NYC Parks Citywide Service Green Roof Manual

NYC Parks' Living Laboratory for
Innovative Green Roof Design & Sustainable Technology

Citywide Services Sustainable Facilities Division

Introduction to the Green Roof at CWS headquarters

In the spring of 2007, the Sustainable Facilities Division of the Citywide Services (CWS) branch of the New York City Department of Parks and Recreation installed its first green roof system. The system was placed on the roof of the CWS headquarters, which houses a large maintenance garage, located on the northern end of Randall's Island next to the Triborough Bridge. Since that time the Sustainable Facilities Division has expanded its green roof program to cover over 45,000 square feet of that garage's roof with over 45 different types of growing systems making it the most diverse green roof in New York City and the world. As the fifth largest green roof in New York City, this diverse green roof is a key component of NYC Parks environmental commitment to OneNYC, an initiative that promotes sustainability efforts across New York City. In addition, it serves as a way to educate and inspire NYC residents and businesses about the many benefits of green roofs for the city and its inhabitants.

The purpose of this document is to introduce readers to the green roof on the CWS's building on Randell's Island. Included in this document will be a description of what a green roof is, a general presentation of its structural components, a listing with some introductory background of many benefits of green roofs, a brief outline of the history of the green roof installation on the CWS garage and providing a listing of the many types of green roofs that are being demonstrated at this Randell's Island site.

The CWS Green Roof and Green Roof Basics

The CWS green roof is the most diverse green roof in the world featuring multiple unique systems staged side by side in order to demonstrate the wide range of green roof technologies available. These systems vary by type of growing media, media depth, system configuration, water retention as well as plant selection. By simultaneously using a variety of planting systems under identical conditions and monitoring their progress, we are able to actively identify the types of green roofs that will thrive in our city's unique urban environment.

A green roof is simply defined as a vegetated system installed on a traditional roof. Although the specifics of a green roof design and structure may vary, almost all green roofs have the same basic components. These components, shown in Figure 1 from the bottom up, are: a waterproofing layer, a root barrier to prevent the plantings roots from growing through the

roof, a water retention/water drainage layer, growing medium, and, finally, the plants. These components ensure that the planting system retains water, sustains its plants, and will not damage the roof.

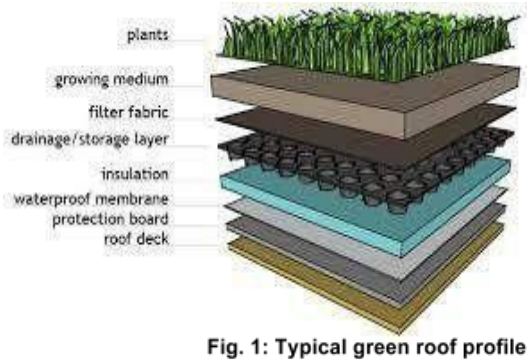


Fig. 1: Typical green roof profile

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 with higher water requirements to grow. These plants include shrubs, larger edible plants and even some types of trees. They are similar to traditional gardens and often allow for social and recreational uses. Intensive roofs normally are heavier due to the larger plants as well as deeper growing media depth and its associated water retention. They require more maintenance and are typically more costly than extensive systems.

In contrast to intensive green roofs, **extensive green roofs** are shallower and generally lighter in weight, as their growing media is less than 6" deep. They provide similar environmental benefits as intensive systems do, but at a decreased capacity. Plants likely to flourish in extensive green roof systems are more specialized and include sedums, succulents, alpine type plants and some grasses. Extensive green roofs contain fewer layers than intensive roofs and tend to require less water and maintenance, which normally makes them the less expensive alternative. However, they are usually not designed for heavy traffic and sequester less carbon and rainwater than their intensive counterparts.

As indicated above, green roofs will vary greatly in weight, depending on their depth, material components and moisture content. The saturated weight of a system, measured in pounds per square foot, is defined as the system's maximum weight when it is supersaturated with water to the point it cannot retain any additional fluid. When adding a green roof to a building, the weight of seasonal precipitation and system's saturated weight as well as potential maintenance traffic must be considered to ensure it can be safely added to the roof; this means that the load capacity of a roof that has been selected as a green roof installation candidate must be known. For each green roof system described in this report, the wet and dry weights of the system are provided as a reference point to help guide green roof selections.

Benefits of Green Roofs

Improving Water Quality: Green roofs reduce stormwater runoff from buildings by 50-90%. This reduces the city's overall peak flow rates into the combined sewer system during rain

events. Decreasing the flow of stormwater into the city's combined sewer system decreases the amount of sewage overflow into NYC's natural water bodies during storms. During a one inch rainfall event our systems can achieve 100% water retention from fully dry conditions, which prevents rainwater from leaving the facility and entering the city's combined sewer system in roughly 90% of NYC storms. The water retention abilities of green roofs can help prevent combined sewer overflows (CSOs.) As an additional water quality benefit, green roofs filter out 95% of cadmium, copper, and lead and 30% of the nitrogen and phosphorus in stormwater, further decreasing environmental contamination and costs of environmental clean ups.

