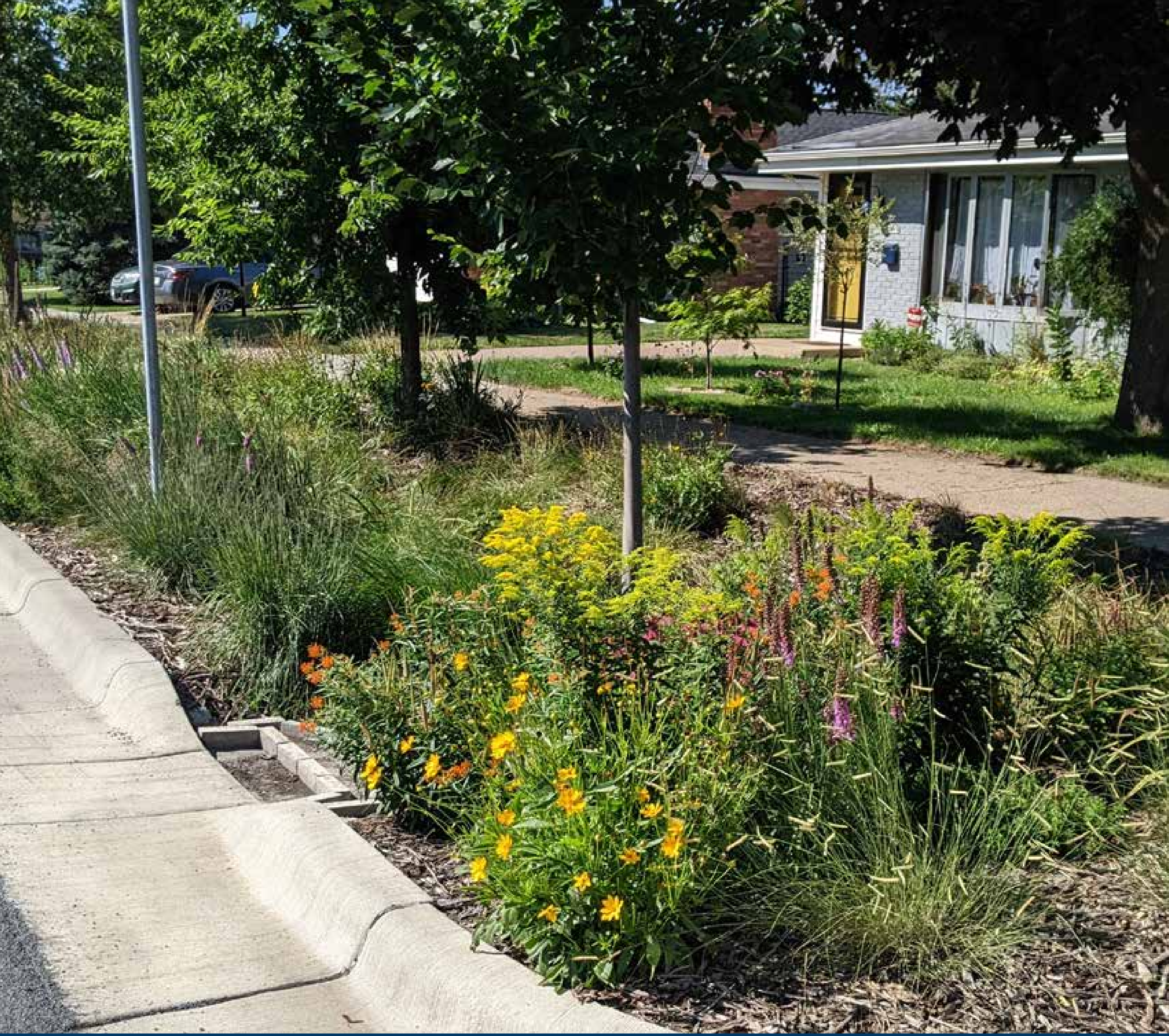

Green infrastructure for Minnesota communities

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

Table of Contents

Front cover image: During the Hoyer Heights street reconstruction, the City of Minneapolis partnered with the neighborhood and the Mississippi Watershed Management Organization to build boulevard rain gardens and tree trenches. Planted with trees and native plants, these gardens soak up stormwater runoff from the streets, filter out pollution, and provide food and habitat for pollinators and wildlife. Some homeowners also added native plants on their own properties to support these habitat goals. Photo courtesy of Erin Hunker, SRF Consulting.

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Welcome!

This booklet introduces green infrastructure principles, practices, and benefits by highlighting green infrastructure projects in and near Minnesota. We hope to inspire residents, communities, local governments, business leaders, and others to integrate green infrastructure into their yards, commercial spaces, and public projects. Electronic versions of this booklet, links to planning, design, and technical information, and links to websites and resources referenced in this booklet can be found in the Minnesota Stormwater Manual (stormwater.pca.state.mn.us/green_infrastructure_booklet).

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Brian Jastram, Rock Leaf Water Environmental
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Ben Johnson, Stantec
Ashlee Ricci, Ramsey-Washington Metro Watershed District
Aaron Gamm, MPCA Watershed Division

INTRODUCTION

What is green infrastructure?

Green infrastructure is an approach to stormwater management that uses the water cycle and ecological systems to mitigate the impacts of human development like roads, pipes, and buildings. Green infrastructure projects allow rain and runoff to soak into the ground, water plants, recharge groundwater, and return to the atmosphere through evapotranspiration.

Green infrastructure projects span a range of complexity from low tech to high tech: from those that a homeowner can install on their own, to those that require substantial planning, design, and installation work. A number of principles and practices are considered green infrastructure, many of which we highlight in this book. Terms such as nature-based solutions and low-impact development also describe many of the principles and practices associated with green infrastructure.

The rain garden at the Capitol Region Watershed District in St. Paul receives rainwater from the building's roof. Water moves through a channel in the sidewalk to water multiple native plant gardens. Photo courtesy of Britta Hansen, Emmons & Olivier Resources.

Why might your community want green infrastructure?

Developed areas like streets, parking lots, rooftops, degraded soils, and low quality green spaces do not absorb rain like undeveloped, natural areas absorb rain. When rain isn't absorbed where it falls, it runs off, becoming stormwater. Stormwater can contribute to local flooding and carry pollutants like bacteria, sediment, nutrients, and other contaminants into local waterways, degrading the lakes, streams, and wetlands that Minnesotans cherish.

Green infrastructure can absorb and treat stormwater, helping protect Minnesota's waters. Green infrastructure can help mitigate flooding, reduce heat islands, clean air, improve ecological resiliency, and beautify communities. Most green infrastructure practices integrate plants. When native plant species are used, green infrastructure can provide pollinator food, wildlife habitat, and a range of ecological benefits.

Green infrastructure provides many benefits.

We’ve briefly discussed what green infrastructure is and why you would want more in your community. We take a closer look at green infrastructure’s benefits below. The Minnesota Stormwater Manual provides detailed information on a range of environmental, social, and economic benefits.

Water Quality. When stormwater runs off impervious surfaces such as roads, rooftops, and parking lots, it can carry pollutants found on these surfaces, like bacteria, algae-growing nutrients, sediment, and heavy metals to streams and lakes. Green infrastructure is designed to capture stormwater and filter out pollutants, which improve water quality.

Water Quantity. Localized flooding can occur when stormwater flow exceeds the capacity of storm sewer pipes. Green infrastructure helps reduce localized flooding by capturing, slowing, temporarily storing, and reducing stormwater. Green infrastructure is often designed to absorb stormwater into the ground which can improve drought resiliency.

Habitat Improvement. The vegetation used in green infrastructure provides food and habitat for birds, mammals, amphibians, reptiles, and insects. Improvements to water quality also improve the aquatic habitats of streams, lakes, rivers, and wetlands, increasing opportunities for fishing and recreation.

Increased Biodiversity. Much of Minnesota's prairies, forests, and wetlands have been lost or degraded. Adding native plants through green infrastructure projects helps restore Minnesota's biodiversity.

Air Quality. The trees and plants used in green infrastructure projects help filter the air to remove pollutants and reduce smog.

