WHITE PAPER / **GREEN STORMWATER INFRASTRUCTURE**

SOLVING BURIED PROBLEMS AT THE SURFACE

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Deferred maintenance and a rising number of significant rain events have become an overwhelming combination for aging stormwater systems. To keep streams clean, regulatory requirements are encouraging communities to invest in robust, sustainable and capital-intensive systems.

THE STORMWATER MANAGEMENT SYSTEM

In older U.S. communities (established pre-1880s), the first underground sewer systems enclosed existing drainage ditches, creeks and streams that had become polluted and were creating a human health risk. Enclosing these polluted drainage paths improved human health but passed the pollution downstream. Later, in the early 20th century, these enclosed piped systems were routed to wastewater treatment plants.

Enclosed systems grew by installing inlets or catch basins in low-lying areas to give rainwater a place to go. These older pipe systems and treatment facilities were not designed for this additional rainwater. Therefore, stormwater runoff quickly can overwhelm a system, which results in a mixture of sanitary flow and rainwater being directly released to creeks or rivers instead of a treatment facility, referred to today as a combined sewer overflow.

Catch basins, grate inlets, and/or drain pipes have been added to the combined sewer system pipes to relieve conditions such as ponding or flooding that are visible at the surface. Despite more stormwater entering the combined system, the pipes remained the same size. This has resulted in combined system overflowing at designated locations along creeks and rivers when the system is overburdened or backing up within the system itself. Sometimes this even results in water in basements of homes and businesses because of an overwhelmed pipe system during a rain event.

In 1994, the U.S. Environmental Protection Agency (EPA) published its Combined Sewer Overflow Policy as a framework and as guidance for reducing and controlling combined sewer overflows. Since that time, federal consent decrees have been issued through the EPA and the Department of Justice to communities across the country, requiring each to reduce combined sewer overflows. Consent decrees outline a schedule and tasks for a community to implement to reduce the volume of combined sewer overflows into local water bodies.

MUNICIPAL SEPARATE STORM SEWER SYSTEMS (MS4)

As part of more recent community infrastructure construction, inlets or catch basins were installed in conjunction with new pipes to control the depth and spread of stormwater runoff at the surface, such as in a parking lot or within the road cross section. The inlets connect to a separate storm sewer that conveys only stormwater runoff directly to creeks and rivers. However, rainfall runoff carries any pollutant found on urban surfaces, such as oils, metals, fertilizers, salt and animal feces, directly to water bodies. This is called nonpoint source pollution and is regulated under a community's MS4 permit.

MS4 permits are issued to communities in urbanized areas and/or with a population greater than 10,000. The MS4 permit states different activities a community must implement to reduce nonpoint source pollution to U.S. waters to the maximum extent practicable (MEP) through the use of stormwater best management practices (BMPs), also known as post-construction stormwater BMPs, which include green stormwater infrastructure.

GREEN STORMWATER INFRASTRUCTURE

Green stormwater infrastructure (GSI) provides a cost-effective alternative to capital-intensive construction programs. Green stormwater infrastructure supplements traditional pipe systems, linking what is visible at the surface with designed collection, storage, infiltration and even conveyance systems for frequent storms. These systems often look like street trees, planters, even street pavement. However, below the surface, tree roots might grow through layers of specialized soil and rock to provide a place for rainwater to collect rather than being directed into a pipe. In addition, because of its aesthetically pleasing attributes, GSI provides an immediate opportunity to integrate with planned development or redevelopment. It also can enhance more traditional infrastructure improvement projects, such as road reconstruction and stormwater management through catch basins and pipes.

The goal of integrating green stormwater solutions as part of an integrated combined sewer overflow and nonpoint source pollution reduction program is to capture and infiltrate stormwater runoff before it reaches the combined system or the separate sewer system. These systems are most effective when they collect stormwater where runoff is generated or when they are adjacent to impermeable surfaces. As runoff migrates farther downstream in the watershed during a storm, the overland flow paths of stormwater begin to merge, and the volume of rainwater significantly increases. This volume can quickly become overwhelming to control, often leading to flooding.

UNDERSTANDING RAIN EVENTS AND DESIGN EVENTS

It is important to understand rain events typical for a community when considering integration of green stormwater infrastructure into traditional stormwater management. Key rain event characteristics to consider are the duration of rain events and the intensity of rainfall. The overall size of a rain event is determined by the amount of rainfall.

