1/3 perlite and 1/3 compost/manure. The vegetables were planted 12 inches on center, and include tomatoes, peppers, muskmelons, squash, pumpkins, cabbage, corn, spinach, eggplant and herbs. A bounty of vegetables and herbs have been grown over the last few growing seasons and donated to a local soup kitchen. The average weight is 18 pounds per square foot at a cost of $15 per square foot.


Technical Services installed six **mineral soil beds** in September of 2010, each measuring 13' x 6.6' and having a total area of 516 square feet. Planted with species from two native plant communities (Hempstead Plains and Rocky Summit Grasslands of the New York City region), each bed has a random arrangement and a soil depth of either 4” or 6” depending on the box. NYC Parks planted beds similar to these on top of ten recreation centers during the fall of 2010. System costs were $10 per square foot including labor and materials. The weight of our mineral soil beds varies from 14 to 24 pounds per square foot depending on saturation.


Two **Bio Roof systems** were installed atop 5-Borough in December of 2010 with the help of one Bio Roof representative and the Parks Weatherization crew. This system consists of native plant seeds and Sempregreen sedum mats in a highly organic growing medium. Lying adjacent to each other, one system is 10" deep (25 pounds per square foot) and one is $4^{1/4}$" deep (14 pounds per square foot). The system cost is $14 - $16 per square foot, including labor and material.


In January 2011, the NYC Parks Weatherization crew installed another very light weight system we refer to as our **Perlite/Metro-Mix system**. It consists of 80% perlite, a lightweight, heated and expanded volcanic material, and 20% Metro-Mix 510, a conventional container growing medium. Covering 800 square feet, this system is 12” deep, planted with native grasses and has weight ranges from 14 to 22 pounds per square foot.


In collaboration with Fluxxlab design, NYC Parks installed a vertical farm prototype known as the **Facade Farm system** in May of 2011. Uniquely designed, this system takes advantage of our south facing walls and has both a test hydroponic and soil system. The unit is cost efficient and easily installed. It can be prefabricated off site and bolted to the building. For more information, see http://www.fluxxlab.com/blog/.


Setting seed and propagation of plants on a roof can be difficult since wind conditions present many roofs with inhospitable chances of pollination by passing insects. In order to help our green roof systems atop 5-Borough thrive, ten **honey bee hives** were installed in April of 2011. The hives were placed on pads to ensure even weight distribution and to provide stable footing, and a month later they were populated with Western honey bees, or *Apis mellifer*. Equipped with fertile queens and around 10,000 worker bees, each hive can grow to have 30,000 bees during its first season. Bee hives help to bridge the gap between intensive and extensive green roof systems by making even the most minimal green roof system productive and healthy. Ongoing pollination encourages thicker, more robust beds of plants, forcing out weeds and grasses that might otherwise become a labor-intensive maintenance issue. NYC Beekeeping (www.nycbeekeeping.org) cares our honeybee hives and solitary bee nests (*Osmia)* and uses them for educational and research purposes.

In spring of 2011, we installed **the Tower Garden™ Growing System** (our first hydroponics!), which uses closed system technology to recycle 100% of the nutrients and water, minimizing waste. These revolutionary systems produce strong healthy plants that can better protect themselves from pests and disease and provide healthy food, all without the use of soil. Unlike traditional gardening methods, hydroponics uses a pH balanced ionic mineral based water solution that, when pumped through a central tower, comes in contact with a plants' roots. This hydroponics use approximately five percent of the nutrients and water that conventional gardening and organic farming typically use. The entire system weighs about 125 lbs (without vegetables) and can hold 20 plants.

Installed in the summer of 2011, this new **Green-Blue Roof system** uses watertight trays that capture potentially 100% of rainwater, creating a shallow cistern over the entire roof. The plants

and mineral soil are suspended on an internal ‘raised floor' over an open water chamber below. An absorbent capillary mat drapes over the internal raised floor, dipping into the water below and passively irrigating the plants above for many weeks. The water chamber height can be manipulated simply by adjusting the tray floor and/or weep holes located on the sides. In order to make the system as light, inexpensive and transportable as possible, the trays are only $3^{1/8}$” tall and filled with $1^{5/8}$” of mineral soil. The remaining space is left for the water, which weighs less than any saturated mineral soil at 5.2 pounds per square foot. On future roofs we hope to connect the trays at the bottom so that we can release the water after heavy rain and have the ability to use the water-filled trays as a combative tool during extreme heat waves. We planted these trays with over a dozen C3 test plants to see if they are able to survive under various harsh growing conditions. Unlike CAM plants (sedum etc.), C3 plants transpire during the day, maximizing the plants’ ability to cool and clean the air when it’s needed most. Some C3s were planted directly in the shallow profile of tray soil and others were planted in grow bags using larger amounts of soil. Currently, we are monitoring their progress and hope to test many more plants and seeding techniques with these trays in the future.

