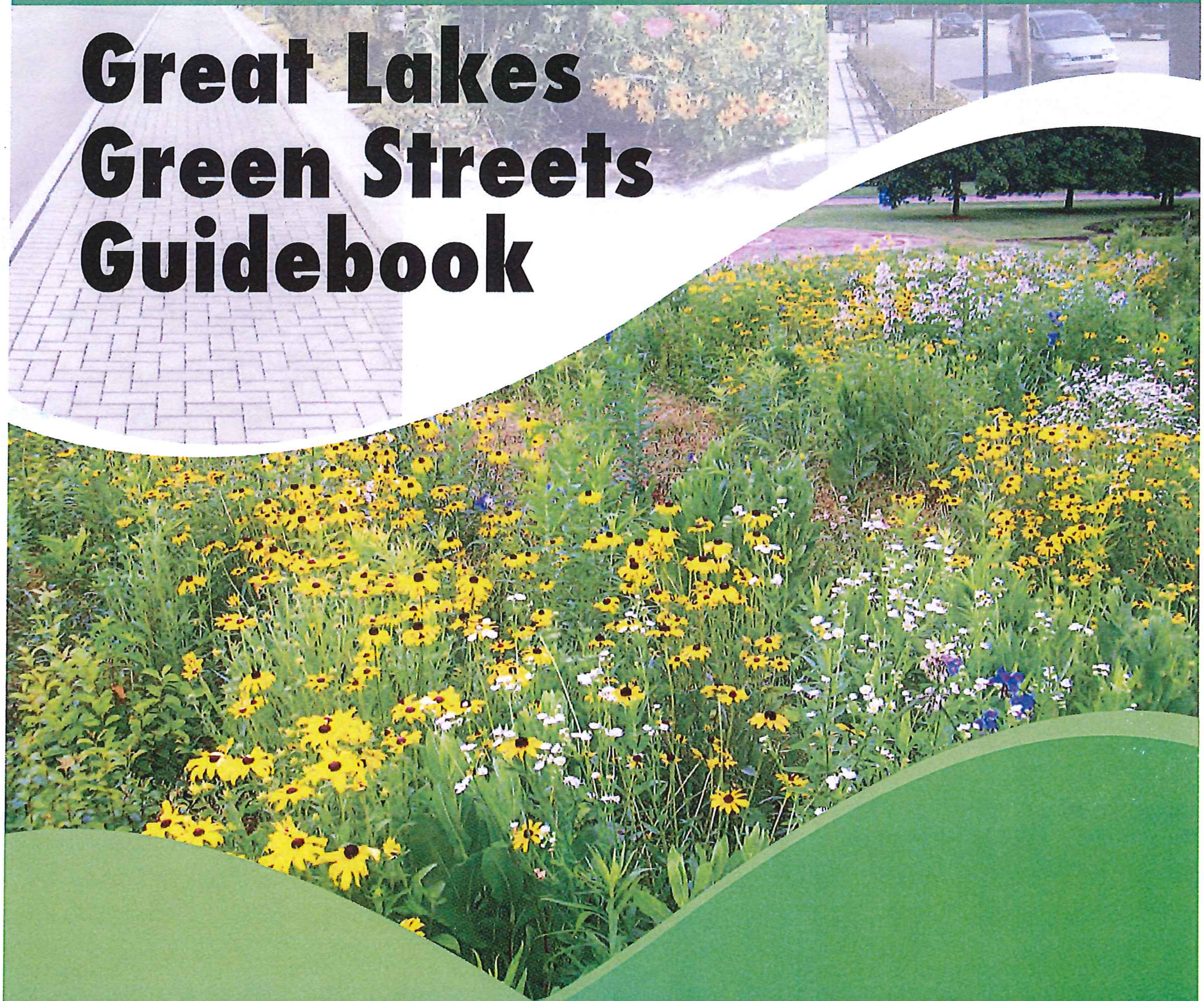
A Compilation of Road Projects Using Green Infrastructure

Great Lakes Green Streets Guidebook



Great Lakes Green Streets Guidebook:
A Compilation of Road Projects Using Green Infrastructure

Abstract

The *Great Lakes Green Streets Guidebook* contains a sampling of road improvement projects within the Great Lakes Watershed that have successfully incorporated green infrastructure techniques to manage stormwater runoff and benefit water resources. SEMCOG developed the *Low Impact Development (LID) Manual for Michigan* in 2008, which includes planning approaches and design criteria for LID techniques. LID/green infrastructure techniques are intended to mimic a site's presettlement hydrology by using best management practices that infiltrate, filter, store, evaporate, and detain runoff close to its source. Designs are typically customized according to local regulatory and resource protection requirements as well as site constraints. Roads present a larger challenge than site development projects to incorporating green infrastructure techniques due to their inherent constrained spaces, multiple transportation requirements, and overlapping jurisdictions. Thus, the outcome of this *Guidebook* is the presentation of case studies showcasing varying approaches to integrating green infrastructure into road projects.

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SEMCOG

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Great Lakes RESTORATION

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Front cover (clockwise from top left):

1. Porous pavers and infiltration planters; Save the Rain – Water Street Green Gateway; Onondaga County, NY.
2. One of numerous rain gardens that help manage stormwater runoff directly to the Au Sable River in Grayling, MI; Huron Pines.
3. Bioretention; Cermak/Blue Island Sustainable Streetscape, Chicago, IL; City of Chicago.
4. Native plant grow zones; Oakland County Sustainable Green Streets Campus; Oakland County, MI; Oakland County Planning & Economic Development Services.

Back Cover (clockwise from top left):

1. Porous pavement and bioretention along Mill Street, Village of Pinckney, MI; Village of Pinckney.
2. Bioretention area in planter box along Michigan Avenue, Lansing, MI; Robert W. Domm from Rain Gardens Sustainable Landscaping for a Beautiful Yard and a Healthy World.
3. The conversion of turf grass to native plant grow zones, Edward Hines Park, MI; Wayne County Department of Public Services – Environmental Services Group.
4. Native wildflower planting in a roadside swale, Robert W. Domm from Rain Gardens Sustainable Landscaping for a Beautiful Yard and a Healthy World.

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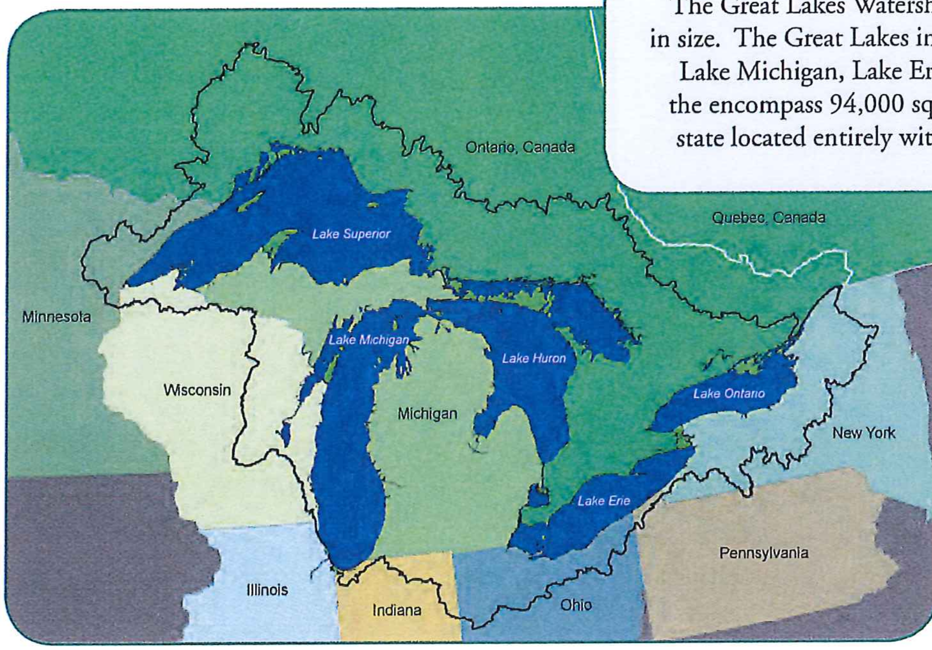
Chapter 1

Introduction to the Great Lakes Green Streets Guidebook

Why this Guidebook was Developed

The *Great Lakes Green Streets Guidebook* (Guidebook) was developed to showcase a sampling of roadway projects within the Great Lakes Watershed that have implemented green infrastructure techniques to improve water quality and reduce stormwater runoff to local water resources.

