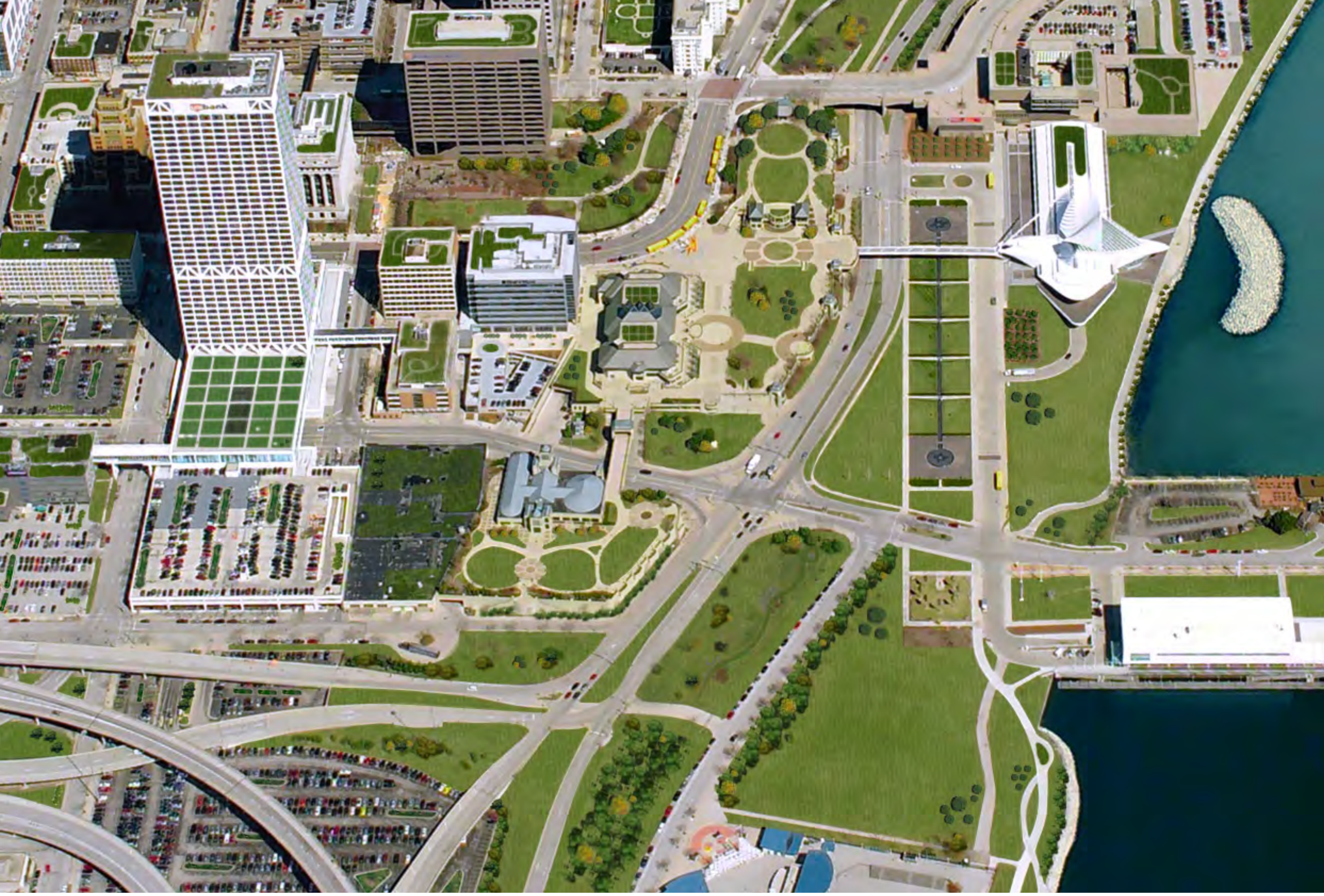
FRESH COAST
GREEN SOLUTIONS

WEAVING MILWAUKEE'S GREEN & GREY
INFRASTRUCTURE INTO A SUSTAINABLE FUTURE



IMAGINE ZERO

A message from MMSD's Executive Director, Kevin Shafer

On behalf of the Milwaukee Metropolitan Sewerage District (MMSD), I would like to present "**FRESH COAST GREEN SOLUTIONS: Weaving Milwaukee's Green & Grey Infrastructure for a Sustainable Future.**" With a decade of experience, MMSD is leading the way on green infrastructure solutions in the Greater Milwaukee Watersheds, demonstrating the benefits they provide for improving stormwater runoff quality and reducing quantity.

Our ultimate goal is simple in concept, but challenging, thought provoking, and a true test of the regional will to further protect our rivers and our fresh coast Lake Michigan. Imagine zero sewer overflows! Green infrastructure is a big part of the solution, and you can help.

Deep Tunnel Inspection

What is MMSD?

Caring for public health and protecting water resources has been a matter of conscience in the Greater Milwaukee Watersheds for decades. Milwaukee was one of the early pioneers in wastewater conveyance and treatment, building the first sewers more than 130 years ago to carry wastewater to the region's rivers and Lake Michigan.

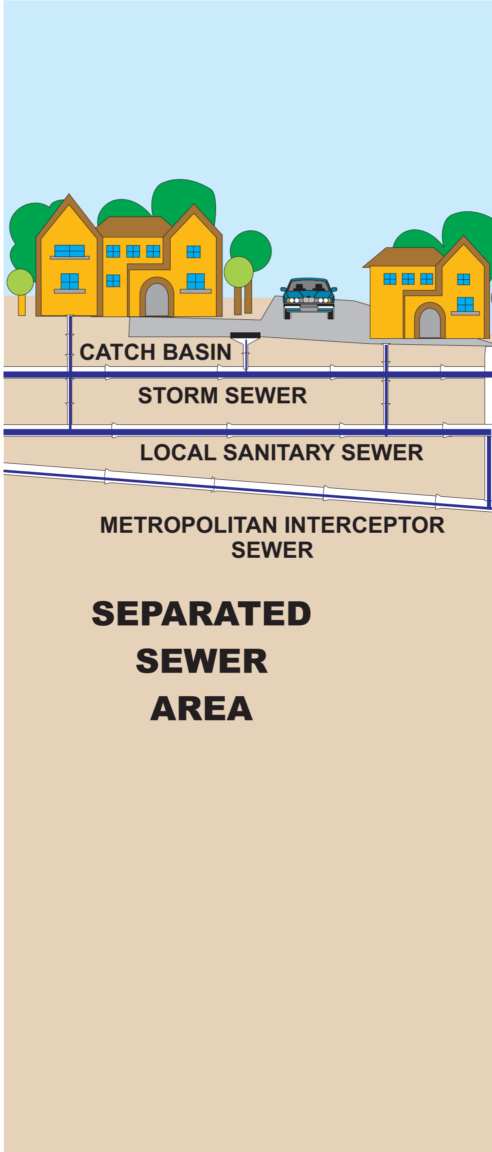
Today, the Milwaukee Metropolitan Sewerage District (MMSD) is a regional government agency that provides water reclamation and flood management services for about 1.1 million customers in 28 communities in the Greater Milwaukee Watersheds. MMSD serves 411 square miles that span parts of six watersheds.