Mitigating the Urban Heat Island Effect: Green roofs cool their surrounding airspace, thereby reducing the ambient temperature of the mass of abnormally overheated hot air that hovers over cities due to dark colored surfaces, heat retaining construction materials, and concentrated pollution. This phenomenon, known as the heat island effect, increases urban air temperatures, on average, by 10°F compared to surrounding suburban and rural temperatures. Urban heat island effects have immense negative impacts on energy use and health of city residents. Installation of green roofs significantly decreases urban heat island effects. For example, when the ambient outdoor temperature outside is 90°F, a conventional black tar roof surface temperature can approach 170°F; installation of a green roof significantly decreases that temperature to 90-95º F. This decreases not only the urban heat island effect outdoors but also makes the building easier to cool in the summer thus decreasing the energy required to run the air conditioning system.

Extending the Service Life of Roofs: Green roofs can double or even triple the usable lifetime of the actual structural roof which. over time saves an immense amount of money and time on roof maintenance and replacement. By reducing seasonal temperature variations on a roof (which cause thermal expansion and contraction stress) and preventing harmful ultraviolet rays from reaching roofing materials (which thermally and photodegrades conventional roofs), green roofs are able to extend the life of a roof by 20-40 years versus traditional tar roofing systems. This cost and time savings should be calculated into the capital cost of a green roof installation; installation of a green roof pays for itself over time.

Conserving Energy: Green roofs reduce the energy required for building heating and cooling. In the winter, green roofs insulate the upper floors of buildings which helps retain heat. In the summer, as introduced above, they cool buildings by decreasing the urban heat island effect of the air around the building through the plants' natural evapotranspiration process.

Removing Carbon from the Atmosphere: Using energy from the sun, green plants convert atmospheric carbon dioxide, a major greenhouse gas, into organic compounds thus reducing the carbon footprint. A green roof increases the amount of green plants in a city thus decreasing the atmospheric contributions that contribute to climate change. The amount of carbon sequestered varies with the type of green plants used in the system, but generally speaking the larger the plants grown, the more carbon you're removing from the surrounding airspace.

Improving Carbon Dioxide/Oxygen Exchange: On average, sixteen square feet of vegetation on a green roof produces enough oxygen per year to satisfy the oxygen requirements of one person.

Reducing Air Pollutants: Green roofs filter airborne particulates that can cause respiratory diseases and infrastructure damage, an especially vital task within an urban environment where such problems are exacerbated from pollution concentration.

Dampening Sound Transmission and Reflection: Green roofs reduce the transmission of noise into buildings by 5-45 decibels and reflected sound by up to 30 decibels, thus contributing to improving the overall quality of life within a building.

Creating Wildlife Habitats and Forage Space: Green roofs improve the potential biodiversity of urban spaces by turning roofs into potential natural habitats. Increased amount of wildlife habitat in urban areas allows for safe nesting areas for birds and other species.

Creating Interactive Educational and Beautiful Social Spaces: All of the related benefits of a green roof can easily be monitored both scientifically and anecdotally, creating opportunities to educate others about the benefits of green roofs through interactive natural classroom spaces. In addition, green roofs can be used as social parks for a variety of events; they can be thought of as parkland on a roof. Green roofs also add to the beauty, utility and value of buildings.

Development of the Green Roof at CWS: A Review in Photos

Ground Level View of CWS Roof Before 2007

Ground Level View of CWS Roof After 2017

Aerial View of CWS Roof Before 2007

Aerial View of CWS Roof After (2019)

Introduction to the Green Roof at CVS headquarters

Our first installation atop the Citywide Service (CWS) complex was a **Layered System**[1] in the spring of 2007. The system chosen, a 12" deep monolithic layered system measuring 20'x40' (800 square feet), was based on an extensive green roof design provided by Barrett Roofs Inc. The most prominent feature of this system is its 6" layer of growing medium, **Gaia Soil**, which is 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 Gaia Soil is structurally lightweight and can easily become windborne. The nine species of plants in this system are all native to the New York City metropolitan area and were 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.

Our second year was a time of major expansion on the CWS rooftop. We installed four extensive green roof systems and five intensive and/or atypical systems in 2008. Two of the systems utilized 2'x2' 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**[2] **and Tray System II**[3] 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

[1] Layered System I (see table at end)

[2] Trays System I (see table at end)

[3] Trays System II (see table at end)

[23]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/texture and winter viability. Our comparison of these two systems over time provided a strong indication of the effect of the growing medium depth on the survivability of sedum green roofs in NYC. The estimated cost to furnish and install Tray System I was calculated to be between $16 to $18 per square foot and for Tray System II the estimated cost was between $18 to $20 per square foot.

A **Green Paks**[4] **The 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"x32"x4" deep. They’re pre-filled with a proprietary growing medium consisting of 80% expanded shale and 20% composted pine bark. **Green Apple Corps** members cut six evenly spaced holes in polyethylene bags and inserted sedum plugs into each hole. The 800 square foot Green Paks system lies atop a root barrier and drainage mat, its dry weight is 12 pounds per square foot and its wet weight is 18 pounds per square foot. The cost of this unique system is roughly $22 per square foot to furnish and install.