The Great Lakes Watershed is over 294,000 square miles in size. The Great Lakes include Lake Huron, Lake Ontario, Lake Michigan, Lake Erie and Lake Superior. Together, the encompass 94,000 square miles. Michigan is the only state located entirely within the Great Lakes Watershed.



Source: US Environmental Protection Agency.

The *Guidebook* was developed as a complement to the *Low Impact Development Manual for Michigan (LID Manual)*. This *Guidebook* includes a sampling of roadway projects within the Great Lakes Watershed that have implemented green infrastructure techniques to improve water quality and reduce stormwater runoff to local water resources.

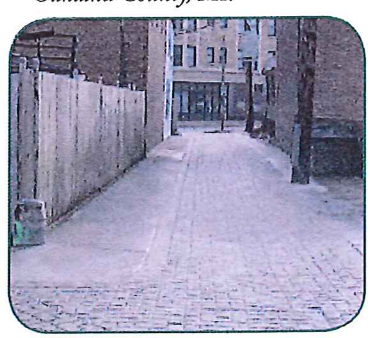
At the same time, municipalities are challenged with developing more creative design solutions to managing stormwater runoff. It is clear, that integrating green infrastructure techniques within existing roadway systems is very challenging. This *Guidebook* is intended as an addition to Chapter 8 of the *LID Manual* with a focus on Green Street projects.

The *Guidebook* contains considerations in the planning, design, and construction of green streets followed by a sampling of case study projects. The green infrastructure techniques described in this *Guidebook* include:

- bioretention/ bioswales,
- native plant grow zones, and
- permeable pavement.

Onondaga County, NY.

Oakland County, MI.



Chicago, IL.

Green Infrastructure Along Transportation Corridors

Implementing green infrastructure along roadways involves changing the traditional stormwater management paradigm. This is a significant challenge and must involve an integrated planning approach to be successful. A willingness to collaborate across multiple agencies and departments will set the stage for developing a process to incorporate green infrastructure into roadway projects.

Typical local road right-of-way.

Challenges associated with constructing above-grade stormwater management features in transportation corridors are primarily attributed to the linear dimensions of the corridor and the constrained space within a typical road right-of-way (ROW). Additionally, much of the ROW is paved with impervious materials built over compacted subgrade.

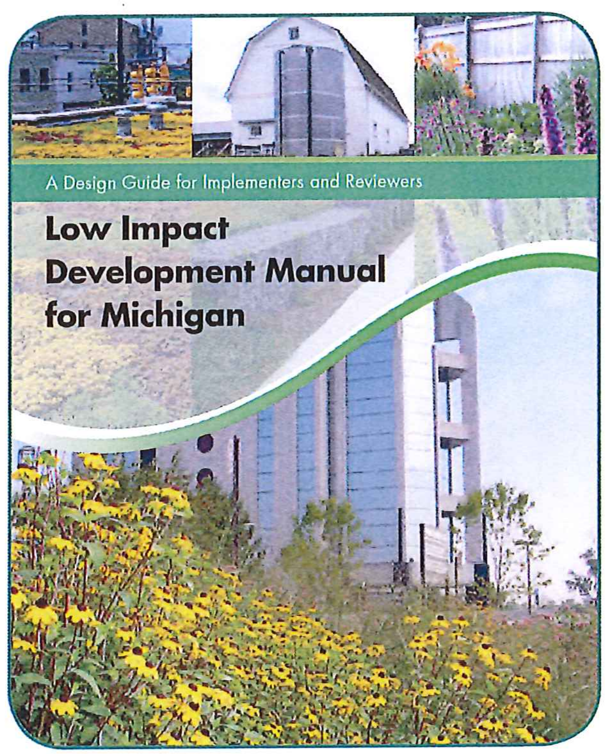
At the same time, coordinating implementation of green infrastructure with broader transportation improvements can provide multiple benefits for both new projects and retrofits within these corridors. Benefits include the following:

Cermak/Blue Island Sustainable Streetscape.

- reduced pollutant loading and stormwater runoff volume;
- enhanced streetscapes;
- improved pedestrian-friendly environments;
- improved air quality;
- reduced urban heat island effects;
- added traffic calming features; and
- developed connections to larger green infrastructure networks.

Stormwater Runoff

Roadways are significant contributors of urban runoff to local natural resources. Urban runoff challenges are typically lumped into both runoff quantity and runoff quality categories. The extent of local, regional, and national watershed planning efforts in urban areas has demonstrated that urban streams are impacted by excessive stormwater runoff volumes combined with excessive pollutant loading following channel forming rain events. Within the Southeast Michigan region, there are over 23,400 miles of roadways with approximately 245 square miles of impervious cover. Annually this equates to approximately 100 billion gallons of runoff with more than 100 tons of phosphorus and 34,000 tons of sediment.



Chapter 9 of the *LID Manual* describes the calculation methodology for designing green infrastructure techniques to reduce both stormwater runoff volume and pollutants. Transportation corridors are a significant source of urban stormwater runoff, containing a variety of pollutants, such as sediment, metals, salt, and deicing materials. Additionally, these corridors are also a source for thermal pollution to receiving waterways. While the chemical constituents of roadway runoff are highly variable, the Federal Highway Administration identified runoff pollutants and their respective sources (Table 1).

Compared to other land uses and impervious surfaces, roadway runoff tends to have higher levels of sediment, metals, salts, and deicing materials. These pollutants impact local water resources and any green infrastructure design should reduce these pollutant loadings.

Green infrastructure techniques along roadways can significantly reduce the quantity of roadway runoff while also improving runoff quality.

Table 1

Pollutants and Sources in Highway Runoff

Pollutants	Source
Particulates	Pavement wear, vehicles, atmospheric deposition, maintenance activities
Nitrogen, Phosphorus	Atmospheric deposition and fertilizer application
Lead	Leaded gasoline from auto exhausts and tire wear
Zinc	Tire wear, motor oil and grease
Iron	Auto body rust, steel highway structures such as bridges and guardrails, and moving engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear and insecticide application
Chromium	Metal plating, moving engine parts, and brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear, and asphalt paving
Manganese	Moving engine parts
Cyanide	Anti-caking compounds used to keep deicing salts granular
Sodium, Calcium Chloride	Deicing salts
Sulphates	Roadway beds, fuel, and deicing salts

Source: FHWA Stormwater Best Management Practices in an Ultra-Urban Setting

Chapter 2

Green Streets Considerations & Challenges

Green Streets Planning Considerations

Michigan Avenue, Lansing, MI achieves both transportation and environmental outcomes.

Local leadership is needed to move green streets forward, the extent of which is varied across the Great Lakes region. Successful green streets programs are more pronounced in areas where long-term combined sewer overflow (CSO) control plans and programs include green infrastructure requirements. Successful programs have linked transportation planning with stormwater management outcomes in order to strategically utilize funding opportunities.

Water Street Green Gateway, New York includes nonmotorized and environmental outcomes.