Besides these core responsibilities, MMSD also handles water quality research, household hazardous waste collection, pharmaceutical collection, industrial waste monitoring, laboratory services, planning and engineering services, and the production of Milorganite®—a fertilizer trusted by professionals for more than 80 years.

As part of its Water Pollution Abatement Program (WPAP), MMSD invested $3 billion in grey infrastructure over three decades through the mid-1990s. Before 1994, when the Deep Tunnel System and other WPAP improvements went into operation, the MMSD sewer system had between 50 and 60 overflows per year, with an annual average volume of 8 billion to 9 billion gallons of overflow. Today, that number is down to only about two overflows per year, with an annual average of one billion gallons of overflow.

MMSD is currently finishing a $1 billion Overflow Reduction Plan that includes additional Deep Tunnel system capacity, sewer construction and rehabilitation projects, treatment plant improvements, scientific research, and planning. The entire effort will be finished by the end of 2010.

Over 80 years ago, Milwaukee became the first community in the country to recycle a by-product of its sewage treatment as fertilizer.



How the System Works

It takes thousands of miles of sewer pipes to collect and transport the region's wastewater to where it can be treated. MMSD owns and operates about 300 miles of regional sewers that collect wastewater from 28 communities. All 28 communities own and operate their own sewers—that's collectively about 3,000 miles of pipes. In addition, sewer laterals from homes and businesses account for about another 3,000 miles of pipes.

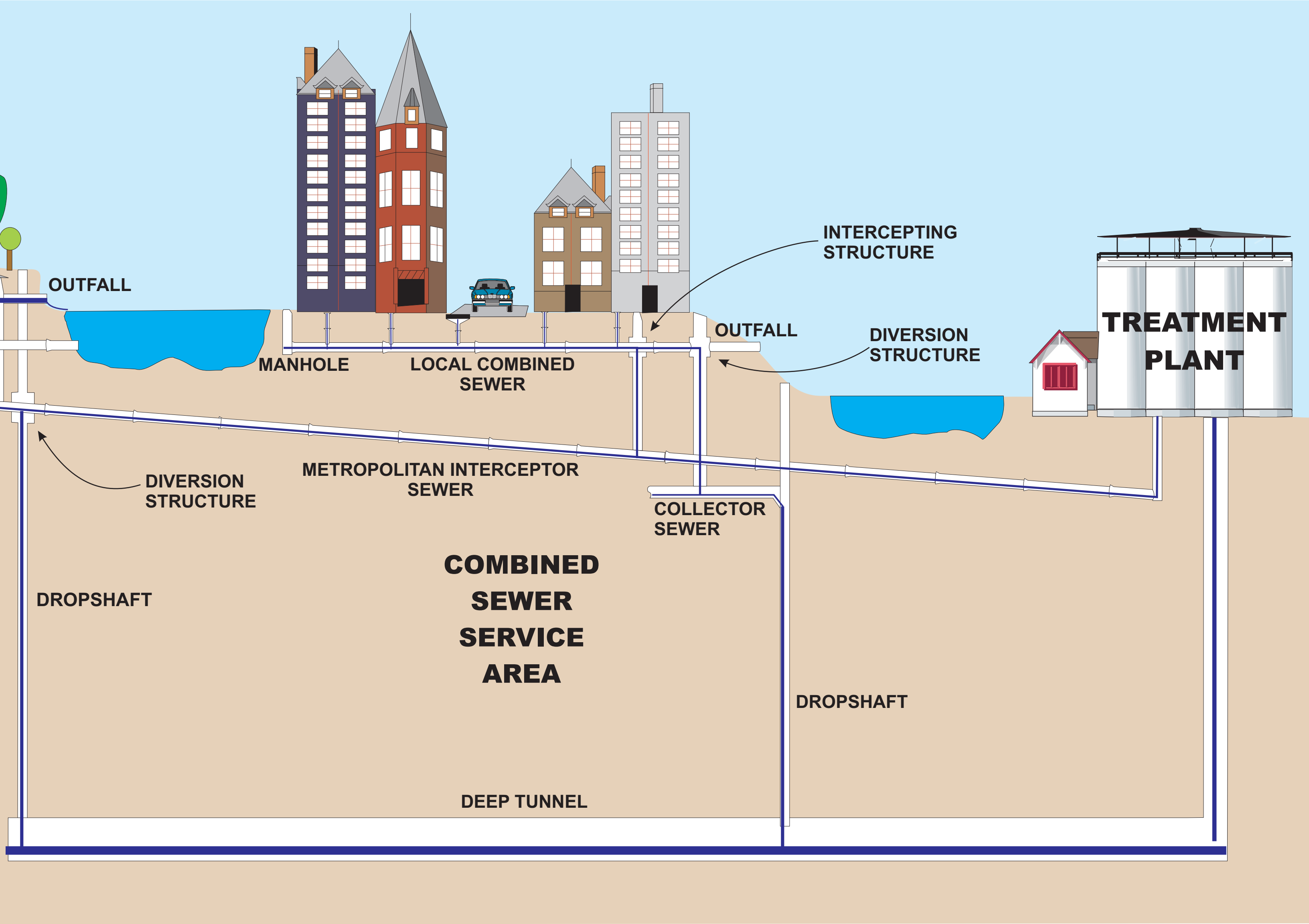
When wastewater leaves buildings within MMSD's service area, it generally travels through privately owned laterals to the municipal sanitary sewer systems that are typically under area roadways. From here, it flows to one of two types of MMSD sewer systems.

SEPARATE SYSTEM: In most of the region (about 95 percent), sanitary sewers convey wastewater separately from stormwater. Sanitary sewers convey wastewater to two water reclamation facilities – Jones Island and South Shore – owned by the MMSD, and the municipal storm sewers convey stormwater directly to area waterways, untreated.

COMBINED SYSTEM: In the older, more densely developed part of the service area (about five percent), sewers convey wastewater combined with stormwater. Combined sewers eventually convey wastewater to the Jones Island Water Reclamation Facility, which means stormwater is treated as well. Combined sewers provide a unique stormwater quality benefit not realized under separate sewer conditions.