[4] Green Paks (see table at end)

The fourth modular green roof system installed in 2008 was 200 square feet of **BIOtrays**[5], by **Green Roof Solutions**. These trays are made of coconut husk fiber and individually measure 17"x17"x2". They were purchased empty, filled with mineral soil and planted with three varieties of sedum. Eventually the modular BIOtrays break down to form a monolithic system and their decaying components will nourish the mineral soil by providing additional organic matter. The BIOtrays dry weight is 12 pounds per square foot and 14 pounds per square foot when saturated, the approximate cost to furnish and install this system is $10 per square foot.

BIOtray System Initial Installation (left) and After BIOtray Break Down (right)

[5] Biotrays (see table at end)

Several types of cedar planters were added to our green roof in the summer of 2008 to showcase a more comprehensive variety of plant species and potential growing dimensions.

Elevated Planters[6] were also installed as a system for propagating extra plant material for green roof system replacements.

Other internally developed systems on the CWS green roof include: a **Wood Parapet System**[7] along the atrium parapet wall; and a **Metal Parapet System**[8] along the west wing's perimeter. By using the top of the parapets, parapet systems not only extended the plantable space of our green roof but additionally allowed us to achieve a compliance goal of 42" security walls (NYC Code) to ensure the safety of rooftop visitors. These systems work around the weight limitations of horizontal planters by growing on a structurally sound vertical surface, greatly increasing the possibilities for different types of growing media, depths, and plantings that work within the boxes.

Overhead Trellising[9] were installed. The trellises had a surface area of 650 square feet and a roof footprint of only 90 square feet. The installation was combined with several of our **cedar planter systems**. Grapevine runners were added to the trellises to incorporate an additional food production element to the roof. There are twenty **Cedar Planter Boxes** measuring 3'x3'x2.3' high filled with **Metro-Mix 510** growing medium (a conventional soil substitute) and planted with three-gallon Mugo Pine as well as Sedum Sieboldiana.

[6] Elevated Planters (see table at end)
[7] Wood Parapet System(see table at end)
[8] Metal Parapet System (see table at end)
[9] Overhead Trellising and Cedar Planter Boxes (see table at end)

In our third year, nine new systems were added to the CWS green roof. The first was another **Gaia Soil system**, dubbed **Layered System II**[10]. This system's overall depth is seven inches, which is five inches less than the original Gaia Soil system installed in 2007. Like its predecessor, Layered System II is monolithic and covers a 20'x40' area. It was planted with 825 native plants from 10 different species. Layered System II is very light, weighing only 8 pounds per square foot when dry 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**[11] was also installed in the spring of 2009. Five 10'x12'x5" 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 it's plants can flourish in a medium not specifically designed for green roofs. Planted with 3 species of natives, the six inch containers weigh 11 pounds per square foot dry and 25 pounds per square foot when fully saturated, the system's cost about $7 per square foot furnished to install.

[10] Layered System II (see table at end)

[11] Container Growing System (see table at end)

The first **Walkable Green Roof System**[12] was also installed at CWS in the spring of 2009. Located on a lower level for ease of access 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, shade and regular foot traffic. The planted species include Creeping Myrtle, Red Wing Phlox, Candy Stripe Phlox and Tall Fescue. The CWS Walkable Green Roof System is 4" deep and covers nearly 800 square feet.

Xero Flor[13]**,** a 2" deep, ultra-extensive system developed in Germany, added 6,350 square feet of green space to the CWS roof. Comprising a pre-vegetated sedum mat, a water retention fleece, a drainage layer and a root barrier, this straightforward system is the go-to option for most large-scale green roof installations worldwide. It's incredibly low dry weight of only 8 pounds per square foot and wet weight of 12 pounds per square foot saturated as well as its installation cost of $10 to $12 per square foot make it an incredibly viable system.

In June 2009 the Technical Services team installed 800 square feet of **GreenGrid**[14] modules, our first pre-vegetated modular system. It can be delivered pre-planted with sedum and each module contains its own built-in root barrier as well as drainage and water retention features. We decided to incorporate salvaged rubber safety surfacing mats into the design for an additional sustainable design element which provides a pathway for entering and servicing the system. The systems dry weight is 10 pounds per square foot and its wet weight is 14 pounds per square foot, its overall installation cost was $26 per square foot.

[12] Walkable Green Roof (see table at end)
[13] Xero Flor (see table at end)
[14] Green Grid (see table at end)

CWS also introduced a 650 square foot lightweight **Native Wildflower System**[15] focused on regional pollinating species. This wildflower system features an internally developed growing medium consisting of 80% Metro-Mix 510 and 20% **perlite** (heated-expanded volcanic glass). Unlike other systems on the CWS roof, this specific module 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**[16] was installed using sedum plants and clippings. This system highlights how sedum planted at different depths foster increased growth rates and utilizes existing structural steel within the roof to hold the raised swales' additional weight. This system's average weight is 35 pounds per square foot and its cost is $10 per square foot.

In our fourth year, we installed a second large scale system and three additional smaller systems. Our largest installation was a 6,350 square foot **3" Xero Flor**[17] system, similar to the two inch deep Xero Flor we installed in 2009, but with an additional one inch of mineral soil placed below the pre-vegetated sedum mat. The mat and soil sit on a water retention fleece, drainage layer and root barrier altogether weighing 12 pounds per dry square foot and increase to 18 pounds at full saturation.