Incorporating green infrastructure into roadway projects is not a minor undertaking. It involves a shift in perspective where the value of water quality and stream channel protection is reflected during different phases of a project, including planning, design, construction, and maintenance.

Desired outcomes in a green infrastructure program should be well defined and green streets are an important component of a program. While those outcomes have traditionally focused on environmental quality, integrated planning helps to further achieve other desired outcomes that provide economic, social, community, and regulatory goals. Multiple outcomes can be achieved by combining transportation with environmental planning.

Local Planning Outcomes

Road agencies, and state and local governments can take a proactive approach to initiate or expand upon a green streets program. Examples of these actions include the following:

1. **Coordinate transportation and watershed planning.** Land use planning is a primary function of local government with local plans and policies reflecting community desires. Road agencies should be familiar with local water issues and the community's efforts to address them, including whether the community is covered by a stormwater permit, as well as the extent to which green infrastructure is applied in site development. Within this context, most urban areas have developed watershed management plans that prioritize goals, objectives, and actions to improve local water resources. Road agencies should work with local watershed groups to identify practices and actions that will work towards achieving water resource goals. Coordinating with watershed management plans, CSO control strategies, or Total Maximum Daily Loads (where they exist) will result in policies that are unique for the needs of the waterway.
2. **Consider green infrastructure techniques early in the planning process.** It is critical to consider green infrastructure opportunities as early in the process as possible. Once designers are committed to the project design, it is hard to change course for what would likely be perceived as a secondary consideration. Early meetings, at the project conception phase, with the local unit of government are encouraged.
3. **Update plans, guidelines, procedures, and manuals.** Consider revisions to existing manuals and procedures that incorporate green infrastructure supportive practices and policies.
4. **Consider developing a local or regional Green Streets Management Plan.** Developing a specific plan lets everyone know expectations, goals, and desired outcomes. The City of Milwaukee in Wisconsin Coastal Management Program, National Oceanic and Atmospheric Administration and CH2MHill developed a Green Streets Stormwater Management Plan that

highlights templates, approaches, and instructions for designing green infrastructure into road projects. The City of Chicago developed the *Chicago Green Alley Handbook* that provides detailed information about converting urban alleys to permeable pavement.

Regional Planning Outcomes

Metropolitan Planning Organizations (MPOs) are designated under the Moving Ahead for Progress in the 21st Century (MAP-21), federal transportation legislation. MPOs have mandated responsibilities for developing long-range transportation plans and transportation improvement programs. Typically, MPOs work closely with road implementing agencies in their jurisdiction. And often, the MPO is also the council of governments representing a variety of local governments. Such is the case for SEMCOG. Thus, MPOs can play a major role in advocating for implementation of green streets.

Furthermore, an emerging trend in federal transportation legislation and regulations is to integrate environmental protection issues early in the transportation planning process. This transportation planning institutional structure and policy trend presents an opportunity to promote green streets in the process of implementing roadway plans and projects. SEMCOG, for example, has developed a procedure for ensuring that transportation agencies in Southeast Michigan consider a variety of potential environmental concerns when proposing a project for the transportation plan and transportation improvement program.

Several suggested action steps are proposed for consideration by MPOs:

1. **Become familiar with green infrastructure and low-impact development techniques.** Transportation planning should evolve to naturally incorporate consideration of green infrastructure techniques early in the planning process.
2. **Incorporate policies into the long-range transportation plan (LRTP) that advance green infrastructure implementation.** Integrate the need for green infrastructure planning and implementation into the recommendations of the LRTP.
3. **Educate and, where feasible, provide technical assistance to road implementing agencies.** Assistance includes identifying potential sources of funding for green streets techniques, providing technical expertise to recommend potential alternatives, encouraging consideration early in the planning process, and recommending changes in operational and maintenance practices to reduce nonpoint source loading impacts.
4. **Convene representatives of road agencies in the area to discuss policy options.** Work to identify opportunities and impediments in supporting green infrastructure. For areas under a stormwater permit program, the benefits of achieving compliance with a green streets program should be considered.
5. **Consider giving priority to projects that incorporate green infrastructure techniques.** These types of projects address multiple outcomes for a local community and the region, and thus should be considered a more economic strategic use of investment funding.

Complete streets with nonmotorized elements.

Green Streets Technical Challenges

The greater the traffic volume and mix of vehicles using the roadway, the fewer features that can be accommodated within the right-of-way (ROW).

Depending on the type of corridor - local, collector, arterial, or highway - transportation elements will vary. Corridor elements can include the number of travel lanes, lane width, impervious and vegetative cover, drainage characteristics, overall ROW dimensions, traffic capacity, traffic volumes, and nonmotorized features. All of these elements can affect green infrastructure planning and design.

Functional roadway characteristics that must be considered when selecting green infrastructure techniques include:

1. **Roadway corridor classification.** Techniques may be limited for larger, higher traffic volume roadways; whereas, local, collector or arterial roadways may provide flexibility for alternative techniques.
2. **Parking requirements.** Determine whether on-street parking is needed for the project.
3. **Complete streets requirements.** Consider incorporating nonmotorized features as part of a larger corridor project.

4. **Site design constraints.** Typical stormwater management design considerations including size of drainage area, soil type, slope, and location of existing utilities are critical.
5. **Operation and maintenance.** Agreement should be early in the process as to what level of maintenance is required, the agency or entity that will maintain the technique(s), the annual costs associated with maintenance, and the source of funding for maintenance.

As described in Chapter 8 of the *LID Manual*, many green infrastructure techniques may be appropriate for use in managing roadway runoff; however, they must be designed and implemented with consideration of the nature of runoff from road surfaces. These runoff characteristics include:

1. **High levels of total suspended solids.** Given the high concentration of sediment in roadway runoff, pretreatment is recommended prior to discharge to a green infrastructure technique. For example, energy dissipaters located at the entrance of bioswales, bioretention features, and tree trenches works to concentrate sediment accumulation at the entrance of the GI technique which will simplify sediment removal maintenance. Nonstructural techniques such as street sweeping and vacuuming also greatly reduce the sediment load in roadway runoff.

Energy dissipator between road and bioretention.

2. **Proper design of vegetative green infrastructure techniques.** Bioswales, bioretention, and tree trenches can be highly effective, but design details such as slope, flow velocity, runoff volumes, overflow structures, and vegetation types must be carefully selected to avoid failure.
3. **Consideration of hazardous material spills.** The potential for spills and any necessary clean-up should be considered in the design of roadway green infrastructure techniques. Vegetative green infrastructure techniques may require replacement in the event of a spill.
4. **Deicing materials and snow removal.** Use of deicing materials and salts may affect vegetation, soil conditions, and water quality. Consider the types of vegetation used in green infrastructure techniques, as chloride levels may adversely affect some vegetation as well as the soil microbial community. Disposing of snow removed from roadways must also be considered. Appendix C of the *LID Manual* contains a list of salt-tolerant plants.

Green Streets Funding Challenges

One of the biggest challenges facing communities and larger metropolitan areas is that the infrastructure system (roads, water, sewer stormwater) has more needs than there are resources to address those needs. At the same time, the current environmental regulatory framework is moving towards increased stormwater management requirements along transportation corridors in the form of decentralized green infrastructure techniques. The American Society of Civil Engineers 2013 Report Card for America's Infrastructure estimated that approximately $3.6 trillion is needed in overall infrastructure investment by 2020 with an estimated $1.6 trillion shortfall. Of that shortfall, ASCE estimates an approximately $930 billion funding gap for surface transportation and water/wastewater infrastructure.