Part of the MMSD's system is known as the Metropolitan Interceptor Sewer (MIS) system. The MIS system intercepts and conveys wastewater flows from municipal systems throughout the region.

Another part of the MMSD's system is known as the "Deep Tunnel." The Deep Tunnel is 300 feet underground and has a total capacity of 521 million gallons. Under extreme storm events, the Deep Tunnel temporarily stores wastewater until the water reclamation facilities have available treatment capacity. Since it went on-line in late 1993, MMSD's Deep Tunnel has prevented more than 80 billion gallons of wastewater from polluting Lake Michigan.



MMSD owns two water reclamation facilities that together can clean up to 600 million gallons of wastewater and stormwater each day it rains:

Jones Island Water Reclamation Facility (WRF) in Milwaukee was initially built in 1925. It uses primary treatment to remove part of the waste stream through settling sludge and skimming floatables, and secondary treatment using microscopic organisms or "bugs" to break down the majority of organic material that remains. The facility is a designated National Historic Civil Engineering Landmark as it was the largest facility in the country to use the power of microorganisms to feed on pollutants and reclaim water. The Jones Island WRF produces a natural fertilizer called Milorganite® from the microorganisms reclaimed through the treatment process. The facility can treat up to 300 million gallons of wastewater a day.

The South Shore WRF in Oak Creek was built in 1968 and also uses primary and secondary treatment. Rather than MMSD producing Milorganite®, microorganisms at South Shore are anaerobically digested to produce a gas that powers air blowers and an electrical generator. Sludge at the South Shore WRF can be pumped back to Jones Island through the Interplant Pipeline after the heat/methane are harvested, to help boost Milorganite® production. The facility can treat up to 300 million gallons of wastewater a day.

Wastewater from some areas served by both plants can be diverted from one plant to another during maintenance or wet weather.

Although the system is one of the most advanced in the world and has excess dry weather capacity, there are times when huge amounts of precipitation or snow melt can overwhelm the system. Combined and/or sanitary sewer overflows occasionally are then necessary to protect public health, protect against property damage and protect the system itself. MMSD and the communities it serves seek to avoid this whenever possible.

MMSD has always planned so the sewer system can meet the needs of a growing region on a regular cycle, and will continue to do so in the future. The emphasis of that past facilities planning has almost exclusively focused on the conveyance, storage and treatment of wastewater to meet the projected needs of the region under a set of agreed upon growth assumptions.

So, What's Next?

Most sewage overflows occur because excessive amounts of stormwater leak into sewers when it rains or when the ground is saturated.

With significant dollars spent by the region on pipes and plants, what more can be done?

Too much unwanted stormwater gets into the system, either through stormwater runoff into the combined sewer system, or by inflow and infiltration of stormwater into sanitary sewer pipes. When this happens, the system fills up, resulting in sanitary and combined sewer overflows. While this only happens an average of twice a year, MMSD and the region are striving to reduce these occurrences even more. One means of accomplishing this includes a greener approach to stormwater management.

To meet these challenges, MMSD will continue to build grey infrastructure and consider ways to reduce inflow and infiltration throughout the entire system as well as to consider widespread implementation of green infrastructure. Reducing inflow and infiltration will help make sure the system works as designed. Green infrastructure will help restore some of the earth's natural soaking benefits. This report focuses on the green infrastructure solution.

The IJC document recognizes MMSD's existing system that significantly reduced overflows. While MMSD continues to maintain the high level of service the region has come to expect, the IJC document notes success in building more infrastructure where and when it's needed. It also makes the case that the region should go further with green infrastructure.

Think Outside the Pipe

How can MMSD and area communities maintain the benefits of our sewer investment? Green infrastructure is a supplementary approach that's been proven in Milwaukee and elsewhere around the country to help manage stormwater and improve water quality.

So, just what is it? Green infrastructure is defined by the US Environmental Protection Agency as "an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly. Green infrastructure management approaches and technologies infiltrate, evapotranspire, capture and reuse stormwater to maintain or restore natural hydrologies." Simply put, it's an approach that helps store, convey and use rainwater in more natural or nature-like ways. It cannot entirely replace the capacity of grey infrastructure in urban areas, but it can add needed capacity.

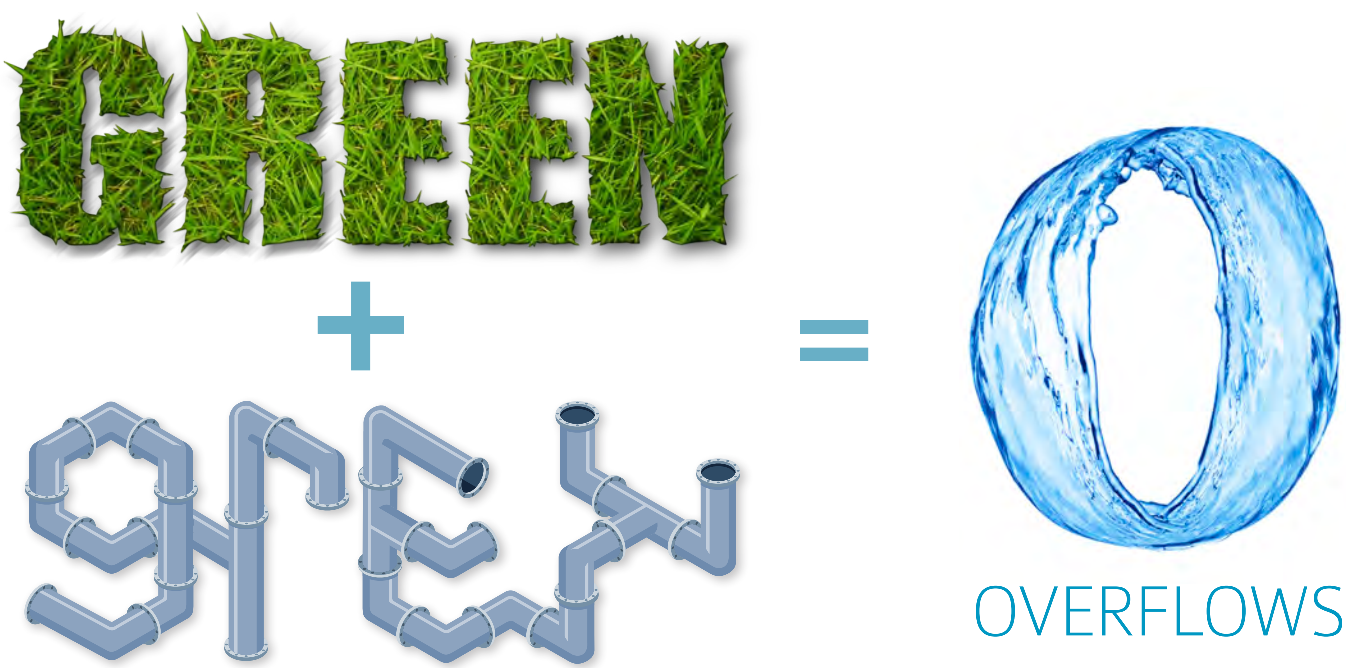
In August of 2009, the International Joint Commission (IJC) of the United States and Canada issued its 14th Biennial Report on Great Lakes Water Quality. The report said that "[h]aving achieved considerable control of CSOs in the Milwaukee area, urban and rural nonpoint source runoff now results in a greater percentage of the fecal-coliform annual loadings than before the significant reduction in overflows were achieved. Similar to Toronto, MMSD has advanced efforts to encourage installation of rain barrels, green roofs, rain gardens and other best practices for stormwater management. Success like the Toronto and Milwaukee examples demonstrates the need for well-designed, long-term plans."