[15] Native Wildflower System (see table at end)

[16] Multi-Depth Mineral Soil System (see table at end)

[17] Xero Flor (see table at end)


In May of 2010, **Columbia University** students without any former green roof construction experience helped design and install a 400 square foot **8" Gaia Soil system**[18] over the course of one day to highlight the accessibility of developing green roof initiatives. Filled with native plants and grasses (American Dittany, Black Eyed 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 and survived many seasons of growth. This system weighs roughly 16 pounds per square foot and costs about $10 per square foot.

Columbia University worked with Technical Services to install six **Mineral Soil Beds**[19] in September of 2010, each measuring 13'x6.6' 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 which has since been left unmaintained for extensive studies on natural growth. Ten separate Parks recreation centers received similar test units during the fall of 2010 as part of the ongoing study to examine the effect of NYC's microclimates on green roofs. The weight of our mineral soil beds varies from 14 to 24 pounds per square foot depending on depth/saturation and cost $10 per square foot including labor and materials.

[18] 8" Gaia (see table at end)

[19] Columbia Study Mineral Soil beds (see table at end)

During April and May of 2010, a 4,000 square foot **Vegetable/Herb Farm**[18] was installed in the form of seven 50'x6' 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 planted included tomatoes, peppers, melons, squash, cabbage, corn, spinach, eggplant, greens, herbs and more. The abundance of produce that has been grown since installation has been donated to local soup kitchens. These systems average 18 lbs per square foot and cost an average of $15 per square foot.

Two **Bio-Module Systems** were installed in December of 2010 through the combined efforts of **Bioroof Systems** and the **Parks Weatherization Crew**. This system consists of native plants and Sempergreen Sedum in a highly organic growing medium. Lying adjacent to each other, one system is 4"[19] (14 pounds per square foot saturated) and the other is 10"[22] (25 pounds per square foot saturated). The cost of these systems is $14 to $16 per square foot including labor and materials.

[18] Vegetable/Herb Farm (see table at end)

[19] Bio-roof (see table at end) [22]

Bio-roof (see table at end)

In our fifth year, the Parks Weatherization Crew installed another light weight system we refer to as our **Perlite/Metro-Mix System**[20]. Covering 800 square feet, this system consists of a 12" deep growing media composed of 80% perlite and 20% Metro-Mix 510. It was planted with native grasses and has a weight that ranges from 14 to 22 pounds per square foot.

In collaboration with **Fluxxlab**, NYC Parks installed a vertical farm prototype known as the **Facade Farm System**[21] in May of 2011. This uniquely designed system takes advantage of a south facing wall and has both a pilot hydroponic and soil system. The unit is cost efficient and easily installed, it can also be prefabricated off site and bolted to a building for quick installation.

[20] Perlite/Metro-Mix System (see table at end)

[21] Facade Farm System (see table at end)

In the spring of 2011, we installed **The Tower Garden Growing System**[22] which uses closed loop technology to recycle 100% of the nutrients and water within the module, conserving resources and minimizing waste. Unlike traditional gardening methods, hydroponic systems raise plants in a pH balanced ionic mineral based water solution instead of a solid growing medium. When water is pumped through the system's central tower it comes into contact with the plantings' bare roots, providing as much direct hydration and nutrients as the plants can utilize. This revolutionary system uses approximately five percent of the overall nutrients and water that comparably sized conventional gardening and organic farming systems require, yet they still outperform traditional agriculture yields and can naturally protect themselves from pests and disease, allowing them to easily provide ample organic produce. The entire system weighs about 125 pounds (without vegetables) and can hold up to 20 individual plants.

[22] Hydroponic Vegetable System (see table at end)

Installed in the summer of 2011, the experimental **Blue-Green Roof System**[23] is designed to maximize rainwater capture through a shallow cistern enclosed within the modular trays base. The plants and mineral soil are suspended on an internal “raised floor” over an open water chamber below. An absorbent capillary mat encloses the internal raised floor, wicking water from the cistern below the raised floor and passively irrigating the plants above it. The water chamber's height can be manipulated simply by adjusting the tray floor and/or weep holes located on the sides, allowing for the system’s water retention capacity to be freely modified. 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). We planted these trays with over a dozen **C3 Test Plants** to see if they would be 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 C3’s 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 this unique plant type’s comparable progress and moving ahead we plan to test many more types of plants and seedlings within this revolutionary system. On future roofs we hope to connect the bottoms of the trays so that we can release the water after a heavy rain event and have the ability to use the water-filled trays as a combative tool during extreme heat waves.

[23] Green-Blue Roof System (see table at end)

In our sixth year, we installed the **Sun-Root SolarLiving Roof System**[24], a fully integrated, non-penetrative solar panel and extensive green roof system. It achieves optimized photovoltaic element (PV) energy gains by creating a significantly cooled microclimate around its panels through evapotranspiration, as electronics (solar panels included) commonly suffer from increasing performance loss as they become hotter. The vegetation beneath the panels naturally reduces the temperature of the airspace around the panels which prevents them from overheating, increases PV efficiency by keeping it within optimal temperature range under 77°F. The panels work synergistically with the sedums and provide a strong buffer against extreme weather, ensuring their long-term survival and ongoing ambient cooling for the panels by proxy, creating a fully sustainable system. Our panels generate enough electricity to help power our automatic roof lights at night.