A recurring theme in this *Guidebook* is that the traditional approach to identifying and selecting infrastructure projects within transportation corridors must be modified to consider multiple desired outcomes through an integrated planning approach. For example, stormwater management is an eligible cost under the federal system, but is often viewed as an "add on" by road agencies. When having to choose between spending limited road funding on resurfacing additional roads or adding stormwater management to their projects, runoff management is often not included. At the same time, the shortage of revenue to even maintain the existing transportation system is causing the perpetuation of actions that increase long-term costs, including costs to manage stormwater runoff.

While these funding shortfalls are significant, the challenges are exacerbated by the fact that current funding methodologies for infrastructure are largely outdated and out of alignment with current realities. Solutions to address these challenges in a cohesive manner are evolving; however, it requires a more collaborative approach to strategically investing in infrastructure improvements. Solutions to address these funding challenges through collaborative, strategic infrastructure investment can include:

1. **Review transportation plans with local watershed plans.** Determine where stormwater management goals may be incorporated into transportation planning goals.
2. **Consider green infrastructure early in the conceptualization process.** Identifying stormwater management approaches during the identification phase of a transportation or infrastructure improvement project will enhance the success of implementation.
3. **Review long-term capital improvement plans (roads, water, sewer).** Plan for stormwater management upgrades or retrofits within transportation corridors.
4. **Identify areas of excess roadway capacity.** Explore options for transportation infrastructure that is significantly underutilized. These may result in opportunities to reduce impervious surface or install green infrastructure techniques within outside lanes.
5. **Utilize asset management programs to prioritize projects.** This will work to strategically invest in infrastructure improvements that achieve multiple outcomes.
6. **Consider Transportation Alternatives Program (TAP) funding sources.** Authorized through MAP-21, this program provides funding for features that address environmental mitigation, on- and off-road pedestrian and bicycle facilities, recreational trail projects, safe routes to school, and other projects that improve non-driver access to public transportation.

Chapter 3

Green Streets Techniques and Design Considerations

Green Infrastructure Techniques for Transportation Corridors

Once there is an understanding of the local and regional outcomes for green infrastructure along transportation corridors, then consideration may be given to identifying those types of techniques that work traditionally well in these constrained areas. Whether the outcome is to reduce stormwater runoff volumes within combined sewer areas or to improve water quality through reduction in runoff volumes and pollutant loading in separated sewer areas, there are techniques that work in both scenarios. Green infrastructure techniques along transportation corridors that have demonstrated success are the focus of this *Guidebook* and include bioretention and bioswales, native plant grow zones, and permeable pavement. Each of these techniques is described in more detail in this chapter. Chapter 4 contains 26 example projects across the Great Lakes Watershed that are in various stages of design and implementation.

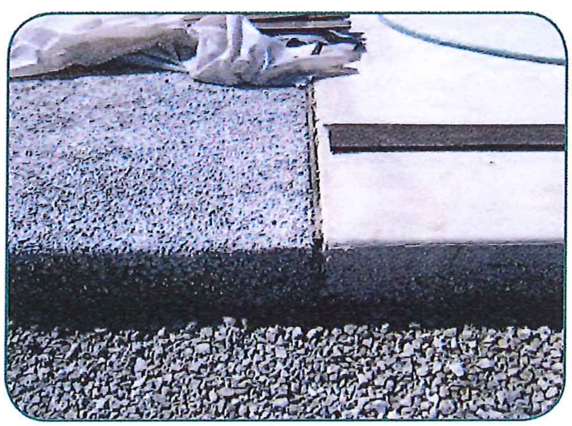
Bioretention & Bioswales

City of Milwaukee, WI.

Native Plant Grow Zones

Wayne County, MI.

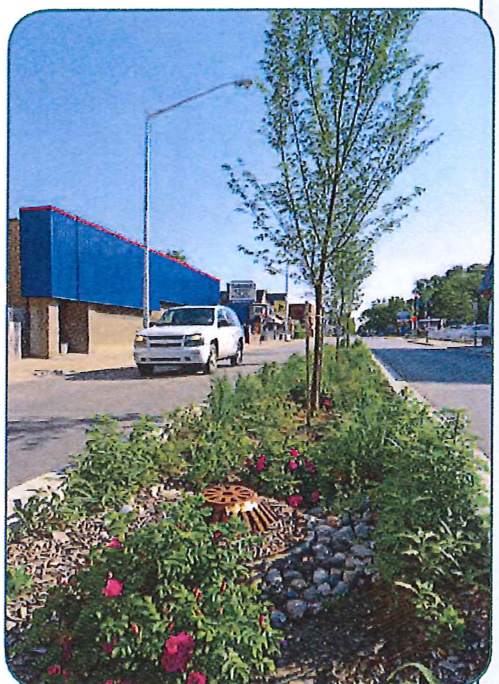
Permeable Pavement



Bioretention & Bioswales

Bioretention techniques and bioswales provide some of the largest runoff reduction and water quality benefits for green streets projects. Bioretention areas are typically shallow surface depressions planted with specially selected native vegetation to capture and treat stormwater runoff from rooftops, streets, and parking lots. A bioswale is a shallow stormwater channel that is densely planted with a variety of grasses, shrubs, and/or trees designed to slow, filter, and infiltrate stormwater runoff. Check dams can be used to enhance performance and maximize infiltration.

Chapter 7 in the *LID Manual* provides detailed design and construction information for these techniques.



Plainfield Avenue, Grand Rapids, Michigan linear bioretention.

Green Streets Application

- Curb bumpouts
- Medians
- Sidewalk planters

Variations

- Subsurface storage/ infiltration bed
- Curb cut to manage smaller rain events
- Overflow structure for larger rain events
- Use of underdrain connected to storm sewer

Key Design Features

- Flexible in size and infiltration
- Ponding depths 6-18 inches for draw-down within 48 hours
- Native plants or turf feasible options with infiltration material
- Amend soil as needed

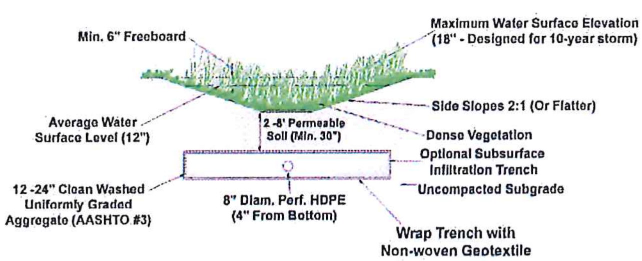
Benefits

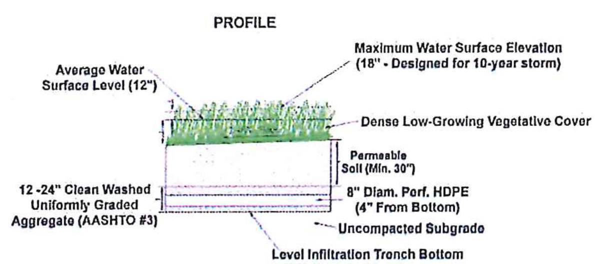
- Stormwater runoff volume reduction
- Moderate peak rate control
- Water quality improvement
- Versatile with broad applicability
- Enhance site aesthetics, habitat
- Potential air quality and climate benefits

Limitations

- Higher maintenance until vegetation is established
- Limited impervious drainage area
- Requires careful selection and establishment of plants
- Consider line of site issues along roadways

Cross-section of a vegetated swale with an underlying aggregate layer





Native Plant Grow Zones

The term grow zone was coined by Wayne County, Michigan as they began converting large-scale park areas to native planting areas for purposes of improving water quality, habitat, and reducing stormwater runoff volumes. Native vegetation has significant root systems that promote runoff infiltration and uptake. Grow zone areas work best in adjacent roadside areas where roadway runoff is directed via sheet flow. Large open areas that have been traditionally managed as turf may be easily converted to native plant grow zones. These may include cloverleaf areas around on and off ramps for highways and large highway medians. Additionally, grow zones are also feasible in linear vegetated areas adjacent to roadway impervious surfaces.