Formula for Better Stormwater Management

Milwaukee's success shows that grey infrastructure is crucial to providing high quality conveyance, storage and treatment in an urbanized environment, but during times of intense or prolonged rain it can become overwhelmed. Impervious surfaces like rooftops, parking lots and roadways that drain to stormwater systems carry nonpoint source pollution directly to rivers and Lake Michigan. All this runoff can scour streambanks, creating an unnatural hydrology.

Many urban communities have started to incorporate green infrastructure along with the traditional grey infrastructure. This can include a wide range of effective, economical techniques that use what nature has taught us to manage water. These practices can be part of stormwater runoff reduction strategies benefitting overwhelmed combined sewer systems during storms and providing water quality improvements in separated sewer systems during small storm events. Restoring more natural hydrologic functions (or at least mimicking those functions) can actually make the grey infrastructure system work better. Putting grey and green together results in a basic formula for success that may help to eliminate sewer overflows.

Nonpoint source (NPS) pollution is pollution from many different sources. NPS pollution comes from storm and snowmelt water that runs across the land surface, picks up contaminants, and drops it into waterways and groundwater. Pollutants include insecticides from agricultural and residential lands as well as oil, grease and grit from city streets and a host of other sources. NPS pollution is the largest threat that our waterways face.   For instance, bacteria contaminates our waterways, causing water quality problems and detrimental effects on habitat, drinking water, and recreation.




Bradford Beach Parking Lot Bio-Swales

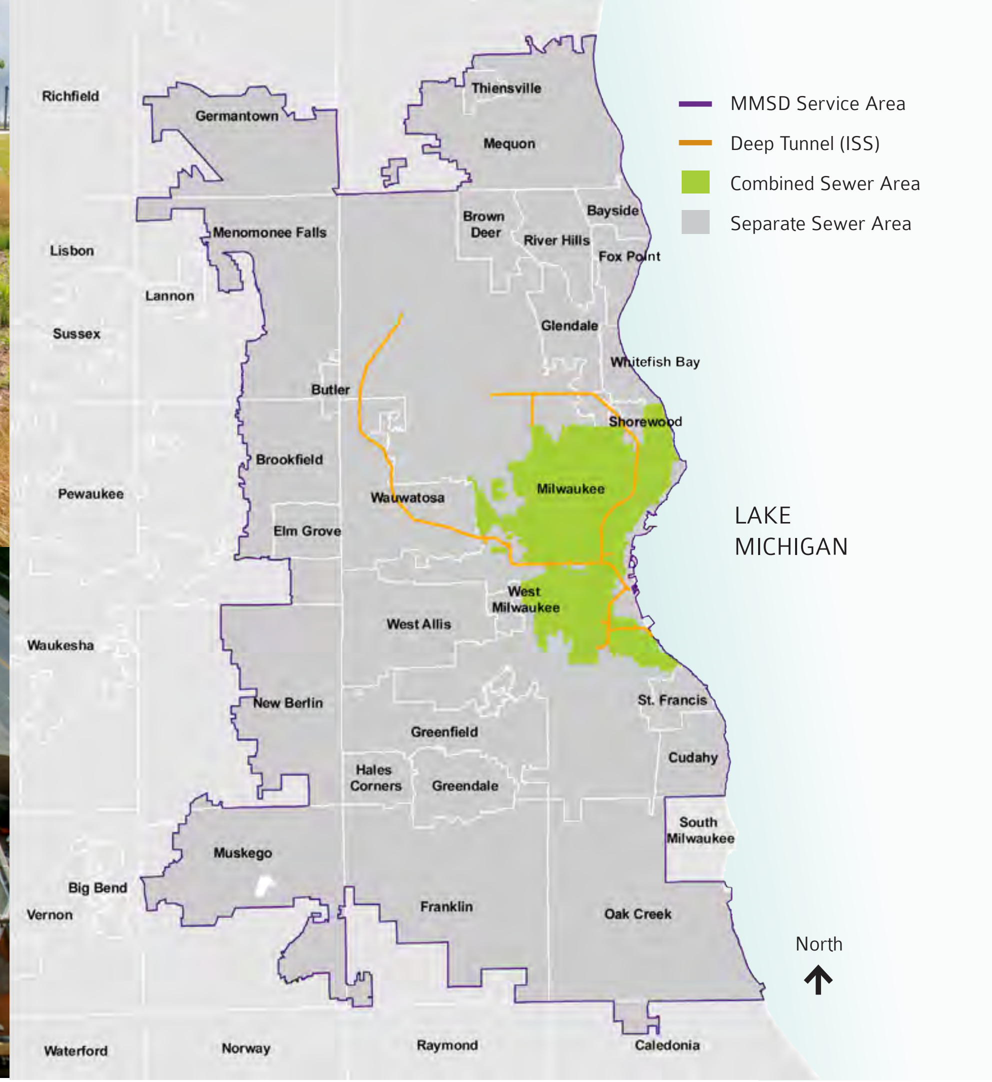
GREEN STRATEGIES

So just what are the green strategies? For purposes of this report, we've identified 10 that are located on the next two pages (12 and 13).

The majority of MMSD's service area, about 95 percent, has two separate sewer systems: one for stormwater and one for wastewater. The remaining five percent – the downtown core and adjacent neighborhoods – is served by one system that combines stormwater with sanitary wastewater. Because the man-made conveyance systems are different under the two plumbing scenarios, so too are the benefits of green infrastructure.