Heat Island. Densely developed areas have a lot of surfaces that absorb, retain, and then release heat, creating higher temperatures compared to less densely developed areas. This is called the heat island effect. Vegetation helps to reduce heat island effects by shading surfaces, deflecting solar radiation, and reducing air temperatures.

A mix of native plants and flowers were used in the restoration of Library Lake in Cumberland, WI. These plants help intercept and clean water as it runs towards the lake. Photo courtesy of Britta Hansen, Emmons & Olivier Resources.

Human Health. Green infrastructure creates green spaces for residents, which promotes outdoor activity and reduces stress. Green infrastructure can also help protect drinking water sources, preventing illness.

Environmental Education. Green infrastructure can serve as a classroom tool to deepen students' connection with the environment. Green infrastructure projects create an opportunity for the public to learn about the benefits of these practices, which can increase public support and stewardship of current and future green infrastructure projects.

Climate Resiliency. Deep-rooted, native plants add organic matter to the soil and sequester carbon. In addition, the benefits to water quantity and quality, air quality, habitat and biodiversity, and community health provided by green infrastructure all contribute to improved climate resiliency.

Green infrastructure should be carefully planned and designed.

We discuss general planning and design considerations below. These factors should be considered for any project, whether low tech or high tech. However, projects that need to meet stormwater regulatory requirements will typically require substantially more planning and design to function as intended. Consult the Minnesota Stormwater Manual for detailed planning and design information.

Location: The project location will dictate the local conditions, on-site constraints, potential utilities or conflicts, native soils, slopes, proximity to waterways, vulnerable groundwater areas, and other details that will inform the design of your project.

A section of turfgrass at Soldier Field Park in Rochester was replaced with a mix of deep-rooted native grasses, sedges, and forbs. The tightly spaced planting reduces weed infestations. Photo courtesy of Aaron Gamm, MPCA.

Size: Low tech green infrastructure like tree plantings can span any size. Projects that are used to meet stormwater regulatory requirements are typically sized to accommodate a specified drainage area, stormwater volume, and pollutant reduction goal.

Soils and Water Table: Soil types and depth to the water table will determine which green infrastructure practices may work at your project site. The soil should be assessed for infiltration potential and used to select appropriate plants. Sandy soils drain quickly while clayey soils drain slowly.

Maintenance: Green infrastructure projects must be maintained. Low tech green infrastructure may simply require basic weeding or pruning. For large or high tech green infrastructure projects, develop an operation and maintenance plan, including a list of plant species used, and timelines for inspections and recommended maintenance actions.

Access: Designing for maintenance access will help the project be properly and more affordably maintained.

NATIVE VEGETATION

This lakeshore restoration site in Cumberland, WI was planted with a diverse native plant community. The site's mid-summer bloom showcases blazing star, coneflower, black-eyed Susan, cut-leaf coneflower, gray-headed coneflower, and wild bergamot. Sedges and grasses provide structure that supports these beautiful blooms. Photo courtesy of Britta Hansen, Emmons & Olivier Resources.

Native plants are plants that evolved in a specific region and ecosystem over millennia. They are specially suited to the soils, climate, plant community, insects, and wildlife of their location. In contrast, non-native plants were introduced to a location and did not co-evolve with the local plant and animal community. Non-native plants are considered invasive species when they aggressively out-compete native plant species.

Why native plants instead of non-native plants?
Advantages of native plants include their hardiness, role as exclusive food sources for some insects, and ability to provide special habitat for local insects and animals. With their deep-rooted structure, native plants offer superior erosion protection, water filtration and cleansing, and soil improvement.

Since native plants and insects co-evolved, they have formed interdependencies. For instance, milkweed plants have substances that are toxic to most insects. However, Monarchs have evolved tolerance to the toxic substances, and the caterpillars can only eat milkweed. Similarly, many native insects have a special relationship with a particular plant during a part of their life: some bees require the pollen of certain native flowers, many caterpillars can only eat the leaves of certain native trees – these insects are called specialists. These closely evolved relationships between plants and insects are partly why non-native plants can outcompete native plants: there are no local insects that have evolved to consume them.

Why do we care about native, specialist insects?
Native, specialist insects are a critical foundation for food webs. In his 2007 book "Bringing Nature Home: How Native Plants Sustain Wildlife in Our Gardens," Dr. Doug Tallamy reports that chickadees feed their nestlings over 6,000 caterpillars in just the first few weeks of their life. Tallamy also found that most caterpillars are specialists and depend almost entirely on native plant species for their food. To preserve our bird and wildlife populations, we must preserve the insects they feed on, and to do that, we must provide the native plant communities they depend on.

Anyone can add native plants to their landscape. Start with a small area and expand through time. Here's how to get started:

- **Get to know your site**. Understand your light conditions (full sun, part sun, or shade), soils (sandy, silty, or clayey), and drainage (well drained, moist). Learn about the native plant communities in your area on the Minnesota Department of Natural Resources website.
- **Determine your project goals and type.** Project types include trees, shrubs, prairie plantings, manicured prairie or woodland gardens, shoreline restorations, and more. Find inspiration by visiting natural areas and local native plantings.
- **Prepare your site.** Site preparation is crucial to any native planting. The prior land use, on-site vegetation, and project size will determine appropriate site prep. Prep methods could include lawn smothering, herbicide treatment, sod removal, cultivation, cover cropping, soil amendments, ground shaping, and more. Often, a full growing season of preparation and weed elimination is needed for sites with invasive species. Good site prep can substantially reduce maintenance early in the project.

These black-eyed Susans, at Minneapolis' Heritage Park filtration basin, are a pioneer species, meaning they fill in and mature quickly. They are commonly included in seed mixes to provide color and density early in a prairie planting. Photo courtesy of Britta Hansen, Emmons & Olivier Resources.

Native shrubs can be planted in rows to create privacy, wind blocks, strategic shade, or in the case of this common elderberry shrub row in Mankato, edible landscaping. Trees along the west side can help shade and cool buildings in the hot summer months. Photo courtesy of Joanne Boettcher, MPCA.

- **Develop your planting list.** Once you know what your site characteristics and project goals are, you are ready to develop a planting list. The Blue Thumb Plant Finder can help you develop a list of native plants suited for your site and project type. The Minnesota Board of Water and Soil Resources website, seed mixes page, and the Minnesota Wildflowers website are also great resources.
- **Buy and install your plants.** Plants should be purchased from reputable Minnesota native nurseries. The Blue Thumb Plant Finder lists retailers. Use caution purchasing plants from nurseries that are not specialized in native plants to ensure you are getting the right species, locally originated, and legally grown and not wildly collected. Small bareroot trees and shrubs are an affordable option, but trees can also be purchased as larger, more expensive established plants. Prairie plantings can be done with seeds, small plant plugs, or potted plants.
- **Maintain your project.** Native plants can take longer to reach maturity. You may need to water in the first year. You will need to remove weeds, especially in the first few years, until your plants fill in. Trees and shrubs can take longer to reach maturity.

Pale purple coneflower, prairie coreopsis, butterfly milkweed, penstemon, and spiderwort create a rainbow of bloom at the RWMWD office in Little Canada. Photo courtesy of Ramsey-Washington Metro Watershed District.

Native vegetation project highlight: the Ramsey-Washington Metro Watershed District landscape

The Ramsey-Washington Metro Watershed District (RWMWD) office in Little Canada is able to capture 100% of the rain and snowmelt from their property, thanks to native plants and green infrastructure. In addition to 36,000 square feet of native planting areas, RWMWD uses rain gardens, green roofs, rain barrels, and permeable pavement. The grounds and facility provide excellent learning opportunities, with groups regularly visiting to learn about green infrastructure and practice plant identification.

RWMWD shares this advice about incorporating native plants into the landscape:

- Include areas for snow storage in the design to avoid crushing plants under snow piles.
- Incorporate spring, summer, and fall blooming plants to provide pollinator food throughout the year.
- Regular maintenance saves money and time in the long term and keeps the grounds beautiful.