Chapter 7 of the *LID Manual* provides design considerations for native revegetation areas.

Permeable Pavement

Wayne County, Michigan grow zone.

Oakland County, Michigan grow zone.

Green Streets Application

- Open areas receiving runoff via sheet flow
- Wide swales
- Cloverleaf intersections

Variations

- Prairie: forb/grass mix
- No-mow lawn area: low-growing native grasses
- Woodland: mix of trees, shrubs, forbs, grasses, and sedges

Key Design Features

- Presence of existing native vegetation
- Soil types
- Hydrologic regimes
- Sun exposure
- Aesthetics

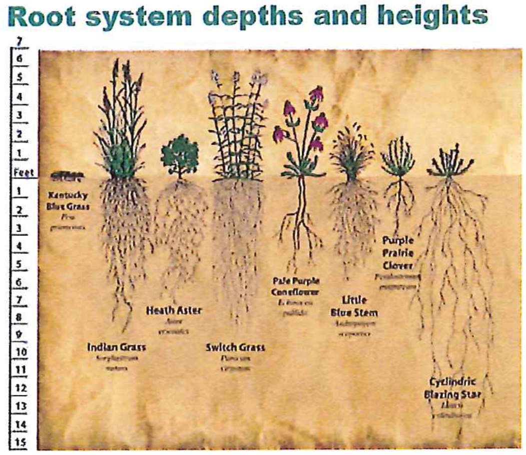
Benefits

- Low long-term maintenance
- Stormwater runoff volume reduction
- Water quality improvement
- Moderate peak rate control

Limitations

- Higher maintenance until vegetation is established
- Consider line of site issues along roadways

Root system depths and heights



Source: Jeffrey C. Domm.

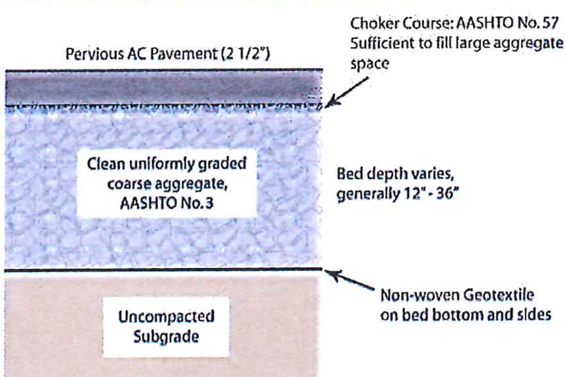
A pervious pavement system consists of a porous surface course underlain by a storage reservoir placed on uncompacted subgrade to facilitate stormwater infiltration. The storage reservoir may consist of a stone bed of uniformly graded, clean, and washed course aggregate with a void space of approximately 40 percent or other pre-manufactured structural storage units. The pervious pavement may consist of porous asphalt, pervious concrete, permeable paver blocks, or reinforced turf/gravel.

Porous asphalt mix has fewer fines and has an open-graded surface over a stone base. Pervious concrete has little to no sand in the mix and contains and interconnected system of voids to allow water to drain. Typical voids achieved in pervious concrete mix is on the order of 15-25 percent. Paver blocks are typically modular systems that vary greatly in design types. For purposes of this *Guidebook*, the examples are limited to pervious pavement applications. Generally, permeable pavement is utilized in areas of low traffic or where there is limited traffic turning, starting, and stopping.

Chapter 7 of the LID Manual provides detailed design and construction information for these techniques.

Easy Street, Ann Arbor, Michigan.

Paver blocks and bioretention



Example cross-section of porous pavement.

Green Streets Application

- On-street parking
- Shoulders
- Nonmotorized areas

Variations

- Porous asphalt
- Pervious concrete
- Permeable paver blocks
- Reinforced turf/gravel

Key Design Features

- Do not infiltrate on compacted soil
- Level storage bed bottoms
- Provide positive storm water overflow from bed
- Surface permeability >20"/hr

Site Factors

- Water table/Bedrock separation: two-foot min.
- Potential hot spots: Not without design of pretreatment system

Benefits

- Stormwater runoff volume reduction
- High peak rate control
- Water quality improvement
- Dual use for pavement structure and stormwater management

Limitations

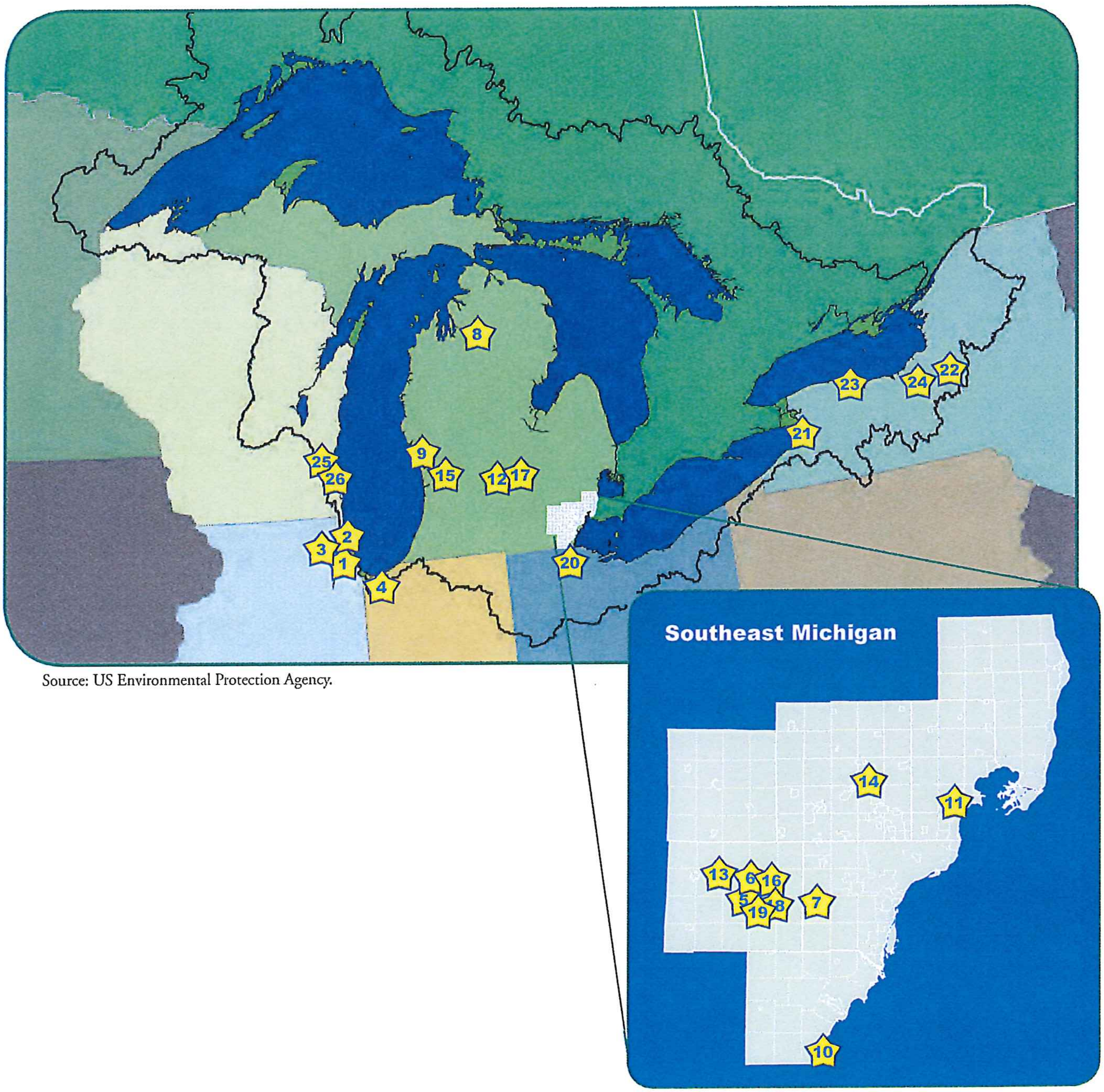
- Regular maintenance, such as street sweeping

Chapter 4

Great Lakes Green Streets Projects

The Great Lakes Green Streets projects consist of a variety of green streets approaches that have been implemented or are under construction across the Great Lakes Watershed. The goal of this chapter is to demonstrate varying approaches and design criteria to managing roadway runoff while also achieving multiple desired outcomes. Each case study includes a project summary and outcomes achieved. It also describes varying funding sources utilized and challenges with implementation.