McKinley Bio-swale

MillerCoors Green Roof



SEPARATE SEWER AREA BENEFITS: In the separate sewer service area, the system's design goal was to keep rainwater out of the sanitary sewer system and carry it to receiving waters. Only the sanitary system was designed to carry water for treatment. Here green infrastructure can help to:

Improve receiving water quality: Storm sewers convey stormwater directly to Milwaukee's streams and Lake Michigan. When rainwater flows by gravity across rooftops, lawns, parking lots and roads, it picks up pollutants deposited from the air, fertilizers and pesticides, petroleum products and metals from cars, and any host of particles (referred to as NPS pollution). The stormwater system delivers that polluted runoff directly to receiving waters. However, when green infrastructure such as rain gardens and bio-swales intercepts stormwater, significant amounts of pollution can be removed. Nitrogen and phosphorous removal can be 50 percent or more of the total pollutant load from stormwater runoff; copper, lead, zinc, ammonium, and calcium have high removal rates as well *(EPA, 2006)*.

Reduce water needing to be treated: In the Milwaukee region municipal sanitary sewer systems carry between two and 40 times the amount of water when it rains compared to when it doesn't rain. There's clearly a benefit to keeping rainwater from getting into sanitary sewers because doing so can help to minimize treatment costs at the water reclamation facilities. Green infrastructure can help by storing stormwater and keeping it from leaking into sanitary sewer pipes.

COMBINED SEWER AREA BENEFITS: Green infrastructure in the combined sewer service area could help capture enough rainwater that might have otherwise contributed to a combined sewer overflow. Reducing the amount of water needing to be treated *(and the resultant energy cost savings)* is a benefit to everyone.

10 GREEN INFRASTRUCTURE DEFINITIONS

GREENWAYS

Greenways include riparian and non-riparian buffer zones and strips that store and drain stormwater runoff into the ground naturally. As vegetated strips that help to infiltrate and evapotranspire both rainwater and snow melt, they can be placed along bike paths, sidewalks, riverbanks and streets. They can be planted in native vegetation, in mowed grass and as gardens.

RAIN GARDENS

Rain gardens are gardens that are watered by collected or pooled stormwater runoff, slowly infiltrating it into the ground along root pathways. They are typically planted with wildflowers and deep-rooted native vegetation, which helps infiltrate rain channeled to them from roofs, driveways, yards and other impervious surfaces. They can be placed near downspouts on homes (although away from building foundations and sewer laterals), and are an excellent means of removing pollutants from stormwater runoff. They should be slightly depressed to adequately hold and infiltrate stormwater runoff.

WETLANDS

Wetlands are areas that have soils that are inundated or saturated for part of the year or for the entire year, and are also known as bogs, marshes, and swamps. Under federal definition, the inundation or saturation of soil in a wetland is at a frequency and duration to sufficiently support a prevalence of vegetation typically adapted for life in saturated soils. Wetlands allow rainwater to pool and slowly infiltrate into the ground, but are also seeps that provide water at the ground surface.

STORMWATER TREES

Stormwater trees can hold rainwater on their leaves and branches, infiltrate it into the ground, absorb it through root systems and evapotranspire it to the atmosphere. They can be used in conjunction with engineered soils and other types of green infrastructure and work best when they're mature (and so are not a quick fix to stormwater issues).

GREEN ROOFS

Green roofs (also known as eco-roofs) are either partially or completely planted with vegetation growing in soil (or a growing medium) to hold rainwater. They can be planted in waterproof trays or on top of a waterproof barrier, and can be intensive (like a rooftop park) or extensive (relatively lightweight). They function for stormwater management purposes when they're lush and green as well as when they're dormant.

Green infrastructure is an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly. At the largest scale, the preservation and restoration of natural landscape features (such as forests, floodplains and wetlands) are critical components of green stormwater infrastructure. By protecting these ecologically sensitive areas, communities can improve water quality while providing wildlife habitat and opportunities for outdoor recreation. On a smaller scale, green infrastructure practices include strategies such as rain gardens, porous pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting for non-potable uses such as toilet flushing and landscape irrigation.

BIO-SWALES

Bio-swales are landscape features that capture and infiltrate runoff and can also remove its pollutants. They are depressed catchment areas planted with vegetation, similar to a rain garden, and are usually used along transportation corridors or parking lots. They can be installed as meandering or straight channels depending on the land that's available, and are designed to maximize the time rainwater spends in the swale.

POROUS PAVEMENT

Porous pavement can reduce and infiltrate surface runoff through its permeable surface into a stone or filter media below. Runoff then percolates into the ground, is conveyed offsite as part of a stormwater system, or is collected and contained for future use. Porous pavement can be asphalt, concrete or pavers, but differs from traditional pavement because it excludes fine material and instead provides pore spaces that store and pass water.

NATIVE LANDSCAPING

Native landscaping (also known as conservation landscaping) is the use of native plant species that can tolerate the drought and flooding cycles of an area. Native plants are those that evolved in a particular area and are adapted to local climate conditions. Besides use in rain gardens, native landscaping can include prairie and other plants that provide habitat for native animal species.

RAINWATER CATCHMENT

Rainwater harvesting encompasses the capture and storage of rainwater. It also includes the ability to reuse stored rainwater for appropriate uses, primarily gardening and lawn watering. Harvesting not only includes the collection systems, but also the rain barrels and cisterns used to store the water. Rain barrels and cisterns are similar, although cisterns tend to be relatively large and sometimes are installed underground.

GREEN ALLEYS, STREETS AND PARKING LOTS

Green alleys, streets and parking lots are typically in the public right-of-way and can provide a combination of different benefits designed to channel, infiltrate and evapotranspire rainwater. They include permeable pavement, sidewalk planters, landscaped medians and bio-swales, inlet restrictors, greenways and trees (as described above), and can also take advantage of recycled materials.

MMSD Green Roof

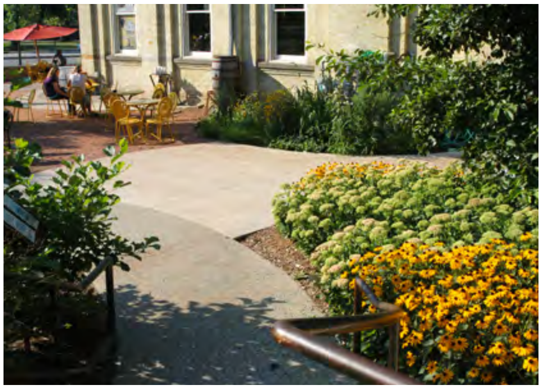
REGION-SPECIFIC **GREEN INFRASTRUCTURE** RECOMMENDATIONS

There is a direct link between urban development and waterway health. Urban development changes the natural hydrological cycle, directly affecting receiving water quality.