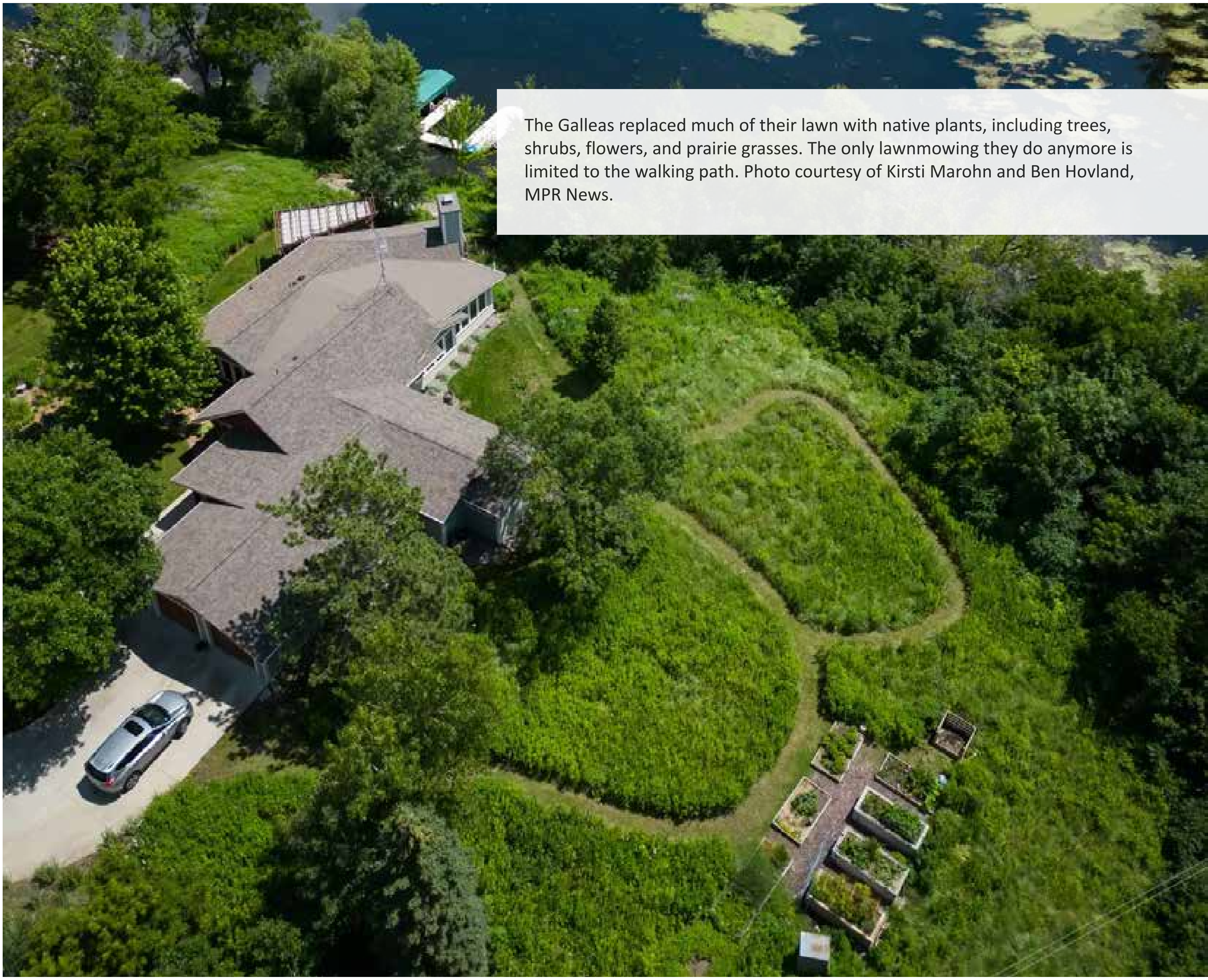
The rich diversity of species planted at the RWMWD native planting provides visual interest, wildlife habitat, and bird food through every season. Photos courtesy of Ramsey-Washington Metro Watershed District.

Native vegetation project highlight: Gallea property lawn conversion

The Gallea home on the Sauk River Chain of Lakes in Cold Spring came with a 308-foot shoreline, over an acre of mowed grass, and a failing retaining wall. When the Galleas applied to replace their failing retaining wall, the Stearns Conservation District riparian specialist asked if they had considered restoring their property to a more natural state.

After extensive research into the benefits of native plants and "lake scaping," the Galleas decided to partner with Stearns Conservation District, transforming their property with lush native plants that help slow and absorb water running off the roof and driveway, keeping phosphorus and other pollutants out of the lake.

The Galleas have since become advocates for shoreline restoration and native plants, hosting annual tours of their property for homeowners considering similar projects. The Galleas have saved hundreds of hours a year on lawn care and spend approximately $600 a year on annual maintenance, which includes periodic controlled burns. A key piece of advice from the Galleas is to not over-irrigate the new plantings—too much water fuels weed growth.



The Galleas replaced much of their lawn with native plants, including trees, shrubs, flowers, and prairie grasses. The only lawnmowing they do anymore is limited to the walking path. Photo courtesy of Kirsti Marohn and Ben Hovland, MPR News.

SOIL HEALTH

Healthy soils tends to be dark in color, have an earthy aroma, and a cottage cheese-type texture. The dark color comes from high organic matter. The earthy aroma indicates a healthy microbial population. The texture is a product of the microorganisms, which “glue” soil particles together in clumps, increasing infiltration and resisting erosion.

Soil health is the simple term reflecting the complex physical, chemical, and biological properties of soil and its organisms, also described as soil’s ability to function as a vital, living ecosystem. Soil health is an often overlooked but critical component to the water cycle and ecology.

Soil is a dynamic, living ecosystem, made up of minerals, organic matter, air, water, and living organisms. A teaspoon of healthy soil can contain a billion microorganisms and thousands of species. Similar to the interdependent relationship native plants and animals have, the microorganisms in soil have relationships with the plants growing in them. Healthy and diverse vegetation relies on healthy and diverse soil microbiology, and vice versa.

Healthy soil acts as a natural sponge, infiltrating, storing, treating, and using water to support plant growth. Healthy soil also resists erosion, captures and stores carbon, and helps recharge aquifers. Healthy soil produces more nutritious vegetables and higher crop yields than depleted soil, requiring less artificial fertilizer and herbicide.

Organic matter content of soil is a critical component of soil health, with 5% being a general minimum recommended value. Topsoil contains the most organic matter. Managing for soil organic matter and soil health includes a few key principles: high cover, low disturbance, living and deep-rooted plants, and high biological diversity.

Management practices to improve soil health

Lawns

- Mow high, at least 3 inches. Avoid mowing too frequently and when the soil is wet.
- Decrease or eliminate the use of chemical fertilizers, herbicides, and insecticides.
- Use high-quality compost or other organic sources of fertilizer when needed, which can be determined by soil fertility testing.
- Interseed or reseed lawns with diverse seed mixes (e.g., bee lawn or native ground covers), low/no-mow fescue grasses, or clover.
- Convert lawns to diverse native plantings and/or add native trees and shrubs for low-maintenance options.

Gardens and landscapes

- Minimize or eliminate tilling and chemical use.
- Never leave the soil bare. Use living ground covers if possible. Organic mulch like leaves, wood chips, or compost can also be used. Avoid rock mulch and landscape fabric.
- Use cover crops before, during, or after food crops.
- Add native plants to flower gardens and landscapes.
- Create “soft landings” under tree driplines by replacing turf with native plants.

Lawns with higher plant diversity, lower mowing frequency, and less chemical use create healthier soils. Clover fixes nitrogen from the atmosphere, providing natural fertilizer to grass. The clover, self heal, and yarrow in this lawn mix also provide food for pollinators. Photo courtesy of James Wolfin, Twin Cities Seed Co.

This skid steer is equipped with a ripper attachment to de-compact the soil. The rubber tracks distribute the weight of the machine, minimizing further compaction of the soil. Photo courtesy of Pat Sauer, Iowa Storm Water Education Partnership.

Management practices to protect and improve soil health during (re)development:

Prior to construction

- Develop a soil management plan, including areas that should not be disturbed.

During construction

- Demarcate areas that are not to be disturbed.
- Select minimally compacting equipment for work.
- Avoid degrading soil structure by overworking soil or smearing soil during construction. Avoid disturbing soil when it is too moist.
- When stockpiling topsoil, build smaller piles so that oxygen is available to the soil in the center of the pile. Cover stockpiles to prevent erosion.
- Cover exposed ground with cover crops or mulch.

