THE STORMWATER QUARTERLY

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GREEN ROOF FUNDAMENTALS

Stormwater News

Northern District of Ohio— On May 3, 2024, Mark Shepherd pleaded guilty to violating the Clean Water Act for discharging pollutants and hazardous substances that killed thousands of fish in the Scioto River (33 U.S.C. §§ 1311(a), 1319(c)(1)(A)). Sentencing is scheduled for August 12, 2024.

Shepherd owned and operated two trucking companies, Cessna Transport, Inc., and A.G. Bradley, Inc. On April 17, 2021, Shepherd negligently discharged approximately 7,000 gallons of a substance containing ammonia into the river without a permit. Environmental authorities determined that the discharge killed more than 43,000 fish, including black bass, flathead catfish, sunfish, and minnows, valued at approximately $23,000. The contaminants flowed approximately 18 miles downstream from where Shepherd illegally dumped them.

A local fisherman reported the fish kill, which occurred in an area routinely used for recreational fishing. According to the Ohio Environmental Protection Agency, a water quality sample taken in 2009 near the site of the fish kill listed the area as "Generally High-Quality Water."

The Ohio DNR, the Ohio Attorney General's Office-Environmental Enforcement Unit, the Ohio EPA, the Ohio Bureau of Criminal Investigation, and the U.S. EPA Criminal Investigation Division conducted the investigation.

(Update: Mark Shepherd has been sentenced to 12 months of probation, a $5,000 fine, and 150 hours of community service by U.S. Magistrate Judge Darrell A. Clay. He was also ordered to pay $22,508.60 to the Ohio Division of Wildlife.)

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Green roofs are a green infrastructure alternative to conventional roofs that reduce stormwater discharge and provide a wide range of additional environmental and aesthetic benefits. Through integrative design approaches, they offer opportunities to maximize the beneficial use of spaces traditionally unused for stormwater management. In contrast to traditional asphalt shingles or metal roofing, green roofs absorb, store, infiltrate, and evapotranspire stormwater. They also serve as thermal buffers for the building's underneath, cooling the buildings during warm weather and insulating them during cold weather. As greenspaces that are often within highly developed landscapes, green roofs can provide habitat for wildlife such as birds and insects and offer aesthetic amenities to building occupants.

If communities implement green roofs widely, localized benefits of green roofs can add up in important and measurable ways. By reducing stormwater discharges, green roofs also reduce impacts to local waterways by reducing stream scouring, lowering water temperatures and improving water quality. Widespread implementation can also reduce combined sewer overflows (CSOs) in areas with combined sewer systems, potentially preventing the discharge of millions of gallons of sewage into local waterways. Through better thermal regulation, green roofs may not only reduce urban heat island effects, they may also increase the energy efficiency of buildings. This reduces heating and cooling energy use, thus helping to reduce greenhouse gas (GHG) emissions.

Applicability

Design engineers can apply green roofs to new construction or retrofit them onto existing residential, commercial and industrial buildings. Many cities, such as Chicago and the District of Columbia, actively encourage green roof construction to reduce stormwater discharges

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Retention vs. Detention

What is retention?
Retention and detention are often used interchangeably, but they do have distinct differences.

Retention is the storage of stormwater runoff without subsequent surface discharge. Retention is also commonly used to describe practices that retain a runoff volume until it is displaced in part or in total by the runoff event from the next storm.

Retention systems maintain a significant permanent pool of water between runoff events. When rain occurs the retention area can hold water until the next rain event which forces the stored water out. The incoming water will be stored in its place.

Retention areas can come in many forms including retention ponds, tanks, tunnels and underground vaults or pipes, as well as wetland basins.

What is detention
Detention is the practice of collecting water for temporary storage with the intention of subsequent release.

Detention systems do not retain a significant permanent pool of water between runoff events .Examples of water detention include detention basins, underground vaults, tanks or pipes, and deep tunnels, as well as temporary detention in parking lots, roof tops and depressed grassy areas.

How do you retain stormwater runoff?
Capturing stormwater runoff can help wetlands and parks flourish, replenish groundwater supplies and provide additional water supplies for cities and residents. Other benefits of stormwater capture include reduced heat island effects, increased flood protection, more green spaces, improved water quality and more habitat for plants and wildlife.

Infrastructure projects like rain gardens, bioswales, porous pavement, green roofs, rain barrels and green streets are all ways to capture stormwater runoff in developed areas.