A typical rainfall event in Kansas City, Missouri, occurs over a one-to-two-hour time-frame, with a total rainfall range of 1 to 1.5 inches. Area rain events that are more extreme will last three to four hours, with more than 5 inches of total rainfall. The purpose of green stormwater infrastructure is to manage the typical events, freeing up capacity within the conveyance systems to better manage the larger, more extreme events.

Traditional stormwater management design calculates a peak discharge rate based on a designated design storm, or design event. For example, a 10-year design event for Kansas City is 5.25 inches of rain in a 24-hour period. This instantaneous peak flow rate is typically determined using the Rational Equation, or other approved hydrology methods such Soil Conservation Service (SCS) Technical Release 55 (TR-55), and requires either a peak rainfall intensity or a total rainfall depth distributed over a 24-hour period. The rainfall associated with a peak discharge rate is significantly higher than an actual typical rainfall event in Kansas City.

It is important to understand why these rainfall event resources were developed and what they produce. The design events focus on using the peak discharge rate for stormwater infrastructure design — these estimates mitigate risk caused by uncertainty in rainfall amounts. Traditional stormwater infrastructure designs are focused on collecting this peak discharge rate from extreme events. Today's rainfall models and pipe models, or dynamic models, enable the routing of real rainfall into pipe systems to analyze those impacts. Dynamic models are more representative of what is actually happening during a rain event. Using these methods, stormwater systems can be designed for everyday rainfall events instead of a conservative peak.

A DUAL-PURPOSE PARK KANSAS CITY, MISSOURI

The City of Kansas City, Missouri, is one of more than 700 communities nationwide with combined sewer systems (CSS). In 2010, the city became the first community to receive a federally approved consent decree that incorporated green infrastructure methods into its long-term control plan (LTCP). This approach will reduce combined sewer overflows by 88 percent, and up to 96 percent in some neighborhood streams by 2035. The Arleta Park project demonstrates how the integration of green and gray (traditional, human-engineered solutions) infrastructure can reduce overflows while providing sustained community benefits.

Arleta Park sits in a natural drainageway and is part of a 375-acre watershed to the Blue River. Existing infrastructure experienced approximately 36 combined sewer overflows per year. To reduce that number, the city implemented bioretention green stormwater infrastructure in combination with other green stormwater infrastructure locations and strategic sewer separation. With design led by our team, the integration of green stormwater infrastructure with new and existing infrastructure has reduced combined sewer overflow (CSO) frequency by more than 80 percent.

As part of the overall project, the city completely transformed the park, integrating a new playground and basketball court adjacent to the stormwater improvements. Signage and other educational materials throughout the park enable the community to interact with the green stormwater infrastructure.

Green stormwater infrastructure is not meant to manage extreme events. Rather, it is intended to manage the most frequent and typical rainfall events, which account for approximately 90 percent of rain events. GSI reduces downstream runoff and preserves capacity within the conveyance systems by absorbing or capturing the runoff where it is generated.

DESIGN APPROACH

The primary objective for GSI is to catch stormwater runoff before it reaches the pipe systems. These solutions, though, differ significantly from traditional infrastructure in that there are no standard details or applications, such as standardized curb inlets. Each application is site-specific and typically designed to supplement traditional gray stormwater infrastructure, including inlets or catch basins and pipe systems.

In its *Green Stormwater Infrastructure Manual*, the City of Kansas City, Missouri, states that "GSI facilities can take on varying looks and functions, each designed specifically for the stormwater drainage reaching it, and to integrate within the surrounding area. GSI is unique to each area because of the surface runoff conditions, subsurface materials and surrounding landscapes."

There are, however, features of green stormwater infrastructure that are common between facilities and are designed to bring stormwater in and out of the facility, protect the infrastructure and promote its overall function. Common components include:

- **GSI inlets** that serve as a collection point for stormwater. Inlets can range from an opening in the curbline along a road to a traditional stormwater inlet.
- **Permeable pavement**, such as a large and thin infiltration system (LATIS), reduces impervious areas and can function as a stormwater collection point.
- **GSI landscaping**, such as rain gardens, provides benefits at or below the surface and can include trees, shrubs, grasses, perennials, wildflowers, and seeding and sodding.
- **GSI energy dissipation and pretreatment** components decrease the velocity of stormwater to prevent erosion and scouring of the surface. These components also can collect sediment, trash and debris from runoff.
- **GSI soil and aggregate media** are the primary means of storage and filtration, allowing stormwater to move downward within the GSI facility. Finer- and coarser-graded media provide filtration and storage. Soil media supports plant growth, from grasses to trees.
- **GSI piping** conveys stormwater to or away, provides access or observation to the subsurface, and protects utilities within the GSI.
- **GSI above-grade barriers** are physical or visual barriers at the edge of the GSI.
- **GSI outlets** are a discharge point of excess stormwater volume, either above or below grade.
- **GSI media liners** are permeable or impermeable synthetic fabric liners used to provide stabilization or separation.