After construction

- Use soil ripping or subsoiling to de-compact any compacted subsoil.
- Respread topsoil and add compost if needed. Till compost into the top few inches of soil.
- Plant vegetation that is as diverse and deep-rooted as possible. Use Minnesota native plants whenever possible.

This previously compacted, unhealthy lawn was aerated and then top-dressed with a thin layer of high-quality compost (top image). The resulting lawn not only looks better but is better able to infiltrate rain. Photos courtesy of Polk County Soil and Water Conservation District.

Soil health project highlight: Residential soil quality restoration

Construction activities during development commonly leave soils compacted and organic matter degraded. This results in pooling water, excessive runoff, and poor-looking lawns. To compensate, residents pour money and time into fertilizer, irrigation, and chemical treatments, not knowing that the root of the problem is their soil.

Iowa Stormwater Education Partnership has developed a soil quality restoration (SQR) program to help residents improve the quality of the soil under their lawns. Soil quality restoration is the practice of aerating the soil and adding compost. This process reduces compaction, increases soil pore space, and increases organic matter, restoring the soil's ability to function like a sponge and absorb rain. They have reported that lawns that have undergone SQR require less overall maintenance, less watering during dry periods, fewer fertilizer applications, and minimal pesticide treatments.

Soil health project highlight: MNDOT soil preservation in construction

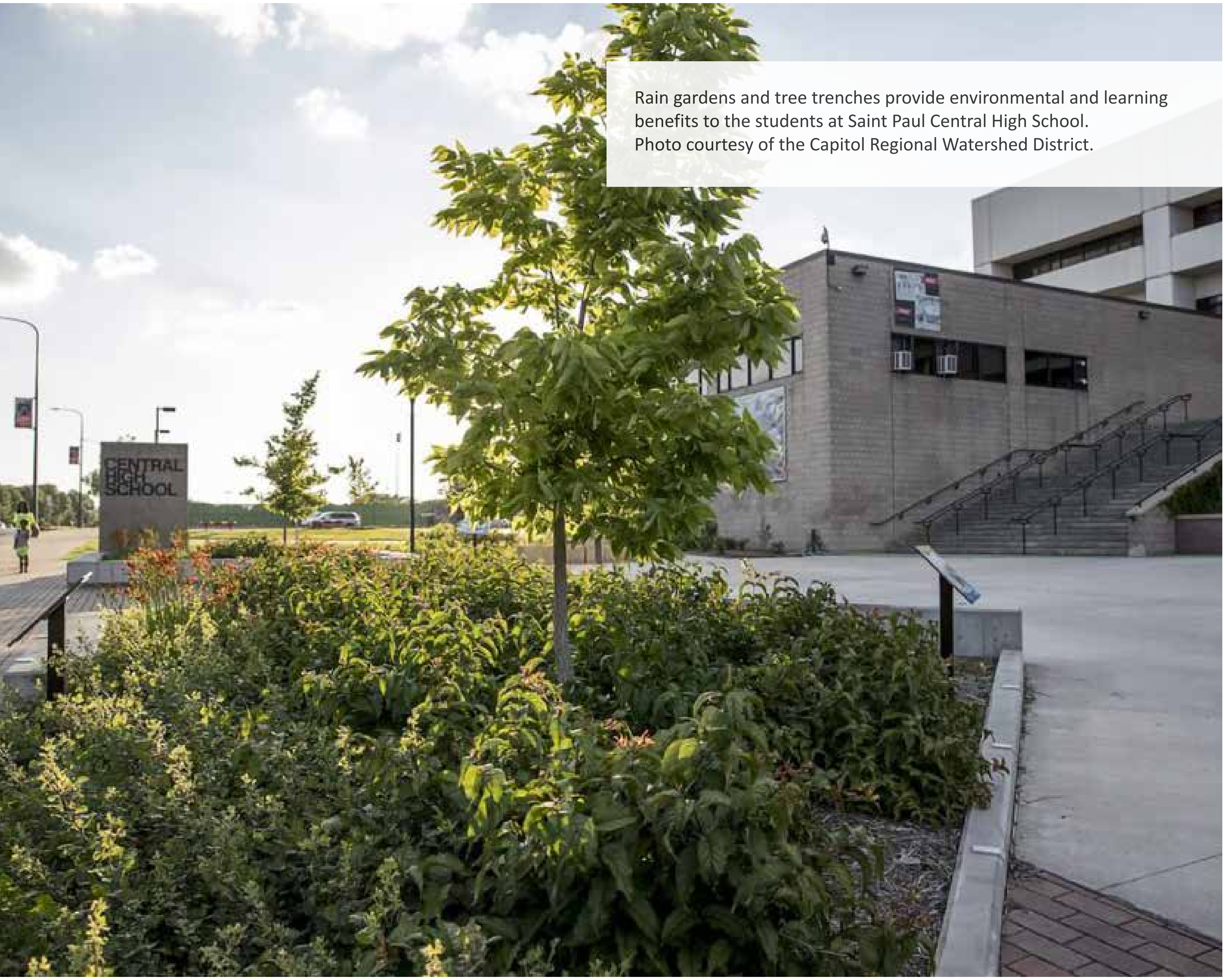
Construction can be a particularly challenging time for soil health preservation. Topsoil can be lost or damaged, vegetation and microorganisms can be adversely affected, and sites can be compacted, all leading to difficult conditions for plants to grow and less ability to absorb water. When working to re-establish vegetation on roadsides across Minnesota, Minnesota Department of Transportation (MNDOT) soil scientists determined that poor soil health was a limiting factor. MNDOT began implementing soil preservation and restoration measures into many projects.

Key soil health practices include removing and preserving topsoil, avoiding and mitigating compaction, avoiding wet soil disturbance, using soil building seed mixes for soil stockpiles and berms, using diverse native seed mixes for reestablishment, and ensuring there is a minimum of 5% organic matter after construction by adding compost. These measures have resulted in better vegetation establishment and roadsides that are able to better infiltrate stormwater during intense rain events and retain water for plants during periods of drought.

Instead of stockpiling topsoil in large piles where a lack of oxygen and excessive disturbance can have dire consequences to soil microbiology, MNDOT has been using topsoil berms. The less disturbed soil in a small berm allows oxygen to penetrate the soil, preserving soil microbiology while doubling as erosion control on the edge of the work area. Photo courtesy of Warren Tuel, Minnesota Department of Transportation.

MNDOT blended compost into the soil in the median on this section of Interstate 94 to reach the desired organic matter content. MNDOT blended dry prairie seed mix with native cover crops for quicker permanent vegetative cover. Photo courtesy of Warren Tuel, Minnesota Department of Transportation.

TREES



Rain gardens and tree trenches provide environmental and learning benefits to the students at Saint Paul Central High School. Photo courtesy of the Capitol Regional Watershed District.

Trees are an excellent way to integrate green infrastructure into the landscape and achieve a number of benefits. Trees intercept rainfall where it can be absorbed by the leaves and rootzone, reducing the amount of runoff. In addition to benefits to water quality and quantity, trees clean air, reduce heat island effects, sequester carbon, reduce noise pollution, and cool houses, businesses, and cars when in the shade.

Trees are a key strategy for communities to address and adapt to climate change moving forward. In fact, the State of Minnesota Climate Action Framework has established a goal for communities to have 40% of their area covered by tree canopies by 2050. To meet this goal and the desired benefits, we need to plant more trees today.

Trees can be used in both low tech and high tech green infrastructure applications. Home and business owners can easily add trees to the landscape. High tech tree applications like tree trenches and tree boxes are often used in dense urban environments with lots of impervious surface area. These practices require substantial planning and design.

Next we discuss recommendations and tree selection options that can help you select and plant trees.