What is a water retention system?
A stormwater system is a tool for managing the runoff from rainfall. Man-made stormwater systems were designed to mimic natural processes and come in a variety of shapes, sizes and forms. They can be built as stormwater retention basins, stormwater swales, dry retention systems and wet detentions.

A stormwater retention basin is designed to store runoff for about 72 hours to allow water to seep through the soil into the shallow groundwater aquifer. A stormwater swale is either man-made or natural areas shaped to allow water to be quickly absorbed into the ground or to allow the water to flow to other waterways. Dry retention systems hold a certain amount of stormwater and dries through percolation.

Wet detention systems are designed to allow material to settle and be absorbed. After a storm, water drains from the ponds through an outflow pipe. Part of the pond, known as the permanent pool, is always below the level of the drain structure.

What is the difference between retention and detention ponds?
A detention pond temporarily stores stormwater runoff. The basin is designed to manage stormwater runoff by storing it and releasing it gradually until it is completely drained.

A retention basin or pond is designed to permanently hold water. Retention basins are used when the groundwater is near the surface of the ground. A retention basin will not have an outlet source. The water collected by a retention basin will either infiltrate the ground or evaporate.

A retention basin will have a higher removal of pollutants. Retention basins can also serve as an aesthetic or recreational amenity, as well as habitat for wildlife and vegetation. They can become their own ecosystem.

ASSET MANAGEMENT: A STORMWATER TOOL

The practice of asset management is well understood and consistently applied in the drinking water and wastewater sectors, but asset management is less developed in the stormwater sector.

The results of the 2022 Water Environment Federation (WEF) National MS4 Needs Assessment Survey reflect that less than half of MS4 programs have an asset management program. It is likely that among those with an asset management plan, many are not robust compared to more well-established infrastructure sectors. But this is starting to change. The experience of one North Carolina community highlights the path forward.

Fuquay-Varina, North Carolina, is undertaking an asset management journey to inventory older, unmapped infrastructure in the town's two downtowns to implement an approach to managing its MS4 assets. The town has a robust inventory of assets except for those downtown areas, and this project will fill the gap. The town's MS4 program strategy includes several essential components:

- MS4 O&M Program:
- Municipal Stormwater Control Measures (SCM) O&M Program:
- Facilities Operation and Maintenance (O&M) Program:
- Spill Response Program:
- Pesticide, Herbicide, and Fertilizer Management Program:
- Vehicle and Equipment Maintenance Program:
- Pavement Management Program:

These nine drivers should be considered when developing an asset management plan:

- Improved financial performance
- informed asset investment decisions
- enhanced risk management
- improved service
- increased efficiency and effectiveness
- regulatory compliance
- enhanced organizational reputation
- improved organizational sustainability, and proactive social responsibility.

Because these considerations often stem from regulatory requirements, environmental protection rules, and community expectations, systems have flexibility to tailor their asset management approach to their situation.

STORMWATER NEWS

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Puerto Rico—On May 3, 2023, Awildo Jimenez-Mercado pleaded guilty to violating the Clean Water Act (CWA) for participating in illegal construction projects that involved dumping fill material into protected wetlands. Co-defendant Luis Enrique Rodriguez-Sanchez recently pleaded guilty to a CWA violation, and co-defendant Pedro Luis Bones-Torres pleaded guilty to violating the CWA (33 U.S.C. §§ 1311(a), 1319(c)(2)(A)) and the Rivers and Harbors Act (RHA) (33 U.S.C. §§ 403, 406).

Rodriguez-Sanchez owned a rock quarry, trucks for moving quarry material, and heavy equipment used in construction and earth moving. Bones-Torres was a licensed truck driver and owned and operated heavy equipment used in construction and land development. Between January 2020 and October 2022, the defendants illegally discharged fill material from excavation and earth moving equipment into the wetlands and waters of the Jobos Bay National Estuarine Research Reserve (JBNERR) and the Las Mareas community of Salinas, Puerto Rico. They also built structures (a dock and a concrete boat ramp) without obtaining the necessary permits from the Army Corps of Engineers.

Awildo Jimenez-Mercado occupied one of the properties, which consisted almost entirely of wetlands within the Reserve. In 2020, Jimenez-Mercado filled it in, and built a 120-ft dock on the water. The property now contains a permanent home, a mobile home, an in-ground pool with a concrete patio, and a septic system. He rents the homes on Airbnb as "Hidden Paradise 2 and 3."