The map below shows the locations for each of the case study projects, followed by a list of projects by state and by green infrastructure technique.



Source: US Environmental Protection Agency.

Illinois

1. Cermak/Blue Island Sustainable Streetscape, Chicago; Permeable Pavement & Bioretention
2. Lawrence Avenue, Streetscape, Chicago; Road Diet, Permeable Pavement & Bioretention
3. Green Alleys, Chicago; Permeable Pavement

Indiana

4. 54th Court, Merrillville; Bioretention

Michigan

5. Buhr Park Alley, Ann Arbor; Permeable Pavement
6. Easy Street, Ann Arbor; Permeable Pavement
7. Ecorse and Morton Taylor Roads, Wayne County; Native Plant Grow Zones
8. Grayling Stormwater Program, Grayling; Bioretention
9. Lake Street, Whitehall; Permeable Pavement & Bioretention
10. Luna Pier Boulevard, Luna Pier; Bioretention
11. Metropolitan Parkway, Macomb County; Native Plant Grow Zones
12. Michigan Avenue, Lansing; Bioretention
13. Mill Street, Pinckney; Permeable Pavement & Bioretention
14. Oakland County Campus, Pontiac; Native Plant Grow Zones
15. Plainfield Avenue, Grand Rapids; Bioretention
16. Sylvan Avenue, Ann Arbor; Permeable Pavement
17. Washington Square, Lansing; Bioretention
18. West Stadium Boulevard, Ann Arbor; Road Diet
19. Willard Street, Ann Arbor; Permeable Pavement

Ohio

20. Maywood Avenue, Toledo; Bioretention

New York

21. CSO 60 Green Street Pilot, Buffalo; Permeable Pavement & Bioswales
22. North James Street, Rome; Permeable Pavement
23. Sawdey Way, Rochester; Permeable Pavement
24. Save the Rain - Water Street Green Gateway, Syracuse; Permeable Pavement & Bioretention

Wisconsin

25. South 6th Street, Milwaukee; Bioswales
26. West Grange Avenue, Milwaukee; Bioswales

1 Bioretention or Bioswale/Permeable Pavement: State Road

Cermak/Blue Island Sustainable Streetscape, Chicago, IL

Project sponsor
Chicago Department of Transportation (CDOT)

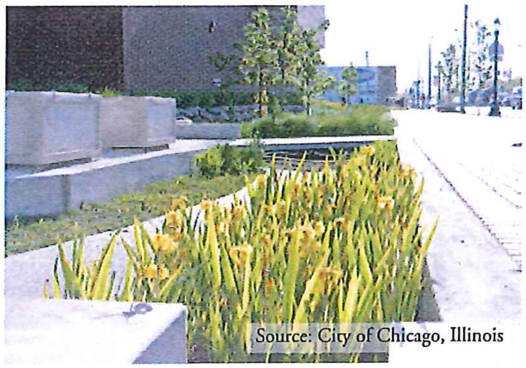
Project designer
Knight Engineers and Architects

Project contractor
Pan Oceanic Construction

Design and construction cost
$14 million

Key design features
- Design Event: 80% of average annual rainfall
- Drainage Area: > 5 acres
- Runoff Reduction: 2.85 million gallons per year

Partners
FHWA, IL EPA, Chicago Public Schools, Metropolitan Water Reclamation District, Commonwealth Edison



Source: City of Chicago, Illinois

Cermak/Blue Island Sustainable Streetscape after reconstruction.

The Cermak/Blue Island Sustainable Streetscape demonstrates how cutting edge sustainable design and complete streets principles can be implemented in the public right of way. Located on Cermak Road between Halsted Street and Ashland Avenue, and Blue Island Avenue between Ashland Avenue and Wolcott Avenue, this 1.5 mile long pilot project demonstrates a full range of sustainable design techniques that improve the urban ecosystem, promote economic development, increase the safety and usability of streets for all users, and build healthy communities. Sustainability goals were acheived in stormwater management, material reuse, energy reduction, and placemaking. The lessons learned from this demonstration project and others are being incorporated into CDOT's new Sustainable Urban Infrastructure Guidelines and Policies. New markets were also developed through area suppliers, including: concrete with 30 percent recycled aggregate and wash water, new recycled aggregates, permeable pavers with a smog-eating photocatalytic cement surface, asphalt with reclaimed asphalt shingles, and reclaimed pavements made using warm-mix technology. Finally, by requiring documentation proving that products meet sustainable project goals, this project has begun a transformation within the industry to understand its own ecological footprint. This creates new value within these industries around existing and new products. Financial support from local funding and tax increment financing, in addition to grant funding by the Federal Highway Administration (FHWA), Illinois Environmental Protection Agency (IL EPA), and Commonwealth Edison.

Project benefits
Water quality • Runoff reduction • Groundwater recharge • Stormwater peak rate reduction • Community aesthetics • Air quality improvements • Urban heat island reduction • Energy efficiency

Project challenges
Regulatory support and permitting

Maintenance
Semi-annual street sweeping

Contact information
Janet Attarian
Jattarian@cityofchicago.org

David Leopold
dleopold@knightea.com

Chicago Department of Transportation | Knight E/A

Road Diet with Bioretention and Permeable Pavement: County Road

2 Lawrence Avenue Streetscape, Chicago, IL

The Lawrence Avenue Streetscape is located on Lawrence Avenue between Western Avenue and Clark Street. The project consists of a road diet, narrowing the roadway from four to three lanes, with a continuous center left turn lane. The road diet allows for the addition of a new bike lane to connect to nearby networks, as well as the widening of sidewalks on both sides of the street by two feet. The project includes energy-efficient, white metal halide light fixtures, as well as infiltration planters and permeable pavement to manage site stormwater. Local funding and tax increment financing are providing financial support for this project. Local community Chambers of Commerce are partners for ongoing maintenance assistance.

(Top) Lawrence Avenue before construction and (right) Lawrence Avenue final rendering.

Project sponsor
Chicago Department of Transportation (CDOT)

Project designer
Christopher Burke Engineering

Project contractor
Sumit Construction

Design cost
$1.3 million

Construction cost
$12 million

Key design features
- Design Event: Captures 60% of the entire drainage area into the green infrastructure techniques and approximately 80% of all rain events
- Drainage Area: > 5 acres

Project benefits
Water quality
Runoff reduction
Groundwater recharge
Stormwater peak rate reduction
Community aesthetics
Urban heat island effect

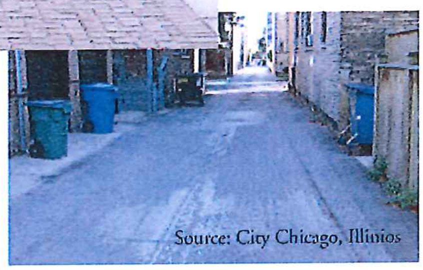
Project challenges
Regulatory support and permitting
Difficulty in partnering for maintenance obligations in the public right-of-way

Maintenance
Semi-annual catch basin cleaning and street sweeping
Monthly watering and weeding of vegetation

Contact information
Janet Attarian
Jattarian@cityofchicago.org
David Leopold
dleopold@knightea.com
Chicago Department of Transportation | Knight E/A

Permeable Pavement: Alleys under local jurisdiction

3 Chicago Green Alleys, Chicago, IL



(Above) Permeable block alley after reconstruction and (right) before reconstruction.