Recommendations for tree plantings:

- **Select the right tree species.** Select a tree for the soil, sun, and moisture conditions. Native trees provide a range of ecological benefits, but non-native trees may work better in some circumstances.
- **Purchase smaller trees.** Smaller trees handle transplantation better than large trees. They are less expensive, require a smaller hole, and are less prone to girdling.
- **Dig the right hole.** Dig a hole as deep as and at least twice as wide as the existing roots. Most new roots will grow out horizontally from the tree's root ball. Square holes may reduce root girdling.
- **Spread the roots.** Trees that come in containers often have roots growing in a circle. These trees are at risk of becoming girdled. Splay the roots away from the center. Cut the roots to free them if they are severely bound.
- **Mulch, water, and protect.** Either plant ground cover species under the new tree or mulch with organic matter. Water new trees deeply weekly or more. Cage or wrap small trees to protect from herbivores in winter and weed whippers in summer.

These tree trenches and parking lot in Eagan were designed to funnel stormwater to an underground collection area, where the trees can access and use it. Photo courtesy of Brendan Dougherty, Barr Engineering Co.

A Dutch-elm disease resistant elm tree variety was planted along the Metro Light Rail Transit Green Line in Minneapolis-St. Paul. Photo courtesy of the Capitol Regional Watershed District.

While Minnesota has over 50 native tree species and over a hundred shrub species, not all work for every application. Do some research before selecting a tree or shrub. For instance, maples are generally not recommended for new plantings because Minnesota's urban landscapes already have an abundance. Another example, cottonwoods are prohibited in some communities due to their abundant spring seeds.

Some native tree and shrub species that you might consider include:

- American Basswood
- Kentucky Coffeetree
- Hackberry
- Swamp White Oak
- Burr Oak
- Ironwood
- River Birch
- Serviceberry
- American Pussy Willow
- American Hazelnut
- Red Osier Dogwood
- Prairie Ninebark
- American Plum
- Arrowwood
- Common Elderberry

The Minnesota Stormwater Manual provides more details on trees, including tree lists for tree trenches and boxes as well as larger lists of native and non-native trees for urban applications.

Native dwarf bush honeysuckle, big bluestem, and ironwood (hornbeam) trees replaced the lawn at Minnetonka's City Hall. Photo courtesy of Fred Rozumalski, Barr Engineering Co.

Tree project highlight: Minnetonka Civic Center

The Civic Center in Minnetonka features several green infrastructure practices including tree trenches, bioretention, and vegetated swales. The bioretention basin (pictured below) receives water from the parking lot. This basin is planted with native trees, a relatively low maintenance bioretention basin plant option that is becoming increasingly popular. This project was recognized in 2007 by the City Engineers Association of Minnesota as an outstanding municipal project.

This bioretention basin was planted with tamarack trees, native grasses, and shrubs, mirroring the species found in the nearby woods. The top image shows the basin early in its establishment, while the bottom image shows how the planting has filled in beautifully, with ideal density to reduce weed pressure and maintenance needs. Photos courtesy of Fred Rozumalski, Barr Engineering Co.

RAINWATER HARVEST & USE

The Capital Region Watershed District office in Saint Paul installed a high tech rainwater treatment and storage system. Rainwater is collected from the building roof, then routed through a treatment system (shown on right side of photo). The treatment system includes pre-treatment to prevent large solids from entering the cistern (shown on the left of the image), three levels of progressively finer filtration to remove small particles, and ultraviolet (UV) disinfection to kill bacteria and pathogens. Treated water is used for non-potable uses inside the building, such as flushing toilets. This system meets 75% of the building's non-potable water needs. Photo courtesy of Britta Hansen, Emmons & Olivier Resources

Rainwater harvest is the practice of collecting, often treating, and storing rain from rooftops for future use. Rainwater harvest practices can be either low tech or high tech, depending on the design and treatment needs. Rainwater harvesting can be as simple as a rain barrel that collects rainwater from a home's gutters to a more complex system like the rainwater system at Capitol Region Watershed District (pictured above). The harvested water should be used between rainstorms to make room for new rain.

Rainwater harvesting helps keep excess water out of the sewer system and prevents rain from becoming polluted stormwater. It also saves treated drinking water from being used for irrigation and cuts down on water bills.

Setting up a home rain barrel:

- **Site and select your rain barrel.** Determine your water source, typically a downspout, and identify a close location for the rain barrel. Source a rain barrel that meets your budget, space, and aesthetic needs. Many Watershed Districts, County Soil and Water Conservation Districts, and cities run rain barrel programs and sell affordable options.
- **Place the rain barrel.** Create a sturdy, level, elevated base for the rain barrel using bricks, wood, or concrete blocks. Elevate the barrel sufficiently so that you can easily fit a watering can under.
- **Modify and connect the downspout.** The downspout will need to be modified to send water to the rain barrel. You may want to get a rain barrel diverter, which allows water to either flow into the rain barrel or go down a typical downspout. This feature makes winterizing the rain barrel easier. You may also need additional components like a flexible elbow, screen, and hose for the overflow port.

This home rain barrel in Mankato collects water from half of a garage roof and only takes a quarter inch of rain to fill. The barrel was raised off the ground to fit a watering can underneath the spigot and dressed up with plants which are watered with rain barrel water. Photo courtesy of Joanne Boettcher, MPCA.

The cistern at the Mississippi Watershed Management Organization (MWMO) office collects rainwater form the building's roof to water the trees in the trench system. Photo courtesy of MWMO.

Maintaining a home rain barrel:

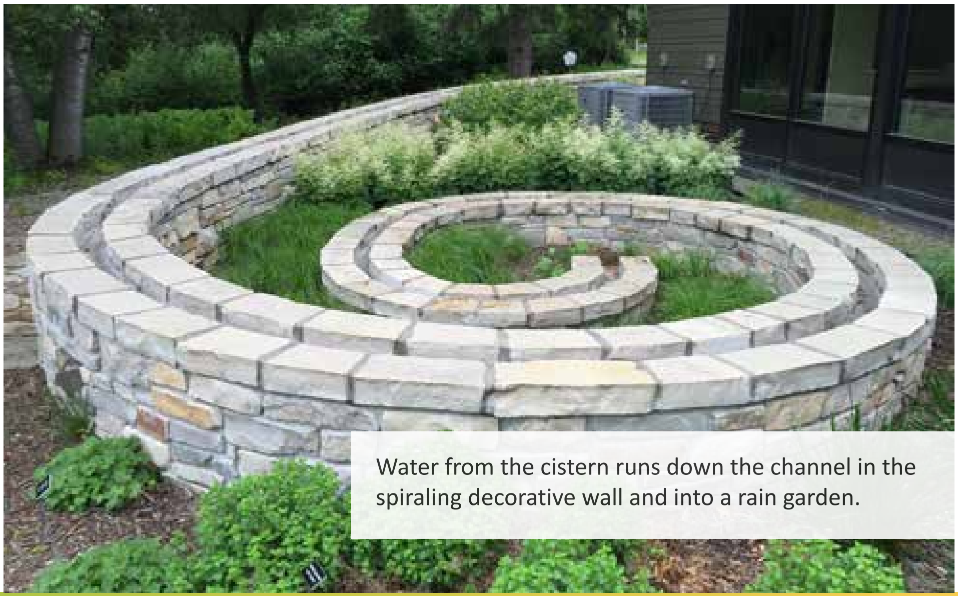
- **Ensure proper function.** Once the rain barrel is completely connected, check that your components are functioning appropriately. The first time it rains, check that water is entering without leaks, the overflow port is working, and the outlet valve is functioning.
- **Intermittent maintenance.** During the growing season when your rain barrel is operational, check the screen every couple weeks to clean any leaves or debris. Check that water is being used frequently enough to avoid festering. Drain, rinse, and let your barrel dry if it develops odors, insects, or other objectionable conditions.
- **Seasonal maintenance.** Prior to air temperatures dipping below freezing, you will need to winterize your rain barrel. Disconnect or switch the diverter so water no longer enters the rain barrel and goes back down the standard downspout. Empty the rain barrel completely and leave the valve open to allow the barrel to fully drain so the valve does not freeze and crack.

The rainwater harvest and use system at Discovery Point sits to the right of this former home converted to Watershed District office. The cistern is surrounded by a decorative brick wall which doubles as a channel for water to flow to a spiral rain garden at the back of the building. Photo courtesy of Brendan Dougherty, Barr Engineering Co.