GSI BENEFITS KANSAS FACILITY

Burns & McDonnell recently designed GSI for the Unified Government (UG) of Wyandotte County and Kansas City, Kansas, to support the redevelopment of the Juvenile Justice Center Building and parking lot. The UG, which is currently under a partial consent decree with EPA, recognized that implementing GSI in conjunction with the site redevelopment provided an opportunity to remove stormwater from the combined sewer system.

The GSI for this project involved a combination of stormwater tree planters, pervious pavers and a bioretention facility that provides 11,000 cubic feet of storage volume, exceeding current requirements of 8,000 cubic feet for this particular site. All of the GSI practices implemented in this project expanded on existing Planning Department requirements. For example, street trees were required as part of the redevelopment. Our design team expanded the function of street trees beyond aesthetics to bring rainfall runoff to them and provide an opportunity for rainfall to infiltrate.

Monitoring of ponding depth and soil moisture within the GSI post-construction can help estimate the water quantity and quality impacts to the downstream system. Most vegetation for green infrastructure has mature roots up to 3 to 7 feet below the surface, so monitoring the soil at those depths — rather than the filtration rate — will tell what moisture the plants are exposed to and give better insight on the total system's performance. Knowing the soil moisture in and around green infrastructure provides insight into how the design is performing for a range of real events. The monitoring process will show if the soil is too dry or too moist, identifying any necessary retrofits to current or future designs.

MAINTAINING GSI

Maintaining green infrastructure is substantially different than maintaining traditional gray infrastructure. For example, the high infiltration rates of engineered soils commonly used in GSI projects indicate that the soil around the vegetation can become too dry to sustain plant life. To best sustain your green infrastructure — and avoid costly maintenance, invasive weeds and poor performance — thorough testing and monitoring, as well as an adaptive design and a comprehensive maintenance plan, are critical.

It's important to note that green infrastructure will not fully sustain itself immediately after installation, even with the best construction. Therefore, it is recommended that contractors perform maintenance activities during the establishment period that include site-specific activities with a frequency for each. The plan also should account for the maintenance of every component of the GSI, such as barriers, landscaping, soil and media liners. Long-range monitoring of ponding depths and soil moisture provides important information on the movement of water in and through the green infrastructure with time. Infiltration performance should improve as maturing plants' root depths increase and the native vegetation becomes more sustainable.

INFRASTRUCTURE FOR THE FUTURE

Philadelphia, Pennsylvania, is the fifth-largest city in the U.S. and also is under a consent decree agreement with EPA to reduce combined sewer overflows by 85 percent. However, according to Yale School of Forestry & Environmental Studies, "rather than spending an estimated $9.6 billion on a 'gray' infrastructure program of ever-larger tunnels, the city is investing an estimated $2.4 billion in public funds — to be augmented by large expenditures from the private sector — to create a citywide mosaic of green stormwater infrastructure." Notably, many of the Philadelphia's GSI projects also support neighborhood revitalization efforts through enhanced parks and playgrounds.

The benefit of GSI is that the solutions provide sustainable benefits beyond stormwater capture. In Philadelphia, Kansas City and numerous other cities working to reduce CSOs, GSI helps cities improve the livability of their communities, enabling residents to gain firsthand benefits of their tax and/or sewer costs.

Moving stormwater management to the surface realizes increased visible infrastructure benefits that integrate into the objectives of many comprehensive and land use plans. These plans typically include streetscaping, providing vehicular and pedestrian connectivity, and defining a land development vision. As both capital and private development projects are implemented, this vision is realized. Incorporating green stormwater infrastructure into this vision can and will set the precedent for the infrastructure of future generations.

BIOGRAPHY

BRENDA MACKE, PE, PE , ENV SP, CFM is a stormwater/green infrastructure project manager at Burns & McDonnell, Brenda has more than 15 years of technical, management and marketing/sales experience in the civil engineering industry. Her passion, and specialty, is planning and designing sustainable infrastructure, including conveyance systems and green infrastructure facilities for both separate and combined sewer systems. She has been involved in a variety of regional and national projects focused on helping communities meet NPDES Phase II regulations, FEMA requirements, and EPA consent orders from both a planning and construction perspective.

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