Project sponsor
Chicago Department of Transportation (CDOT)

Project designer
Knight Engineers and Architects

Project contractor
Pan Oceanic Construction

Design and construction cost
Average cost per alley approximately $150,000, including partial and full reconstruction

Key design features
- Design Event: 2-year; 24-hour event
- Drainage Area: typically < 1 acre

Partners
Chicago Streets and Sanitation Department for ongoing maintenance

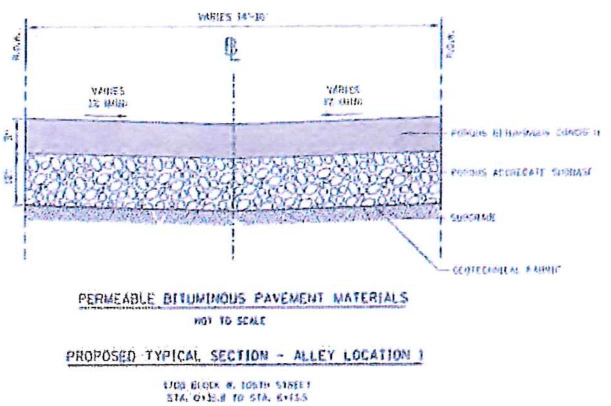
The vision of the Green Alley Program is to reinvent the traditional practices used by Chicago Department of Transportation to solve the pavement wearing and flooding issues that can develop over time in an alley. The goal was to develop a new design toolbox using sustainable design and construction methods, including:

- Stormwater Management- In a typical Green Alley, up to 80 percent of the rainwater falling on its surface throughout the year passes through permeable paving back into the earth, thereby reducing localized flooding, recharging groundwater, and saving taxpayer money that would otherwise be spent treating stormwater. Permeable asphalt, concrete, and pavers are used in the program.

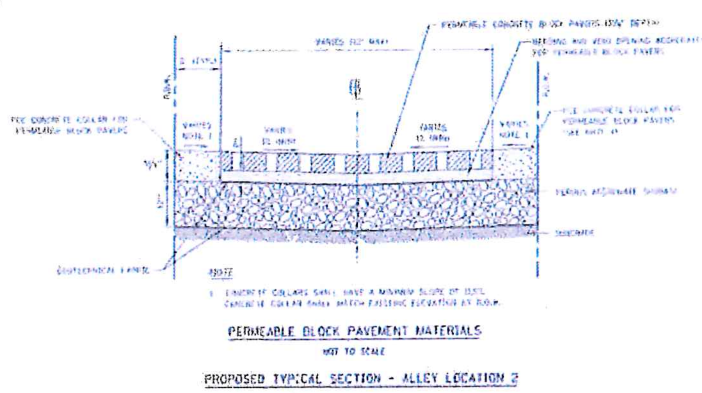
- Heat Reduction- Green Alleys utilize high albedo concrete, pervious concrete, and brick pavers with a high solar reflective index in order to mitigate the urban heat island, a condition where dense urban areas become several degrees warmer due to heat absorbing paved areas. Monitoring data have shown that the pavement surface temperature of a high-albedo green alley can be 23 or more degrees cooler than traditional asphalt pavement.

- Material Recycling – Green Alleys use recycled materials, thereby reducing landfill waste and the consumption of natural resources.

- Energy Conservation and Glare Reduction- Energy efficient, dark sky compliant light fixtures used in the Green Alley pilots are specially designed to direct light downward, focusing light where it is needed, keeping the night sky dark, and reducing glare. These fixtures use a white light source instead of the yellow light produced by the existing fixtures. The selection of a white light allows for better color and light perception while using less energy. These environmental goals were incorporated into five prototype designs that were piloted in the fall of 2006.



Permeable pavement profile



Permeable block profile

Chicago has received multiple awards for the *Green Alley Handbook* including:

2007 - Honor Award from the American Society of Landscape Architects
2007 - Honor Award from the Illinois Chapter of the American Society of Landscape Architects
2007 - Gold Award from the Illinois Chapter of the American Planning Association

Project benefits

Water quality
Runoff reduction
Groundwater recharge
Stormwater peak rate reduction
Community aesthetics
Air quality improvements
Energy efficiency

Contact information

Janet Attarian
Jattarian@cityofchicago.org
David Leopold
dleopold@knightea.com
Chicago Department of Transportation | Knight E/A

Project challenges

Additional street sweeping for maintenance is not difficult/expensive, but requires more maintenance than traditional alley designs.

Maintenance

Semi-annual catch basin cleaning and street sweeping

Bioretention or Bioswale: Local Road

4

54th Court, Merrillville, IN

(Above) Before reconstruction and (right) after reconstruction of the island on 54th Court.

Project sponsor
Town of Merrillville, Indiana

Project designer
Merrillville Stormwater Utility and Robinson Engineering

Project contractor
Olthoff

Total project cost
$63,000

Key design features
- Design Event: 0.5-inch of runoff
- Drainage Area: < 1 acre
- Runoff Reduction: approximately 29,000 cubic feet
- Soil Modifications: with 50% sand, 25% topsoil, and 25% compost

The Town of Merrillville, Indiana designed a bioretention rain garden in a city-owned island located on 54th Court. The rain garden uses several species of native plants with amended soil to maximize infiltration and evapotranspiration. Additionally, the rain garden is surrounded by a buffer of low-mow fescue. The technique will serve as a demonstration project for future use in other residential areas. Funding was provided by the Town of Merrillville and the Indiana Department of Natural Resources Lake Michigan Coastal Program. Partnerships included the Lake County Soil & Water Conservation District; Merrillville Public Works Department; and local schools, businesses, and residents.

Project benefits
Water quality
Stormwater runoff reduction
Community aesthetics

Project challenges
High material costs

Contact information
Matt Lake
Executive Director,
Merrillville Stormwater Utility
mlake@merrillville.in.gov

5 Permeable Pavement: Alley Under Local Jurisdiction

Buhr Park Alley, Ann Arbor, MI

Buhr Park alley is the City of Ann Arbor's first permeable concrete project. The 800-foot, unnamed alley runs between two rows of residences between Wells Street and Scott Court, parallel to Martin Place and Lincoln Avenue. Crews replaced the gravel and crumbling concrete surface in the alley with permeable concrete that transmits stormwater to an underground 18-inch thick stone reservoir for storage and infiltration. Funding has been provided by the Michigan Department of Environmental Quality State Revolving Fund program. The Washtenaw County Water Resources Commissioner's Office was also a project partner.

Completed permeable concrete alley.

Project sponsor
City of Ann Arbor

Project designer
City of Ann Arbor

Project contractor
Audia Concrete Construction, Inc.

Design cost
$34,000

Construction costs
$155,000

Maintenance costs
$5,000

Key design features
- Design Event: 10-year; 24-hour (3.7 inches)
- Drainage Area: 1 – 5 acres
- Runoff Reduction: 3,100 cubic feet

Project benefits
Water quality
Runoff reduction
Stormwater peak rate reduction
Groundwater recharge

Project challenges
Limited work space

Maintenance
Semi-annual pavement sweeping

Lessons learned
Test pour of the concrete mix was conducted to verify permeability prior to final placement of pavement.