To cost-effectively protect public health and the environment by reclaiming wastewater and managing out-of-bank flooding, MMSD knows that minimizing costs to ratepayers is extremely important. As a point of comparison for considering the cost-benefits of green infrastructure, MMSD made a gallon-for-gallon construction cost comparison of storing a gallon of stormwater in the Deep Tunnel vs. storing a gallon of stormwater in each of the 10 green infrastructure strategies.

Based on the table on page 16, most of the green infrastructure strategies are relatively ***less*** expensive than Deep Tunnel storage, gallon-for-gallon in terms of construction costs. In fact, the more natural the solution, the lower the cost per gallon. For instance, wetlands ($0.06) and native landscaping ($0.07) are naturally occurring features, and are the two lowest-cost approaches. These may be difficult to site in urban environments, however, as they require both space and care.

In order to complete the cost-benefit analysis, more work must be completed to illustrate the regional benefits of the green infrastructure strategies and the grey infrastructure strategies. This benefits modeling is ongoing throughout many cities in the United



States including Milwaukee. The results of this modeling will adjust these costs up or down depending on their ability to reduce overflows and reduce polluted runoff. These green infrastructure strategies beneficially handle stormwater runoff in three ways:

EVAPOTRANSPIRATION is water evaporation together with plant transpiration. Evaporation is the movement of water to the air from soil, plants, the built environment and bodies of water. Transpiration is the movement of water within a plant and the loss of water through plant leaves.

STORAGE is the practice of capturing and holding stormwater on a temporary or permanent basis. Storage can be on a rooftop, at the ground level or underground.

INFILTRATION is the process by which water on the ground surface enters the soil. This term is also used to describe stormwater that leaks into pipes. When this occurs, infiltration is not considered beneficial.

Some green infrastructure strategies perform only one of these beneficial functions, while others perform multiple functions. Using green infrastructure in combinations can help maximize its stormwater management benefits.

Avoiding infiltration *into sewer pipes* is also important. To study this, MMSD commissioned four projects in 2005-06 to determine the potential for green infrastructure to infiltrate into private laterals and public sewer pipes. Two of the projects were conducted by consultants, one was conducted by the City of Milwaukee and one was conducted by UW-Milwaukee.

The green infrastructure measures tested included porous pavement, rain gardens, stormwater ponds and green roofs. Findings included:

- In the case of large-scale stormwater ponds, no evidence of inflow and infiltration into sewer pipes was detected in ponds 60 feet or greater from pipes (shorter distances were not tested).
- For smaller-scale green infrastructure, a horizontal distance of at least 10 feet from pipes is recommended, although shorter distances will probably not lead to significant increases in infiltration to pipes.
- Several BMPs will actually help reduce inflow and infiltration into pipes. With an integrated program, MMSD can define the selection, design and location of green infrastructure strategies to provide the maximum benefit.

It is important to note that all of these strategies provide additional benefits not quantified here, such as aesthetics/property value increases and, in the case of green roofs, energy cost savings. These benefits cover a full range of "sustainable" social, economic and environmental benefits and are further shown on pages 22 & 23.

CONSTRUCTION (CAPITAL) COST COMPARISON OF GREEN INFRASTRUCTURE MEASURES

No. of actions	GI Measure	Capital Cost per Unit of Measurement	Gallons per Unit of Measurement	Cost per Gallon	Action Classification	DEEP TUNNEL COST $2.42/GALLON
SINGLE	STORMWATER TREES	$250/each	169-449 gallons/year	$0.80	Evapotranspiration	
SINGLE	RAIN BARREL	$45-$190/each	40-80 gallons/barrel	$1.95 (MMSD Barrel = $0.81 /gallon)	Storage	
SINGLE	CISTERN	$500-$10,000/ each	Dependent on cistern size	$1.00 (based on 500 gallon cistern)	Storage	
DOUBLE	RAIN GARDENS	$3-$12/sq. ft.	1-3 gallons/sq. ft.	$3.75	Storage, Evapotranspiration	
DOUBLE	NATIVE LANDSCAPING	$3,400-$5,975/ acre	43,560-87,120 gallons/acre OR (1-2 gallons sq. ft.)	$0.07	Storage, Evapotranspiration	
DOUBLE	BIO-SWALE	$3-$10 cu. ft.	5 gal/cu. ft. (based on swale size of 10m long × 2m wide × 1m depth)	$1.30	Storage, Evapotranspiration	
DOUBLE	GREENWAYS (Walk/Bike Trail/ Riparian)	$200,000 - $500,000/mile	246,000 gallons/mile (based on 75 ft wide × 1 mile long trail)	$0.70	Storage, Evapotranspiration	
DOUBLE	GREEN ROOF	$8-$25/sq. ft	1.0-5.0 gallons/sq. ft.	$5.50	Infiltration, Evapotranspiration	
DOUBLE	POROUS PAVEMENT	$87,120- $217,800/acre	130,680-740,520 galllons/acre *OR* (3-17 gallons/sq. ft.)	$0.35	Infiltration, Storage	
TRIPLE	GREEN ALLEY/ STREET/ PARKING LOT	$260,000- $455,000/acre	130,680-740,520 gallons/acre *OR* (3-17 gallons/sq. ft.)	$0.82	Infiltration, Storage, Evapotranspiration	
TRIPLE	CONSTRUCTED WETLANDS	$39,000- $82,000/acre	360,000-1.5 million gallons/ acre *OR* (8.3-34 gallons/sq. ft.)	$0.06	Infiltration, Storage, Evapotranspiration	

KEY

ACTION SYMBOLS

- INFILTRATION
- STORAGE
- EVAPOTRANSPIRATION
- 50¢
- DEEP TUNNEL COST

These are approximate costs and holding capacities, since systems are specialized for their location and region. The price and holding capacity ranges vary based on specific designs.

Deep Tunnel cost is based on capital investment cost/holding capacity.

Cost/gallon is calculated by taking the capital cost only divided by the number of gallons per unit measurement. This is not a complete cost. For instance, land acquisition costs are not included. Therefore, additional investigation is recommended.

Note: if there is a price/capacity range, the average of each was taken and used for the calculation.

GREEN INFRASTRUCTURE STRATEGIES

South 2nd Street in Walker's Point, Milwaukee, 2009

GREEN INFRASTRUCTURE STRATEGIES
Stand-Alones vs. Combinations

Water currently runs off most streets when it rains or when snow melts. Providing porous features like the ones mentioned allows water to soak in where it falls, turning imperviousness into perviousness and mimicking natural hydrology to the extent possible.