In our seventh year, the **WaterGrip**[25] green roof system was installed on CWS, this unique system consists of 12”x24”x3” “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 promote and protect healthy root and plant development. Each brownie is able to hold eight times its weight in water, providing enhanced water management for the facility. The WaterGrip system also does not break down when saturated, making it virtually mess-free. 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. We’re currently evaluating different sedum and native plant growing plans utilizing this system. The WaterGrip roof system weighs 2 pounds per dry square foot and roughly 11.8 pounds per saturated square foot and costs approximately $9 to $12 per square foot.

[24] Solar-Living Roof System (see table at end)

[25] Water Grip (see table at end)

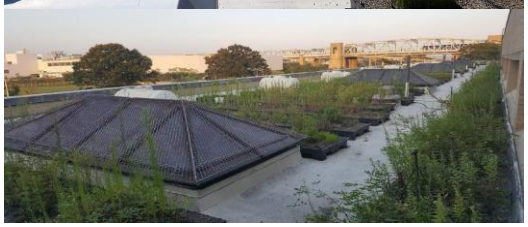
In July of 2013, **Tournesol**[26] replaced the green wall installed in 2009. **Tournesol VGM Green Wall System** is a recycled plastic planting module attached to stainless steel hanging rails. The system provides complete coverage of any vertical surface and a wide variety of plant designs can be used within the trays. Each planting module has a 4" or 8" soil profile and grow-in typically takes 1-3 months prior to hanging. The CWS green roof interns are currently experimenting with different plant varieties in this system including sedum plugs, Plumbago, Catmint, Geraniums and Verbena.

In our eighth year, CWS Technical Services began the process of installing 19.8 kW of solar PV onto the roof of the CWS Technical Services building in order to showcase the economic feasibility of solar power. In collaboration with the **DCAS Energy Management** (DCAS DEMS), we received funding for our design through the DCAS Expenses for Conservation and Efficiency Leadership (ExCEL) program. **CWS Solar's** designs for CWS Technical Services building includes 60.5 kW of solar PV mounted from the roof parapet with 19.8 kW currently installed. This installation is expected to alleviate high demands of energy during the cooling season while offsetting about 8% of CWS electricity usage. Furthermore, our current green roof systems will mediate the air temperature, which will allow the solar PV installations to operate efficiently and improve overall sustainability at the CWS building. According to calculations, these 20 kw solar panels will provide long term energy costs and reduce our dependence on the electric grid from the calculated yearly cost of $3.80/watt and generation of 23,139 kW/h. The continued measured success of these systems will allow further additional funding for the 40.7 kW of the 60.5 kW.

[26] Tournesol (see table at end)

In our efforts to become more sustainable, we have begun experimenting with a **Layered Bed System**[27] of what were once considered our waste streams (cardboard, leaf litter, mulch, pallet wood and food scraps). This pilot system not only has the potential to divert a broad range of waste categories, but additionally, is inoculated with edible wine cap mushroom spores to become a passive food producing bed.

In our ninth year we continued our progress on **The Lower Green Roof Project**[28] thanks to a kind and sustainable material donation by **Silvercup Studios**. This system was the first to be located on the 2nd floor roof and has an assembly constructed from 100% salvaged materials diverted from New York City's waste stream. The modular trays are filled with a custom 60:40 perlite to mineral soil mix and a native pollinator garden was planted in them to test what makes for optimal regional bee forage in NYC. This module, which was completed in 2016, weighs 20 pounds per square foot dry and 25 pounds per square foot when saturated.



In our tenth year, several tumbling compost bin models were added to the roof in order to enhance our organics processing capacity and limit the amount of organics waste leaving the facility. An aerated three bin system was also added outside of the facility garage to rapidly process organics. Food scraps collected from small food waste bins around the facility (implemented in the ninth year) feed all these experimental composting systems as well as our compost tea brewer, vermicomposting tower and bokashi pilot. The compost produced is used for numerous green roof projects, and the facility itself is an official composting demonstration site for New York City, similarly showcasing the wide range of methods of available methods on the market to process organics.

[27] Layered Bed System (see table at end)

[28] Lower Green Roof Project (see table at end)

We took this year to coordinate **Lower Roof System Upgrades** using additional orders of natives and dressing beds with wood chips to retain additional water. Our native plant center provided us with the orders for these upgrades. We also had the good fortune to get several small saplings which, although not appropriate for standard green roof use at full size, we intentionally "dwarfed-in" a **Bucket Sapling System** so that we could experiment with small tree performance.

In our eleventh year, the agency found that the passive cooling effects of green roof technology had a significant benefit to the efficiency of our HVAC systems. Due to the evapotranspiration value of the green roof, our air conditioner workload was lowered to a point that there was no longer a need for such a large cooling system. The facility was then able to replace the old cooling units with smaller, more efficient systems.