Rainwater harvest project highlight: Discovery Point Cistern

Discovery Point in Eden Prairie houses the Nine Mile Creek Watershed District office and education center, which showcases green infrastructure projects. An artistic and functional highlight of Discovery Point is the rainwater harvest and use system. Rain is collected from a quarter of the building roof (1,300 square feet) and directed to 1,050-gallon cistern, which fills with one inch of rain.

Rain is captured from the roof and flows through the square gutter into the vertical pipe along the cistern. The vertical pipe T's into the top of the cistern to fill the cistern, while the rest of the pipe is an emergency overflow in case the cistern inlet becomes clogged. When the cistern fills, water flows into the very top of the wall on the right of the cistern. The cistern can be partly drained using a valve and pipe shown on the left of the cistern, which also sends water down the channel in the wall. Photos courtesy of Brendan Dougherty, Barr Engineering Co.



Water from the cistern runs down the channel in the spiraling decorative wall and into a rain garden.

BIORETENTION

The bioretention basin at the University of Minnesota's Huntington Bank Stadium parking lot uses multiple plant species to create a dense root zone to filter and use stormwater. The different colors and textures in this basin make this a visual show piece. Photo courtesy of Erin Hunker, SRF Consulting.

Bioretention refers to a physical process as well as a group of land-based practices that use vegetated depressions to capture and infiltrate stormwater. There are different types of bioretention including bioswales, rain gardens, and biofiltration basins – the last two we will feature separately next.

Bioretention applications, like other green infrastructure practices, can be low or high tech. A couple of examples of low tech bioretention practices are a planted low spot in a homeowner's yard that receives water from a downspout or a swale or ditch planted with water-loving native plants.

In high tech bioretention applications with specific regulatory requirements, bioretention practices often use engineered soils to ensure design infiltration rates are met. Engineered systems can also include outlet structures or underground pipes to control water levels.

Bioretention is customizable to the space and needs of a site. The versatility of bioretention allows it to be frequently used as a stormwater retrofit, adding new technology to an existing space to improve stormwater management.

Bioretention design considerations:

- Use natural depressions for low tech bioretention by planting with native shrubs or other plants.
- Sandy (best) or silty (moderate) soils provide better infiltration. Soils can be amended to improve infiltration.
- Ponded water should drain within 48 hours so mosquitos cannot breed there.
- Plant species must be selected for the specific conditions like intermittent flooding and drying. Blue Thumb Plant finder has a rain garden search option.

High tech bioretention systems designed to meet stormwater regulatory requirements require detailed planning and design including:

- detailed soils and site assessment including groundwater elevation, bedrock, and pollutant hotspots.
- sized for the needed treatment volume and include pretreatment.
- possibly include overflow or underdrains.

This new bioretention facility in Eagan is capturing and holding stormwater from the adjacent parking lot during this rainstorm, functioning as intended. Photo courtesy of Brendan Dougherty, Barr Engineering Co.

The recently completed rain garden at the Presbyterian Church of the Way in Shoreview was planted with plugs. Water enters from the parking lot through a rock channel. Rock strips are used in strategic places in the rain garden to help slow and filter runoff before entering the outlet structure, which is elevated and covered with a yellow grate. Photo courtesy of Kendra Sommerfield, Rice Creek Watershed District.

Bioretention maintenance considerations:

- **Plants.** Water new plantings, replace dead plants, remove invasive or unwanted plants.
- **Debris and sediment.** Remove trash and debris, clean out sediment deposits.
- **Water flow.** Keep inlet and outlet areas clear of plants and debris.
- **Ponding.** Make sure the area drains within 48 hours. If it is not draining adequately, you may need to address fine sediment accumulation, blockages, or consult an expert.
- **Structure.** Watch for erosion in the basin or around inlet and outlet structures or berms, shifted rocks, or any other structural issues and correct or consult an expert.

Looking across the pollinator hillside in Duluth's Lincoln Park, the parking lot bioretention basin is shown in the middle of the photo. This design uses curb cuts, sloped gaps in the curb that allow water to flow from the parking lot into the basin, to direct runoff into the basin. The native plants in the basin filter stormwater to reduce flow and take up nutrients prior to the water entering Miller Creek. Photo courtesy of Heidi Bringman, LHB, Inc.

Bioretention project highlight: Lincoln Park

Situated along Miller Creek, historic Lincoln Park in Duluth has experienced severe flooding and erosion in recent years due to heavy upstream development and the effects of climate change. The flooding damaged the park's infrastructure, jeopardizing the park's historic integrity. A park-wide integrated approach to stormwater management memorializes the park's history while using green infrastructure to build resilience to future flood events.

The park includes a pollinator hillside, as well as six stormwater bioretention practices, ranging from small rain gardens to large bioinfiltration basins, to help improve water quality and slow down runoff before entering Miller Creek. The park serves as a model for how to integrate resiliency into our landscape.

Top plant picks for bioretention practices: moist/lower zone

Plant	Season in bloom
Black Chokeberry Shrub	Spring
Red-osier Dogwood Shrub	Spring
Winterberry Shrub	Spring
Fox Sedge	Spring
Palm Sedge	Spring
Bottlebrush Sedge	Spring
Porcupine Sedge	Spring
Soft Rush	Spring
Sensitive Fern	Spring
Switch Grass	Summer
Prairie Cord Grass	Summer
Marsh Milkweed	Summer
Northern Plains Blazing Star	Summer
Giant Hyssop	Summer
Blue Lobelia	Summer
Sneezeweed Helenium	Fall
Joe-Pye Weed	Fall
Red-stemmed Aster	Fall

Top plant picks for bioretention practices: dry/upper zone

Plant	Season in bloom
Wild Geranium	Spring
Golden Alexanders	Spring
Prairie Alumroot	Spring
Wild Strawberry	Spring
False Solomon's Seal	Spring
Prairie Dropseed	Summer
Little Bluestem	Summer
Indian Grass	Summer
Butterfly Milkweed	Summer
Mountain Mint	Summer
Long-bracted Spiderwort	Summer
Spotted Bee Balm	Summer
Prairie Wild Onion	Summer
Prairie Sage	Summer
Prairie Coreopsis	Summer
Showy Goldenrod	Fall
Smooth Aster	Fall
Western Sunflower	Fall

Bioretention projects should be planted with moist-tolerant plants in the lower zones and dry-tolerant plants in the upper zones of the area. Plants that bloom through all seasons should be used.

The City of Crosby redirected its downtown stormwater to a series of rain gardens and to an underground stormwater retention system, preventing several pounds of phosphorus and 1,000 pounds of sediment from entering Serpent Lake every year. The rain gardens were planted with native shrubs, wildflowers, prairie grasses, and trees. Photo courtesy of Britta Hansen, Emmons & Olivier Resources.