Officials with NOAA designated the JBNERR as a National Estuarine Research Reserve in 1981. The area is comprised of approximately 2,800 acres of coastal ecosystems in the Southern coastal plain of Puerto Rico. The JBNERR contains mangrove islands, mangrove forests, tidal wetlands, coral reefs, lagoons, salt flats, dry forest, and seagrass beds. It is also home to the endangered brown pelican, peregrine falcon, hawksbill turtle, and West Indian manatee. Rodriguez-Sanchez is scheduled for sentencing on June 10, 2024; Bones-Torres will be sentenced on July 24, 2024; and Jimenez-Mercado's sentencing is scheduled for July 31, 2024.

The U.S. Environmental Protection Agency Criminal Investigation Division, the Federal Bureau of Investigation, the U.S. Army Criminal Investigation Division, U.S. Department of Commerce Office of Inspector General, National Oceanic and Atmospheric Administration Office of Law Enforcement, and the U.S. Fish and Wildlife Service Office of Law Enforcement conducted the investigation

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and CSOs. Other municipalities encourage green roof development with tax credits, density credits or grants. In addition, green roofs can often provide several points toward a Leadership in Energy and Environmental Design (LEED) certification.

Green roofs provide an opportunity to utilize traditionally unused spaces for stormwater management.

Regional Applicability

Green roofs apply in all parts of the country, though designers should carefully consider vegetation type and media thickness based on local climate. In climates with extreme temperatures, the thermal benefits of green roofs can make them more financially justifiable for many facility operators. In drought-prone regions, drought- tolerant vegetation is crucial, and greater media thickness can often improve vegetation resilience

Urban Areas

Green roofs are ideal for urban areas because they provide stormwater benefits and other valuable ecological services without consuming additional land. To help offset costs and increase adoption of the practice, many highly urban municipalities have incentive programs such as grants or reduced stormwater fees.

Stormwater Retrofit

A stormwater retrofit is a practice that design engineers put into place after development has occurred to improve water quality, protect downstream channels, reduce flooding or meet other specific objectives. Green roofs are a useful tool for retrofitting existing impervious areas associated with building footprints. An important consideration for retrofit applications is the load-bearing capacity of the existing roof. Most existing flat-roofed buildings can accommodate the weight of a green roof without structural modifications, but qualified structural engineers should make this determination.

Siting Considerations

Construction staff can install green roofs during initial construction or place them on buildings as part of a retrofit. The following factors determine the amount of stormwater a green roof retains: the surface area of the green roof, the depth and type of growing medium, the slope, and the type of plants. Green roofs are appropriate for industrial and commercial facilities and multi-family residential buildings such as condominiums or apartment complexes. Green roofs can also prove useful for small residential buildings. In all cases, green roofs should be easily accessible and property owners should understand the maintenance requirements necessary to keep the roof functional.

Design Considerations

A building should be able to support the loading of green roof materials under fully saturated conditions and snow loads, if applicable. This load typically ranges from 10 to 40 pounds per square foot but is design-specific (GSA, 2011; MAPC, 2010).

Green roof materials, or layers, vary according to specific types and applications but typically include (from top to bottom) a vegetation layer, an engineered planting medium, a filter mat, a drainage layer and a moisture barrier. Vegetation should be suited for local climatic conditions and can range from sedums, grasses and wildflowers on extensive roofs to shrubs and small trees on intensive roofs. Construction staff can build green roofs layer by layer or purchase them as a complete system. Some vendors offer modular trays containing the green roof components.

Design Variations

Green roofs include extensive, semi-intensive or intensive design variations (GSA, 2011; MDE, 2009; Tolderlund, 2010). The design selection depends on the loading capacity of the roof, the project budget, local climate and design goals such as the desired volume of stormwater retention.