We took this year to begin experimenting with an **Upper Roof Walkable Pilot**[29] in which we used salvaged components of other projects to develop a system that might withstand ongoing foot traffic while still remaining vegetated. This work later influenced future walkable system designs.

In the interest of furthering our understanding of vertical systems, a **Tournesol VGM Green Wall**[30] system was added. We installed a revised solid growing medium block in order to aid in water retention and plant rooting. A third vertical system is scheduled for the future, which will include an integrated irrigation system to overcome the watering challenges of non-horizontal planting.

[29] Upper Roof Walkable Green Roof Pilot (see table at end)
[30] Tournesol Siteworks (see table at end)

In 2017 a **Composting Garden Towers** was constructed. The Garden Tower 2 functions as a closed natural loop that grows healthy vegetables, herbs, and plants in a small vertical space. This system hosts a central column that houses the organic food waste and worms. The worms consume the organic waste and create nutrient rich manure for the attached 50 planting pods. The vertical structure of the garden tower allows water to be added on top, filtered down to subsequent layers, and where it is collected at the base of the structure. This nutrient-rich tea composition can then be added back to top of the system to complete the loop.

In 2018 several installations were done. **FilterSoxx were installed around CWS Drains**. NYC Parks installed permeable mesh and wood chip material around drains on the roof to assist with keeping drains clear of debris. **Filtrexx SiltSoxx** is a three-dimensional tubular device made of **FilterMedia** encased in **Filtrexx Mesh**. It is designed to support stormwater management, sediment and erosion control, and pollutant removal Best Management Practices (BMPs). It is generally used in areas where delimiting the risk areas and diverting, cleaning and filtering stormwater runoff is critical. **SiltSoxx** is often used in combination with other sediment control systems to create a complete solution. Most typical applications are check dam, concrete washout, inlet protection, perimeter control, runoff diversion, slope interruption, sediment traps and diverse filtration systems.

A **Sedum Bridge Xero Flor System**[31] was installed between our larger Xero Flor systems with a perlite-based growing medium in which sedum were planted to test options for a future walkable system.

Installation of **Solar Green Roof Ballasts**[32] was also done in 2018. These filled permeable bags with soil and added plants to them to test ballasting of additional solar arrays using more sustainable alternatives to standard cinder block ballasting. Cooling and sediment reduction benefits will also be measured over time, furthering the benefits of this organic design.

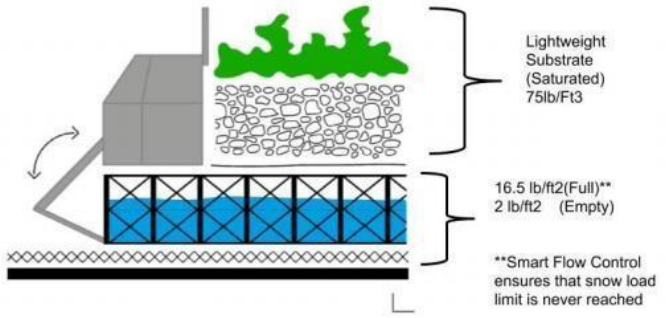
In 2018 Walkable **Green Roof Expansions**[33] were also done. Using **GeoCell**, a 3:1 Perlite to compost mix for growing media, root barrier, combo fleece and native plants, we began piloting a new walkable green roof project on the upper roof of the CWS Complex using our overall understandings on best practices surrounding this challenging system.

[31] Sedum Bridge Xero Flor System (see table at end)

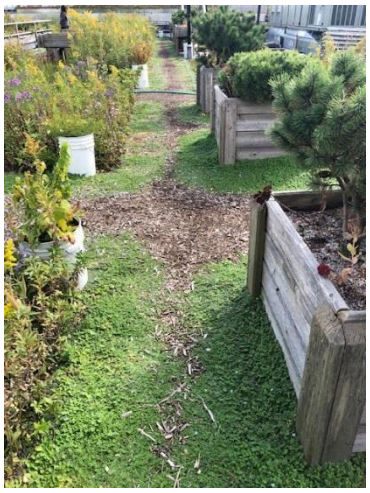
[32] Solar Array (see table at end)

[33] Walkable Green Roof (see table at end)

In 2019, **Polder Blue Green Roof**[34] was installed. Polder Roofs are a smart roof solution focused on rain collection. The system uses a mill to control the amount of stormwater retained, as well as sensors in the system that are connected to the internet to show this data in real time. The "polder" portion of the roof is a foundation that is placed underneath the green roof materials but above the waterproof membrane to collect rainwater. The system records the rainfall collected, evaporation, water level, and temperature, and water storage can be emptied remotely, allowing for optimal management of rainwater in an attempt to best mitigate combined sewer overflow events.



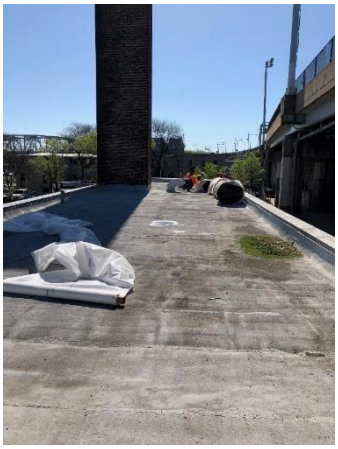
In 2019 we installed **Walkable System Phase 2**[35]**.** Based on our prior walkable system design, we constructed a new upper roof walkway path using a lightweight growing media, woodchip topdressing and a geotextile which distributed the impact on traffic so creeping herbs would be able to survive as groups walked the trails.