Combinations of grey and green infrastructure strategies are important to stormwater management and treatment. Government ordinances often dictate which types of green infrastructure strategies can be used *(FHWA, 2009)*, and therefore different combinations of green infrastructure should be chosen to maximize the benefits depending on the location. Factors to consider in choosing green infrastructure include costs, storage capacities and treatment abilities.

In a study of stormwater best management practices, MMSD found that land uses tend to dictate best green infrastructure measure fit *(Stormtech, 2003)*. These include:

RESIDENTIAL STRATEGIES: In residential areas, disconnecting downspouts and directing them into a rain barrel, rain garden and across the lawn are effective combinations. These are relatively low-cost measures that can handle small-scale stormwater discharges. If implemented neighborhood-wide, up to a 39 percent reduction in peak flow and a 32 percent reduction in annual volume can result.

2010 Green Vision
2nd Place Redesign for "Good Magazine" Catalyzes Sustainable Street

Provided by Urbanmilwaukee.com
Photo Credit: Kieran Sweeney

Grange Ave. bio-swale, Greendale

Effective combinations of green infrastructure are determined by cost as well as their ability to store/treat adequate volumes of water. They also need to meet the requirements of city ordinances.

Walnut Way Cistern

COMMERCIAL/INDUSTRIAL STRATEGIES: In commercial and industrial areas green roofs, porous and green parking, and bioretention are a good fit. Together, these are relatively moderate-cost measures that can handle moderate and large-scale stormwater discharges. These promising practices can obtain up to a 55 percent reduction in peak flow and a 15 percent reduction in annual volume.

GREEN STREETS: Green streets include features designed to hold, infiltrate and evapotranspire stormwater. Features include (but are not limited to) bioretention planters, curb bump-outs, ground-level bioretention, porous pavement along the curb lane, inlet restrictors and tree canopy.

27th Street Curb Bump-outs

Rain Barrel and Disconnected Downspout in Shorewood

OTHER ENHANCEMENTS

Besides green infrastructure measures alone and in combination, there are a number of practices that should be considered.

IMPROVING OVERALL EFFECTIVENESS

There are a number of approaches that can enhance the ability of green infrastructure to store, infiltrate, and evapotranspire water. These include:

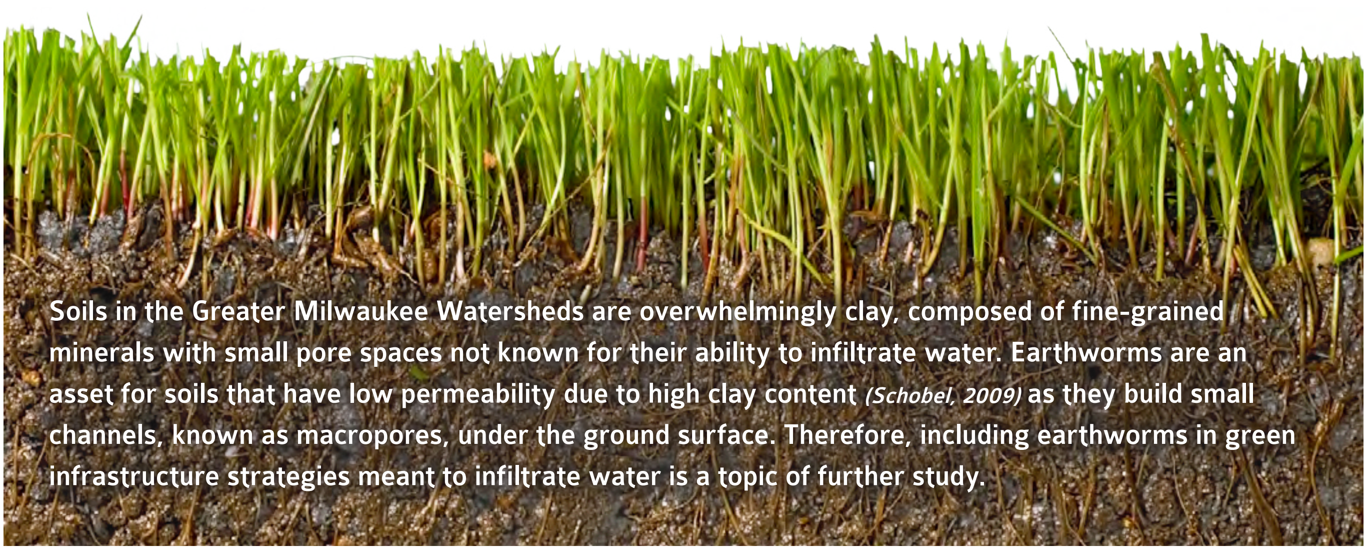
- **Disconnecting Downspouts:** During a heavy storm, downspouts on homes and businesses can deliver up to 12 gallons per minute to the sewer system, contributing to basement backups and sewer overflows. By simply disconnecting a downspout from the combined or storm system, excess water may stay out of the sewer system. Directing the downspout to a rain barrel or rain garden can provide an additional enhancement mentioned above, maximizing the amount of water that is saved for future use or that infiltrates into the ground. Across the country, cities have mandated that residents disconnect their downspouts from the sewer system, providing valuable extra sewer capacity and helping to keep our waterways clean by reducing the risk of sewer overflows.

- **Improving Soil Porosity:** Increasing soil porosity induces subsurface flow and increases the rate at which stormwater is removed from the surface of the land. This decreases the amount of water that runs across the land surface, especially in areas that have highly impermeable soils. It has been shown in many studies that earthworm channel building (macroporosity building) increases infiltration rates. On agricultural lands with no-till practices there can be up to a 17 percent increase in field holding capacity; in areas where there is earthworm activity the cumulative rainfall intake into the soil was increased by one half *(Edwards & Bohlen, 1996)*. Water infiltration rates in soils with earthworms are 4 to 10 times faster than in soils without worms *(Edwards & Bohlen, 1996)*.

Valley Park, along the Menomonee River

- **Planting Conifers:** Stormwater trees are a valuable green infrastructure tool because of the benefits they provide. Stormwater trees planted near areas with impervious surfaces can reduce runoff by 30 percent through interception and evapotranspiration. Conifer trees are more effective than deciduous trees; they can intercept 18-25 percent of annual rainfall in addition to having an evapotranspiration rate of 10 percent *(Herrera Env. Consultants, 2008)*. In studies of the Pacific Northwest, conifers, on average, can intercept 414 gallons per tree per year, with a range of 169 gallons per year to 449 gallons per year *(McPherson et al., 2002)*. The range and average are based on the size and type of conifer. It has also been shown that an urban area with 22 percent tree cover can reduce small precipitation event runoff by seven percent *(Sanders, 1986)*. Additionally, stormwater trees can help reduce the urban heat island effect, create habitat, and provide air quality benefits by removing contaminants.