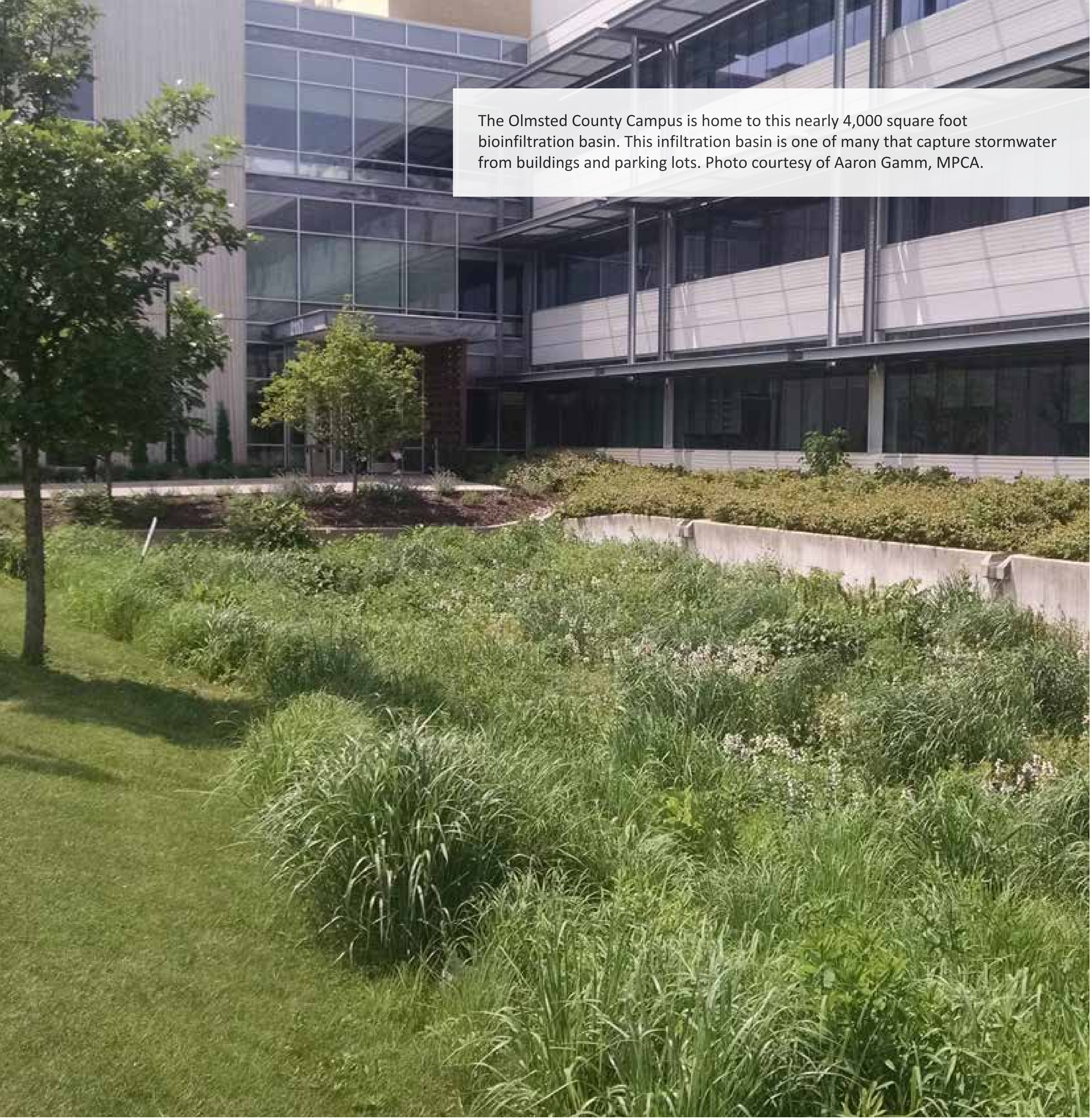
RAIN GARDENS

Rain gardens are a common bioretention practice typically distinguished from other bioretention practices by their smaller footprint and simpler design. Water can be routed to a rain garden using downspouts, small surface channels, by using a cut in a street curb, or other creative ways. When selecting plants for your rain garden, you need to select plants for the bottom (moist) area of your rain garden and the sides and top (drier) areas. You want to select a range of plants to provide pollinator food and visual interest through the seasons. To keep weeding easier, some prefer to limit the number of plant species. More experienced gardeners or those who want to provide the most benefit may choose to use a diverse number of species. Use the Blue Thumb Plant Finder to find plants appropriate for a rain garden.

Rain garden project highlight: Front yard rain garden

A metro-area homeowner claimed a portion of their front yard for a rain garden. Prior to the rain garden, rain could readily run off the turf. Now that the area is vegetated and soils are improved, rain that falls on the roof and yard are soaked into the front yard.

This home had a typical rain gutter and turf front yard. Just a year after the project was installed, the plants have started to fill in. The rain gutter flow is directed to a rock swale and into the rain garden, where the plants and soil are able to soak it up. Photo courtesy of Metro Blooms Design+Build.



The Olmsted County Campus is home to this nearly 4,000 square foot bioinfiltration basin. This infiltration basin is one of many that capture stormwater from buildings and parking lots. Photo courtesy of Aaron Gamm, MPCA.

BIOINFILTRATION BASINS

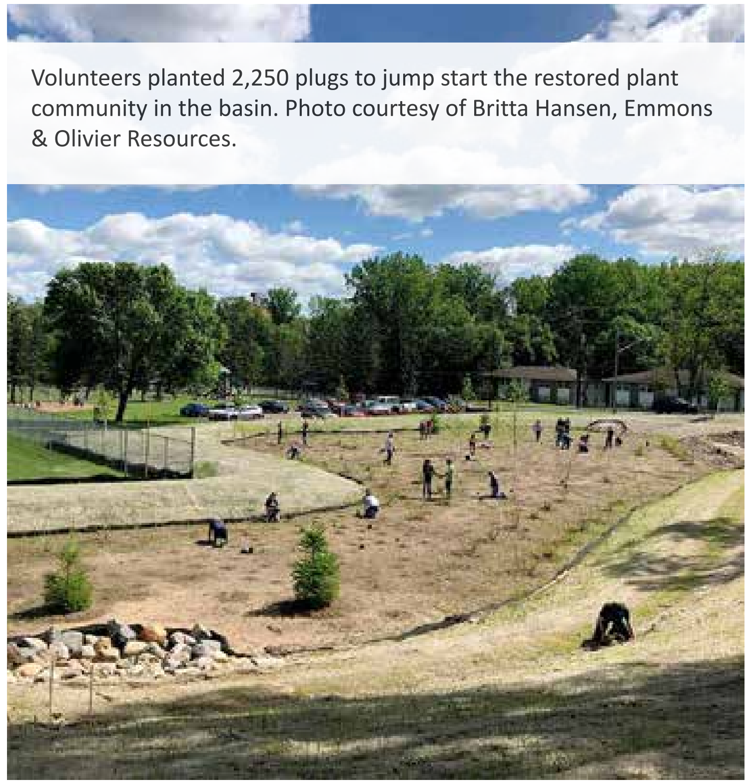
Bioinfiltration basins are similar to rain gardens except they typically are larger scale and are designed without underdrains. Because the scale is larger, they are typically high tech bioretention applications designed to meet stormwater regulatory requirements. Compared to infiltration practices, bioinfiltration practices incorporate plants. The plants use up more water because they evapotranspriate water to the atmosphere. They also infiltrate more water with the flow paths created by their deep roots.

Bioinfiltration basin project highlight: Lily Lake

The bioinfiltration basin in Stillwater was key to improving water quality in Lily Lake. The community invested substantial work to improve water quality in Lily Lake over many years, installing rain gardens, retrofitting stormwater ponds, and doing volunteer clean-up days. Still, the lake water quality was impaired.

The 15,000 square foot bioinfiltraiton basin was designed to treat the runoff from 15 acres of commercial, residential, and park areas. In addition to water quality benefits, the basin was designed to create wildlife habitat and provide community amenities, including an acre of native vegetation, native trees, walking paths, benches, and educational signage. The basin was seeded with native species, and 20 community volunteers installed hundreds of plants to jump start the native plant community.

All of the work invested in this community-driven project has paid off. The water quality in Lily Lake has improved and the lake is no longer impaired, a benefit to the human and wildlife communities.



Volunteers planted 2,250 plugs to jump start the restored plant community in the basin. Photo courtesy of Britta Hansen, Emmons & Olivier Resources.

The matured Lily Lake bioinfiltation basin is filled with dense native plants, providing water quality, ecological, and community benefits. Photo courtesy of Britta Hansen, Emmons & Olivier Resources.

CONSTRUCTED & RESTORED WETLANDS

Wetlands are areas with water at or near the surface, typically vegetated depressions, and can be either natural or constructed. Constructed wetlands are typically referred to as stormwater wetlands when they are designed to meet stormwater regulatory requirements in urban settings. Degraded natural wetlands that are improved by removing sediment, reshaping, revegetating, or improving hydrology are called restored wetlands.

Stormwater treatment wetlands are a high tech practice requiring substantial planning and design. The designs often include shallow marsh areas, deeper, permanent pools, and overflow areas to provide water quality treatment and simulate the function and habitats of natural wetlands.

With proper maintenance, wetlands can provide stormwater management benefits and other ecosystem services for many years. The most common maintenance activities include addressing erosion in the storage pools, removing trash, debris, and sediment from inlets and outlets, ensuring the establishment of vegetation, replanting bare areas, as well as weeding and invasive species control.