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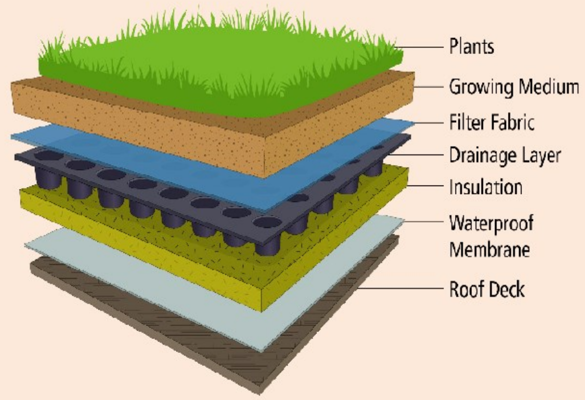
Generally, extensive green roofs have 6 inches or less of growing medium, whereas intensive green roofs have more than 6 inches of substrate. Semi-intensive green roofs are a hybrid between intensive and extensive green roofs, where at least 25 percent of the roof square footage is deeper than or shallower than the 6-inch threshold. Extensive green roofs provide many of the environmental benefits of intensive green roofs but are very low-maintenance and do not typically allow for public access. Engineers generally design semi-intensive and intensive green roofs for the public or building tenants to use as parks or relaxation areas. However, these green roofs require greater capital and maintenance investments than extensive green roofs. Intensive green roofs are particularly attractive for developers, property owners and municipalities in areas where land prices command a premium and property owners want to provide park- like amenities.



Green roof cross section showing typical material layers.

Limitations

In most climates, green roofs should include drought-tolerant plant species. In semiarid and arid climates, it can be a challenge to keep plants alive in a green roof shallower than 4 inches (Tolderlund, 2010). Therefore, developers typically prefer semi-intensive or intensive green roof systems in these climates. In arid regions, supplemental irrigation is sometimes a necessity

Therefore, developers typically prefer semi-intensive or intensive green roof systems in these climates. In arid regions, supplemental irrigation is sometimes a necessity

Structurally, the roof slope and the load-bearing capacity of the building may limit green roof design. Roof slope should not be too steep, as steeper slopes can promote overland flow, uneven drainage or rapid drying of uphill portions. Although sources often cite 30 degrees as a maximum slope, design engineers should exercise caution when considering any slopes that are not flat. In new construction, engineers should design buildings to manage the increased weight associated with a saturated green roof. When designing green roofs for existing structures, engineers should take the load restrictions of the building into account.

Green roofs can also entail greater capital costs than conventional alternatives. In recognition of this possible barrier to adoption, a number of large cities have some type of incentive program to reduce upfront costs.

Maintenance Considerations

Immediately after construction, property owners need to regularly monitor green roofs to ensure that vegetation is healthy. During the first season, owners may need to water green roofs periodically if precipitation is insufficient. After the first season, property owners may only need to inspect and lightly fertilize extensive green roofs approximately once per year. Property owners need to maintain intensive green roofs like any other landscaped area. Maintenance may involve gardening and irrigation in addition to general roof maintenance.

Green roofs are less prone to leaking than conventional roofs. In most cases, detecting and fixing a leak under a green roof is no more difficult than doing the same for a conventional roof. Still, a qualified professional should use proper construction techniques and conduct leak testing before planting occurs. Many green roof guidance documents—including this General____Services Administration report—provide helpful descriptions of leak detection methods, including flood tests and low- voltage leak detection.

Effectiveness

Green roofs can effectively reduce peak flows associated with storm events, reduce the total volume of stormwater discharge, and reduce the export of some pollutants often associated with traditional roofs. In a literature review of studies across climate and design types, Akther et al. (2018) found that green roofs had stormwater retention rates of at least 80 percent for small storm events but highly variable stormwater retention rates for larger storm

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events. In a review of green roof hydrology, Li and Babcock (2014) found that green roofs can reduce total stormwater volume and peak flow rates by around 30 to 90 percent and capture greater portions during smaller rain events prior to media saturation. Through exploratory modeling of the combined sewer system of New York City, Rosenzweig et al. (2006) also showed that a 50 percent adoption of green roofs across the sewershed would reduce total stormwater volume by up to 10 percent.

The ability of green roofs to address pollutant loading to downstream waters is mixed. As precipitation tends to be low in nutrients, green roofs often need fertilization to support healthy vegetation. When property owners fertilize green roofs excessively or outside of the growing season, green roofs may release nutrients, including nitrogen and phosphorus. Proper fertilization, combined with the ability of green roofs to reduce the total volume of stormwater, mitigates these effects. Still, in a study comparing the water quality of green roof and conventional roof discharges, EPA concluded that, if possible, property owners should direct green roof discharges to another green infrastructure practice for nutrient management and not discharge directly to a receiving water (U.S. EPA, 2009). However, green roofs have a clearer advantage over conventional roofs when it comes to toxic pollutants, as conventional roofs often produce discharges containing heavy metals and polycyclic aromatic hydrocarbons (Van Metre & Mahler, 2003).