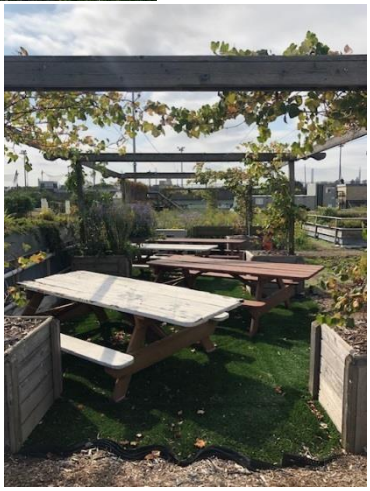
Beginning in 2019 **phase 2 of the Parapet Wall System** was begun[36]. Currently in progress this expansion of the existing upper roof parapet wall was designed to extend to all additional parapets on the upper and lower roof dramatically increasing the square footage of the green roof and adding more deep bed and high organic growing zones.

[34] Polder Green Roof (see table at end)
[35] Walkable System Phase 2 (see table at end)
[36] Parapet Wall System Phase 2 (see table at end

In 2019 a **green roof was installed on the boiler room**[37] , a small building near our garage. Working on the facility adjacent to the Citywide facility, we decided to build an incredibly diverse native system on our boiler room building. This uses a layering system similar to the lower roof, but in a monolithic design, we look forward to seeing how sustainable the final established plant palette turns out once the plants root and adjust to these unique circumstances.

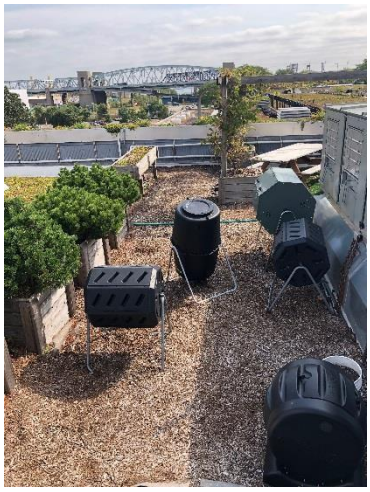


Picnic Turf Areas[38] were also installed in 2019. As a solution for growing systems under the heavy traffic and fully shaded picnic areas, we installed turf, which is lined with water absorption fabric, allowing for even the inert zones of the roof to contribute towards our facilities environmental goals.



[37] Boiler Roof Green Roof (see table at end)
[38] Picnic Turf Areas (see table at end)

In 2019 we also installed **Permeable Compost Bin Roofing**[39]. Deciding to boost the sustainability of our compost demo site even further, we dressed the area underneath the bins with green roof layers, engineered soil and woodchips, allowing the space to retain additional stormwater.



In 2021 We resumed our green roof operations with upgrades to several of our existing beds, building out multiple systems with denser plantings of natives from our plant nurseries. This both increased their water retention capacity as well as made the seedbank within the systems more self-sustaining.

In 2021 we also saw the third expansion of our walkable pathways, stretching the span of the garage roof and connecting the farm to the apiary. With this the majority of the main thoroughfares across the CWS roof are now permeable.

We wrapped up the year by removing the aluminum dividers between our farm beds and adding deep woodchip medians to detain more supplemental rainwater for our crops, increasing future farm harvests viability by creating additional passive irrigation potential.

Ongoing Projects on the Green Roof at CWS

The Citywide Services facility and the efforts of the NYC Parks Sustainable Facilities Division are constantly evolving as new technologies emerge and as new environmental priorities are established. It is through this evolution that our many teams thrive, rising to the challenge of defining our agencies best practices with an unparalleled enthusiasm for continually expanding our unbiased and people-focused efforts towards sustainable and resilient improvements for our city. This ongoing piloting work would not be possible without the dedicated efforts of the Emerging Technology Team, a group which has been composed of thousands of volunteers over the years lending an incredible diversity of backgrounds, skills, and voices to our agency's overall efforts. If you would like to receive a facility tour, acquire supplies, gain training, learn more from and/or be a part of this work please feel free to contact Max Lerner at Max.Lerner@parks.nyc.gov to discuss!

Thanks for reading and good luck in your green infrastructure efforts!