Sun-Root solar-living roof system is a fully integrated, non-penetrative solar and extensive green roof system. It optimizes photovoltaic (PV) element energy production by creating a cooler surrounding micro-climate through evapotranspiration. In other words, the vegetation beneath the panels significantly reduces rooftop temperatures, increasing PV efficiency. Our panels generate enough electricity to help power the nighttime automatic roof lights.

WaterGrip™ green roof system was installed atop 5-Borough in the summer of 2013. This system consists of 12” x 24” x 3” “brownies” that combine traditional organic mix ingredients, such as coconut coir and fir bark, with proprietary ingredients to create a lightweight, hydrophilic matrix. The result is a sponge-like media that contains beneficial bacteria, nutrients, and fertilizer to protect and promote healthy root and plant development. Each brownie is able to hold 8x its weight in water, reducing overall water use and providing enhanced water management. The WaterGrip™ system also does not break down when saturated, making it virtually mess-free. We are currently evaluating different growing methods with sedum on this system. About one-third of the brownies were delivered pre-planted, a few have been punctured and plugged with sedum, and many have been spread over with sedum clippings from the Xero Flor. Two brownies have been left bare in order to see if neighboring plants or airborne seed will start to grow. The WaterGrip™ roof system costs $9 - $12.25 per square foot, and weighs 2 pounds per dry square foot and nearly 11.8 pounds per wet square foot.

In July of 2013, the **Tournesol VGM® green wall system** replaced the green wall installed in 2009. Tournesol VGM® is a recycled plastic planting module attached to stainless steel hanging rails. Once grown in it provides instant, complete coverage of any vertical surface. A wide, controllable variety of plant designs can be used in any horticultural condition. Each planting module has a 4” or 8” soil profile and grow-in typically takes 1-3 months prior to hanging. The 5-Borough green roof interns are currently experimenting with different plant varieties in this system including sedum plugs, Plumbago, Catmint, Geraniums and Verbana.

	Installation Mo/Yr	System	Type	Size (sqft)	labor/material ($/sqft)	dry/wet weight (lbs/sqft)
1	2007	Layered System I (12" Gaia)	extensive, monolithic	800	$13/ $13	14/25
2	2008	Tray System I (4" Rooflite)	extensive, modular	800	$8/ $8	14/25
3	2008	Tray System II (6" Rooflite)	extensive, modular	800	$9/ $9	22/34
4	2008	Green Paks (4" shale/pine bark))	extensive, modular	800	$10/$8	12/18
5	2008	Tray System III Bio-trays (2" mineral)	extensive, modular	200	$4/ $5	12/14
6	2008	25 Cedar Planters (Metro-Mix)	atypical	250	$27/$18	25/50
7	2008	Trellis (mineral soil)	atypical	800	$2/$3	42/48
8	2008	Parapet Wood	intensive	200	$5/$9	12/25
9	2008	Parapet Metal	intensive	1200	$5/$10	12/25
10	2008	Elevated Planters	atypical	200	$30/$15	25/50
11	2009	Layered System II (7" Gaia)	extensive, monolithic	800	$8/ $8	7/13
12	2009	Container Growing Medium (6" Metro-Mix)	extensive, monolithic	600	$5/$2	11/25
13	2009	Xero Flor 2" System	ultra-extensive	6250	$2/$9	8/12
14	2009	Green Grid (4" mineral)	extensive, modular	800	$18/$2	10/14
15	2009	Green wall	vertical, modular	35	$10/$2	n/a
16	2009	Native Wildflower from seed (80/20 mix)	extensive, monolithic	650	$5/$5	17/29
17	2009	Walkable Green Roof-Atrium (4" mineral)	extensive	800	$5/$5	14/21
18	2010	Vegetable/Herb Farm	intensive	4000	$5/$5	15/18 avg
19	2010	Gaia 8" - by Columbia Students	extensive	400	$2/$8	10/16
20	2010	Xero Flor 3" System (1" extra mineral soil)	ultra-extensive	6350	$2/$8	12/18
21	2010	Mineral Soil Beds (4"& 6") Rec Center model	extensive, monolithic	516	$5/$5	14/21 22/24
22	2009	Multi-depth Mineral Soil System	monolithic	400	$5/$5	22/34 avg
23	2010	Bio-Roof (10")	intensive	250	$3/13	15/25
24	2010	Bio-Roof (4.25")	extensive	250	$3/11	9/14
25	2011	Perlite/Metro Mix (12")	intensive	800	$2/$7	14/22
26	2011	Façade Farm	atypical	50	n/a	n/a
27	2011	Green-Blue roof trays	extensive, modular	650	n/a	12/25
28	2011	Hydroponic Vegetable system	vertical, hydroponic	15 unit	n/a	n/a
29	2012	Solar Green Roof	solar panel	250	$11/$5	14/21
30	2012	BIOTOP Containers	hydroponic	200	$50/1x3 unit	n/a
31	2013	WaterGrip roof system (3”)	extensive	96	$1-5/$9-12.25	2/12
32	2013	Tournesol VGM green wall (8”)	vertical, modular	36	n/a	n/a
			Total area (sqft)	**30,233**		

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