**Cost Considerations**

Green roofs generally cost more to install than conventional roofs. However, they can be cost- competitive over their full life cycle when considering factors such as stormwater benefits, increased life span, increased energy efficiency and improved real estate value.

The life span of a green roof is generally similar to, if not better than, a conventional roof. For example, an extensive green roof can last around 25 years, which may be twice the life span of a conventional roof (Kosareo & Ries, 2007). This increased life span can often justify the high installation cost. The size and type of a green roof influences its installation cost, with smaller installations, and extensive systems costing less per square foot than less than deeper, intensive systems.

Compared to conventional roof installation costs of around \$10 to \$20 per square foot (Niu et al., 2010), green roof material costs are fairly low—with materials costing between \$1 and \$3 per square foot—but green roofs are labor-intensive to install and require a crane to lift materials to the roof, which can cost between \$4,000 and \$5,000 per day. Sources often cite the total cost of a green roof as \$15 to \$35 per square foot, with cost per square foot decreasing as size increases (GSA, 2011; RSMeans, 2019), though costs can be as high as \$60 per square foot (Tolderlund, 2010). Maintenance costs for green roofs vary over time, and costs are initially higher to establish the vegetation. After the first 5 years, maintenance costs are typically between \$0.10 to \$1.00 per square foot per year (MPCA, 2020).

To capture the true cost of green roofs, including monetizable benefits, several studies have performed life cycle costing or net present value (NPV) assessments comparing the cost of traditional roof installations to green roof installations. Although the range of benefits varies between studies, most authors found net economic benefits for green roofs, especially for green roofs on larger buildings. A life cycle assessment by Blackhurst et al. (2010) found that green roofs may not be as cost-effective on individual small, residential single family homes, but multi-family and commercial building green roofs are competitive when considering social benefits like reductions in the urban heat island effect, GHG emissions and stormwater treatment. Using NPV and incorporating air quality, energy savings and stormwater reduction benefits, Niu et al. (2010) found the NPV of green roofs to be 30 to 40 percent less than conventional roofs over a 40-year lifetime. Additionally, GSA (2011) developed cost-benefit models for green roof implementation on commercial and institutional buildings ranging in size from 5,000 to 50,000 square feet. Using national averages as well as cost figures specific to the District of Columbia, GSA (2011) found that accounting for reductions in stormwater, energy use and GHG emissions was generally enough to balance out installation costs, and green roofs offer a significant cost advantage when considering real estate and community-based benefits

**Information presented from the EPA NPDES Stormwater Best Management Practice—Green Roofs Fact Sheet**
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NYC INVESTS IN POROUS PAVEMENT

The New York City Department of Environmental Protection (DEP) Commissioner Rohit T. Aggarwala and Department of Design and Construction (DDC) Commissioner Tom Foley joined with Brooklyn officials to announce that work is underway to install seven miles of porous pavement along area roadways to help better manage stormwater and reduce flooding and sewer overflows.

DDC is managing the $32.6 million contract for DEP and construction is anticipated to be completed in the Fall of 2025.

Unlike traditional asphalt roadways, porous pavement allows stormwater to pass through and be absorbed naturally into the ground. Porous pavement is installed along the curb line of a street, where the stormwater typically drains towards a catch basin on the corner, and can withstand the weight of motor vehicles, including trucks. Prior to any construction, soil samples are taken from beneath the roadways that are under consideration to determine if the soil will absorb stormwater.

Once a roadway is approved for construction, the work includes removal of the existing roadway along the curb line to a depth of roughly 24 inches. Drainage cells and stone are added to aid in storage and drainage of the stormwater, as well as to provide structural support for the porous concrete slabs that are laid on top.

According to a New York City government press release, porous pavement will keep 35 million gallons of stormwater out of the Combined Sewer System. Its announcement follows a tropical storm last fall that inundated homes and shut down transit lines.

"[The project] will also save time and money, since porous pavement installations can prevent flooding without the need of going underground and expanding sewers," New York City Department of Design and Construction Commissioner Thomas Foley said in a statement.

The city pointed to one limitation of porous pavement, however: It can't be installed in locations blocked by other infrastructure, like sewer and water pipelines.

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