- **Inlet Restrictors:** Slowing down the water before it can reach the grey infrastructure system provides some relief to the system during the peak of the storm. This can be done on flat roofs, where roof drains can be fitted with narrowed openings, and in streets, where inlets may be made smaller or raised along the curbline. Both restrictions result in the temporary ponding of water that eventually drains to the system once the rain subsides.



Soils in the Greater Milwaukee Watersheds are overwhelmingly clay, composed of fine-grained minerals with small pore spaces not known for their ability to infiltrate water. Earthworms are an asset for soils that have low permeability due to high clay content *(Schobel, 2009)* as they build small channels, known as macropores, under the ground surface. Therefore, including earthworms in green infrastructure strategies meant to infiltrate water is a topic of further study.

GREEN INFRASTRUCTURE'S IMPACTS BEYOND WATER

Both the traditional grey and green infrastructure approaches to stormwater and CSO management can be very expensive to retrofit within older urban areas. Both approaches can also generate important environmental, social, and other benefits to local watersheds and urban-area communities. However, the green infrastructure, Low Impact Development (LID) oriented approaches may generate a broader and more valuable array of environmental, public health, and social benefits than do traditional CSO control strategies. *(City of Philadelphia Water Department, 2009)*




TRIPLE BOTTOM LINE APPROACH

ENVIRONMENT + SOCIAL + ECONOMIC

Further analysis of the true benefits of sustainable infrastructure in the MMSD service area is needed. There are several reasons for this:

- Potential Interest in Considering the Full Spectrum of Sustainable Infrastructure Benefits: We all understand the need to foster partnerships that result in a full range of environmental, economic and social benefits. To encourage partnerships and robustly report the full benefits of sustainable infrastructure, additional benefits to consider may include (but are not limited to) reducing CSO/SSO/blending volumes, reduced flooding, reducing stormwater runoff volumes, reducing energy usage, reducing greenhouse gas emissions, keeping beaches open, enhancing aesthetics that result in higher property values and reducing polluted stormwater runoff. Acknowledging these full benefits is often referred to as Triple Bottom Line accounting.

- Uniquely Developed System: The Milwaukee region's system has mostly solved the problem of combined sewer overflows through grey infrastructure, reducing the number of combined sewer overflows (CSOs) from an average of 50 (until the mid-1990s) to about two per year and reducing the average volume of overflow from over 8 billion gallons to just under 1 billion gallons per year. Calculating the green infrastructure benefits to the existing MMSD system will help target best practice types and watershed placement unique to Milwaukee's situation.

- The Need for Right-Size and Right-Locate Solutions: MMSD recognizes that it has a responsibility to place sustainable infrastructure in locations where it can have the most positive effect on the environment. A more detailed analysis will be performed to allow for a better long-term comparison.

- The Need to Consider Life-Cycle and Avoided Treatment Costs: The analysis presented in this report is intentionally simple. A more detailed analysis, including life-cycle costs and avoided treatment costs, will allow a better long-term cost-benefit comparison ultimately more useful to alternatives analysis and long-term planning to eliminate CSOs.

- Widely Variable Data From Across the Country: While there is good literature on the costs and benefits of sustainable infrastructure, experiences around the country vary greatly depending on climate, energy costs, soil types and a host of other factors. Cost and benefit information related to the Midwest would provide the Milwaukee region with a greater degree of accuracy in achieving the benefits claimed.

To address the issues above, MMSD will consider taking a Triple Bottom Line approach to quantifying green infrastructure benefits to the region's stakeholders.

BENEFITS OF GREEN INFRASTRUCTURE

		Grey Infrastructure Storage	Greenways	Rain Gardens	Wetlands
ENVIRONMENTAL	Reduces Volumes of CSOs and SSOs	●	●	●	●
	Reduces Amount of Polluted Stormwater Runoff	●	●	●	●
	Reduces Energy Use	○ tunnel pumping assumed	◉	◉	◉
	Reduces GHG Emissions and/or Stores Carbon	◉	●	●	◉
	Reduces Flood Management Facility Size or improves drainage issues	◉	● needs massive implementation	● needs massive implementation	● needs massive implementation
	Enhances Groundwater Recharge and/or Evapotranspiration	○	●	●	●
	Improves Air Quality	◉	●	●	●
	Reduces Urban Heat Island Effects	◉	●	●	●
	Effective Substantial Runoff Reduction (Water Quality)	◉	●	●	●
ECONOMIC	Creates Green Jobs	●	●	●	●
	Reduces Infrastructure and Site Costs (relative to grey infrastructure)	N.A.	● assumes on-site space available	● assumes on-site space available	● assumes on-site space available
	Economical (relative to tunnel, capital costs only)	◉	●	○	●
	Increases Property Values	◉	●	●	●
SOCIAL	Improves Community Quality of Life	●	●	●	◉
	Reduces Days Beaches Close	●	●	●	●
	Improves Aesthetics	◉	●	●	●
	Provides Recreational Amenity	○	●	○	○

Although these benefits are difficult to quantify, it is important to understand the positive and/or negative benefits involved with each practice, which will help to compare and locate where specific practices may be economically, socially or environmentally feasible.

KEY

● **YES** (positive benefit)

◉ **MAYBE** (neutral/neither negative or positive benefit)

○ **NO** (negative benefit)

Stormwater Trees	Green Roofs	Bio-Swales	Porous Pavement	Native Landscaping	Rain Barrels/ Cisterns/Harvesting	Green Alleys/ Streets
●	●	●	●	●	●	●
●	●	●	● (assuming storage, no under drain)	●	●	●
●	●	◉	◉	●	◉	◉
●	●	●	◉	●	◉	●
● needs massive implementation	● needs massive implementation	● needs massive implementation	● needs massive implementation	● needs massive implementation	● needs massive implementation	● needs massive implementation
●	●	●	●	●	◉ not until collected water is used	●
●	●	●	●	●	◉	●
●	●	●	○	●	○	●
◉	●	●	●	●	◉	●
●	●	●	●	●	●	●
● assumes on-site space available	● assumes on-site space available and up front costs may be more	● assumes on-site space available	● assumes on-site space available and up front costs may be more	● assumes on-site space available	● assumes on-site space available and will be emptied	● assumes on-site space available and up front costs may be more
●	○	●	●	●	●	●
●	●	●	Need to research	●	◉	●
●	◉	●	◉	●	◉	●
●	●	●	●	●	●	●
●	●	●	○	●	◉	●
●	◉ design dependent	○	○	●	○	○

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MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

260 West Seeboth Street
Milwaukee, Wisconsin 53204

(414) 272-5100
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