[39] Permeable Compost Bin Roofing (see table at end)

Table of System Details

Box	Installed	System	Type	Size (sq ft)	Cost ($ per sq ft)	Dry/Wet Weight (lbs per sq ft)
1	2007	Layered System I (12" Gaia)	Intensive,Monolithic	800	$13	14lbs/25lbs
2	2008	Tray System I (4" Rooflite)	Extensive, Modular	800	$8	14lbs/25lbs
3	2008	Tray System II (6" Rooflite)	Extensive, Modular	800	$9	22lbs/34lbs
4	2008	Green Paks (4" shale/pine bark))	Extensive, Modular	800	$8-$10	12lbs/18lbs
5	2008	Tray System III Bio-trays (2" mineral)	Extensive, Modular	200	$4-$5	12lbs/14lbs
6	2008	Elevated Planters	Intensive, Atypical	200	$15-$30	25lbs/50lbs
7	2008	Wood Parapet System	Intensive, Atypical	200	$5-$9	12lbs/25lbs
8	2008	Metal Parapet System	Intensive, Atypical	1200	$5-$10	12lbs/25lbs
9	2008	Trellis (mineral soil)	Atypical	800	$2-$3	42lbs/48lbs
9	2008	25 Cedar Planters (Metro-Mix)	Intensive, Atypical	250	$18-$27	25lbs/50lbs
10	2009	Layered System II (6" Gaia)	Extensive, Monolithic	800	$8	7lbs/13lbs
11	2009	Container Growing Medium (6" Metro-Mix)	Extensive, Monolithic	600	$2-$5	11lbs/25lbs
14	2009	Walkable Green Roof-Atrium (4" mineral)	Extensive, Monolithic	800	$5	14lbs/21lbs
13	2009	Xero Flor 2" System	Extensive, Monolithic	6250	$2-$9	8lbs/12lbs
14	2009	Green Grid (4" mineral)	Extensive, Modular	800	$2-$18	10lbs/14lbs
15	2009	Native Wildflower from seed (80/20 mix)	Intensice, Monolithic	650	$5	17lbs/29lbs
16	2009	Multi-depth Mineral Soil System	Extensive, Monolithic	400	$5	22lbs/34lbs
17	2010	Xero Flor 3" System (1"extra mineral soil)	Extensive, Monolithic	6350	$2-$8	12lbs/18lbs
18	2010	Gaia 8" - by Columbia Students	Intensive, Monolithic	400	$2-$8	10lbs/16lbs
19	2010	Columbia Study Mineral Soil Beds (4")	Extensive, Monolithic	516	$5	14lbs/21lbs
19	2010	Columbia Study Mineral Soil Beds (6")	Extensive, Monolithic	516	$5	22lbs/24lbs
20	2010	Vegetable/Herb Farm	Atypical, Monolithic	4000	$5	15lbs/18lbs
21	2010	Bio-Roof (4")	Extensive, Atypical	250	$3-$11	9lbs/14lbs
22	2010	Bio-Roof (10")	Intensive, Atypical	250	$5-$13	15lbs/25lbs
23	2011	Perlite/Metro Mix (12")	Intensive, Monolithic	800	$2-$7	14lbs/22lbs
24	2011	Façade Farm	Atypical	50	n/a	n/a
25	2011	Hydroponic Vegetable system	Vertical, Hydroponic	15 units	$500/unit	n/a
26	2011	Blue-Green roof trays	Extensive, Modular	650	n/a	12lbs/25lbs
27	2012	Sun Root System	Extensive, Monolithic	250	$5-$11	14lbs/21lbs
28	2013	Watergrip Green Roof System (3')	Extensive, Atypical	96	$9-$12	2lbs/12lbs
29	2013	Tournesol VGM Green Wall (8”)	Vertical, Modular	36	$10	n/a
30	2014	Layered Bed System	Extensive, Modular	16	n/a	15lbs/20lbs
31	2015	Lower Green Roof	Extensive, Modular	5,000	n/a	17lbs/22lbs
n/a	2016	Lower Green Roof Upgrades	n/a	n/a	n/a	n/a
n/a	2016	Bucket Sapling System	Intensive, Modular	100	n/a	n/a
32	2017	Upper Roof Walkable Pilot	Intensive,Monolithic	50	n/a	17lbs/22lbs
33	2017	Tournesol VGM Green Wall (Solid Media)	Intensive, Modular	160	$10	n/a
34	2018	Sedum Bridge Xero Flor System	Extensive, Atypical	250	$6	12lbs/14 lbs
35	2018	Solar Green Roof Ballasts	Atypical	100	$4	14lbs/16lbs
36	2018	Walkable Green Roof Expansions	Extensive, Monolithic	875	$5	12lbs/16lbs
37	2019	Polder Blue Green Roof	Extensive, Modular	900	n/a	n/a
38	2019	Walkable Green Roof Expansions Phase 2	Extensive, Monolithic	1,285	$5	12lbs/16lbs
39	2019	Parapet Wall System Phase 2	Intensive, Monolithic	2,600	$5-$10	12lbs/25lbs
40	2019	Boiler Room Green Roof	Intensive, Monolithic	2,750	n/a	15lbs/25lbs
41	2019	Picnic Turf Areas	n/a	900	n/a	10lbs
42	2019	Permeable Compost Bin Roofing	Extensive, Monolithic	200	n/a	10lbs/15lbs
43	2021	Replanting of Native Systems	Intensive, Monolithic	n/a	n/a	7lbs/13lbs
44	2021	Walkable Green Roof Expansion Phase 3	Extensive/ Monolithic	1,100	n/a	12lbs/16lbs
45	2021	Farm Bed Medan Expansions	Intensive/Monolithic	500	n/a	15lbs/18lbs
Total Square Feet = 47,300 of Green Roof						

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