Years ago, Cascade Creek was forced into a straight channel through a former golf course in Rochester. The straight channel was stuck in its deep banks with fast flowing water that added to downstream flooding problems. The City of Rochester, Minnesota Department of Natural Resources, Olmsted County Soil and Water Conservation District (SWCD), and Minnesota Board of Water & Soil Resources collaborated to fund constructed wetlands, wetland restoration, and stream and prairie restoration on this 29-acre site. The restored stream channel is on the left of the photo. The center of the photo shows a part of the stream no longer connected to the stream channel, which now functions as a restored wetland. A constructed wetland is shown in the foreground, and several constructed wetlands are shown in the background of the photo. The restored and constructed wetlands fill during high stream flow events and help manage flooding downstream. Photo courtesy of Olmsted County SWCD.

In addition to work at the former golf course to improve Cascade Creek highlighted above, work was completed in the upstream rural countryside near Byron (top). This constructed wetland was created on private land with a county easement.

This is one of two constructed wetlands in series, designed to address peak flow and sediment in the Creek. When stream flow is high, it overflows into the wetlands and is treated by the wetlands before flowing back into Cascade Creek (bottom). Photos courtesy of Olmsted County SWCD.

Stormwater from the West St. Paul Thompson Lake watershed is now cleaned by a series of treatment practices including a forebay to settle out sediment (upper right of photo) and into the recently constructed wetland (center of photo) before flowing into Thompson Lake (not pictured). The project was designed to provide water quality improvements as well as community amenities, like the pedestrian bridge crossing the wetland. Photo courtesy of Joe Barten, Lower Mississippi River Watershed Management Organization (WMO).

Wetland project highlight: Thompson Lake restoration

For decades, untreated stormwater flowed from the highly urbanized West St. Paul area into Thompson Lake, resulting in poor water quality. Polluted sediment started filling in the lake, which degraded fish and wildlife habitat.

The Thompson Lake constructed wetland was part of the larger Thompson Lake restoration project. The constructed wetland is the last step in a series of stormwater treatment practices. The series of treatment practices begins with two hydrodynamic separators to remove floating trash and debris, then a pretreatment pond settles out sediment. Finally, the stormwater wetland helps further clean the water. Areas around the wetland and lake were planted with native species to provide fish and wildlife habitat.

Before the wetland was constructed, the narrow channel inlet to the lake had filled with polluted sediment and was choked with invasive cattails (top image). After the project was installed, water enters the forebay (forefront of bottom image), then the constructed wetland (background of bottom image). Photo courtesy of Joe Barten, Lower Mississippi River WMO.

IMPERVIOUS SURFACE REMOVAL

After completing an impervious surface replacement project, Mercado Central in Minneapolis now features a rain garden and local art. The parking lot now drains to the pretreatment structure (metal grates in picture) that captures trash and sediment before that runoff flows into the new native plant rain garden. Photo courtesy of Metro Blooms Design+Build.

Impervious surface removal means replacing hard surfaces like asphalt, concrete, or compacted gravel with vegetated areas or pervious materials. For these projects, the hard, impervious surface materials are removed, the soil is decompacted, and the area is either vegetated or repaved with permeable materials that can infiltrate water. Impervious surface removal is generally a high tech practice because removal can require heavy equipment and replacements are often carefully designed. By changing the surface materials and addressing the compacted soil, rain and runoff are able to absorb into the soil instead of contributing to water pollution and flooding.

Impervious surface removal can be an important strategy for degraded pavement in dense urban areas to address not only water quality, but add much-needed green space, improve neighborhood aesthetics, and improve community well-being.

Impervious surface removal project highlight: Mercado Central

Mercado Central is a cooperative marketplace that fosters business development for Latinos in Minneapolis. When the parking lot at Mercado Central needed resurfacing, co-op members saw the opportunity to provide additional benefits. The co-op met with the Metro Blooms Design+Build project team, and together, they planned a conversion of some of the parking space to green space. The converted area now includes native trees, a channel to route stormwater from the resurfaced parking lot to the new 400 square foot rain garden, a trash and sediment capture pretreatment structure, perimeter fencing, and a patio area.

The old parking lot surface was removed at Mercado Central, leaving a rough construction site before the new project features were installed (top). About a year after the project was completed, the rain garden (background) is helping clean water, while the row of young serviceberry trees planted between the newly paved lot and the sidewalk provide food for pollinators and birds (bottom). Photos courtesy of Rich Harrison, Metro Blooms Design+Build.

PERMEABLE PAVEMENT

Saint Mary's University-Rochester Campus uses several different permeable paver types to create artistic and visual interest while addressing stormwater. Rain infiltrates through the seams in the pavers and is routed into the tree box. Photo courtesy of St. Mary's University.

Permeable pavements are hard surfaces designed to let water absorb through the material and into the ground. Below the pavement, a layer of gravel and sand is designed to infiltrate water into an underlying reservoir or soils. This practice contrasts traditional pavement that does not allow water to infiltrate. The most common permeable pavement types are pervious concrete, porous asphalt, and permeable interlocking pavers. Permeable pavements are often incorporated into high tech designs, but low tech versions for home patios and parking areas are also available.

Permeable pavements can be used instead of impervious surfaces for sidewalks, plazas, patios, parking areas, and driveways. They can also be used where trees are wanted within a paved area, because they allow water to reach the roots. However, permeable pavement is only recommended for areas with low to moderate traffic to prevent sediment buildup and clogging.

Permeable pavement requires special, routine maintenance (cleaning and vacuuming) to keep the pavement open for water to infiltrate. Because of their open-cell structure, permeable pavers can also help to reduce the urban heat-island effect, especially when lighter colored materials are used.

Permeable pavement project highlight: U of M Pleasant Street corridor

The Pleasant Street corridor design project was an asphalt pavement rehabilitation and reconstruction project at the University of Minnesota (U of M) East Bank Campus. The project is located at an intersection that experiences high volumes of pedestrians, bikes, buses, and cars.

The U of M chose to adopt permeable paver and tree trench green infrastructure practices to enhance stormwater management goals of reducing the volume and improving the quality of stormwater from this area. These projects were also chosen for their abilities to enhance the public space and when combined with new signals and bike lanes, lead to improved pedestrian safety at this busy intersection.

The brick pavers and permeable seams allow stormwater to infiltrate into the soil and provide water to the tees in the embedded tree boxes. Photo courtesy of Erin Hunker, SRF Consulting.

GREEN ROOFS

The green roof at the Ramsey-Washington Metro Watershed District Office is one of many green infrastructure practices that treat the site's stormwater and snowmelt. Photo courtesy of Ramsey-Washington Metro Watershed District.

Green roofs are specially designed roofs that incorporate growth media (soil) and plants to capture and use rain where it falls, with excess rain routed to a drainage system. Green roofs are a high tech practice that require specialized design and construction. In addition to soil and plants, green roofs usually include waterproofing systems, electric leak protection systems, insulation, root barrier layers, drainage layers, filter membranes, and erosion protection.

The plants for a green roof need to be appropriately matched to the design's soil type and depth and reflect the local climate, irrigation availability, maintenance frequency, fire resistance needs, and project goals. Diverse plant communities are usually more resilient than those with limited species diversity, while also providing greater ecological benefits.

The initial cost of a green roof is higher than a conventional roof. However, if properly designed, constructed, and maintained, green roofs can last 40 to 50 years, twice as long as a conventional roof. In addition to the typical suite of benefits green infrastructure practices provide, green roofs insulate buildings, keeping them warmer in the winter and cooler in the summer, which reduces energy costs.

Maintenance of green roofs includes checking for ponding, inspecting drains, irrigating, inspecting plant growth and growth media, removing and replacing dead plants, re-planting bare patches, and weeding. Improperly designed, installed, or maintained green roofs can have poor drainage and standing water, leaks, accumulation of trash and debris, and weeds.

Green roof project highlight: Greenway office building

Built in 1999, the Greenway office in Minneapolis has a 4,000 square foot green roof in addition to other conservation features including solar panels, a geothermal heating and cooling system, and a native prairie lawn. The green roof was planted with both Minnesota native species and European sedums. It also features an outdoor seating area for users of the office building. Photo courtesy of Paul Chellsen, City of Minneapolis.

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