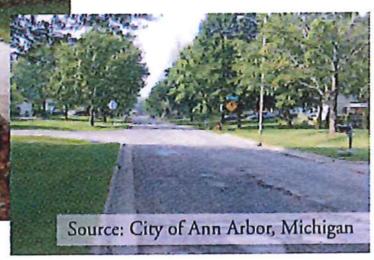
Contact information
Harry Sheehan
Washtenaw County Water Resources Commissioner's Office
sheehanh@ewashtenaw.org

Permeable Pavement: Local Road

6 Easy Street, Ann Arbor, MI

Easy Street, a residential street in Ann Arbor, Michigan, was reconstructed with approximately three feet of porous pavers along the edge of the pavement and additional bioswales to further manage stormwater runoff from the roadway surfaces. Easy Street is located in southeast Ann Arbor and drains to Malletts Creek that ultimately leads to the Huron River. The residents initiated an effort to collaborate on the redesign of Easy Street to achieve multiple outcomes, including stormwater management, traffic calming, pedestrian access, and community aesthetics.

(Left) Easy Street after and (below) before construction.



Project sponsor
City of Ann Arbor

Project designer
Pollack Design Associates, Conservation Design Forum, Cardno JFNew and Stantec

Project contractor
Audia Concrete Construction, Inc.

Total cost
$1,280,000

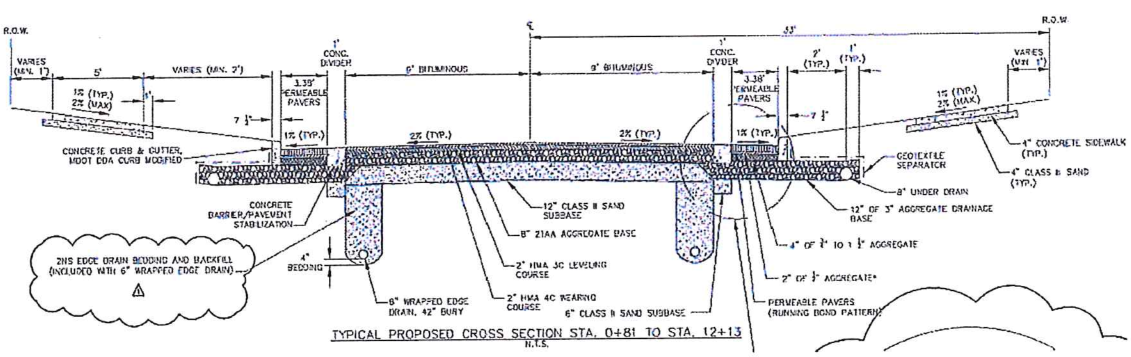
Key design features
- Drainage area: 12 acres
- 60% peak flow and 80% runoff volume reduction for 2-year; 24-hour rain event. GI features designed to fit into space available.

Project benefits
Water quality • Runoff reduction • Community aesthetics • Traffic calming Pedestrian safety • The pavers and swales have virtually eliminated flooding along Easy Street for approximately 95 percent of the annual rain events.

Project challenges
Difficulties calibrating existing conditions model because the flow monitors were not accurately recording the actual volumes of runoff.

Contact information
Harry Sheehan
Washtenaw County Water Resources Commissioner's Office
sheehanh@ewashtenaw.org

Lessons Learned
For roadway retrofits, visually inspect how the stormwater system functions during actual rain events prior to design stages.



Native Plant Grow Zone: County/State Road

7

Ecorse Road and Morton Taylor Road, Wayne County, MI

Ecorse Road and Morton Taylor Road projects within Wayne County, Michigan both have consisted of establishing native plant grow zones within the road rights-of-way to reduce long-term maintenance and runoff volume in addition to improving water quality. This is an expansion of their multi-year grow zone initiative to convert turf to native plant grow zones in strategic locations across the entire county. As an identified implementation activity in the Rouge River Watershed Management Plan, Wayne County has constructed over 47 acres of grow zones that have demonstrated water quality and wildlife habitat improvements in the Rouge River and its tributaries. Funding was provided by the Environmental Protection Agency Great Lakes Restoration Initiative through the Southeast Michigan Council of Governments (SEMCOG).

Native plant grow zones.

Source: Wayne County, Michigan

Project sponsor
Wayne County

Project designer
Environmental Consulting & Technology, Inc.

Project contractor
Erie Construction LLC

Design cost
$35,000

Construction costs
$81,000

Key design features
- Design Event: 2-year; 24-hour event
- Drainage Area: 19 acres
- Runoff Reduction: 38,000 cubic feet
- Annual Pollutant Loading Reduction: 4,400 lbs total suspended solids; 6 lbs total phosphorus; 20 lbs total nitrogen

Project benefits
Water quality
Runoff reduction

Project challenges
High material costs
High construction costs

Maintenance
Basic mowing will be conducted annually rather than more frequently through the growing season.

Contact information
Razik Alsaigh
Wayne County
ralsaigh@co.wayne.mi.us

Bioretention/Bioswale: Local and County Roads

8

Grayling Stormwater Project, Grayling, MI

Project sponsor
City of Grayling
Huron Pines

Total cost
$1.2 million

Key design features
- Design Event: 0.5-inch runoff
- Drainage Area: < 1 acre per rain garden

The Grayling Stormwater Project is an example of a hybrid project that combines green infrastructure with end-of-pipe treatment. This project demonstrates that a small community is capable of making the fundamental shift in management towards green infrastructure and providing leadership for other communities to make similar changes. The City of Grayling embarked on a residential rain garden project beginning in 2002 to manage runoff from local roads.

The project, completed with leadership from Huron Pines and partnerships with Crawford County, Michigan Department of Transportation, and area residents, installed 86 rain gardens through the city along with installation of an "end-of-the-pipe" detention basin and underground Vortechnic units. Several of the smaller rain gardens or those that accommodate higher runoff volumes include underdrains. The rain gardens were planted with native plants and, to promote community involvement, Huron Pines organized an Adopt-A-Rain Garden program. All major outfalls of stormwater from the City of Grayling to the Au Sable River are now treated by one or more of these measures. The project included a maintenance program with incentives for landowners who water and weed their rain gardens.

Source: Huron Pines

Typical Grayling rain garden.

Lessons Learned

The adopt-a-rain-garden program made a huge difference in the success of the projects. The initial rain gardens were planted with seed and a few shrubs, but those planted with larger plant stock had higher success in getting the gardens established.

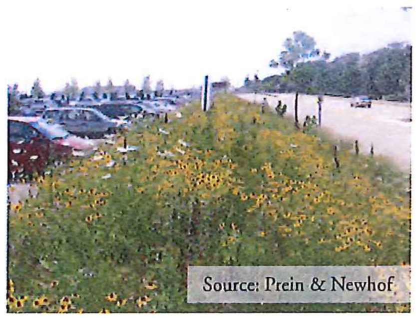
Contact information
Jennifer Muladore
(989) 344-0753 ext. 30
Jennifer@huronpines.org

Bioretention/Permeable Pavement: Local Road

9

Lake Street, Whitehall, MI

Lake Street in Whitehall, Michigan included reconstruction of approximately 2,800 lineal feet of roadway surface while incorporating various green infrastructure techniques to manage stormwater runoff from the roadway and adjacent areas. Green infrastructure techniques include bioswales, bioretention, and pervious pavement. Additional stormwater management techniques include discharge into detention areas and wetland treatment areas prior to entering White Lake, a significant tributary to Lake Michigan. Funding was provided by the EPA Great Lakes Restoration Initiative. Additional partners included the Muskegon Conservation District, the Tannery Bay Developer, and Alcoa-Howmet.



Lake Street after construction.

Project sponsor
City of Whitehall

Project designer
Prein & Newhof

Project contractor
Thompson Brothers

Design cost
$25,000

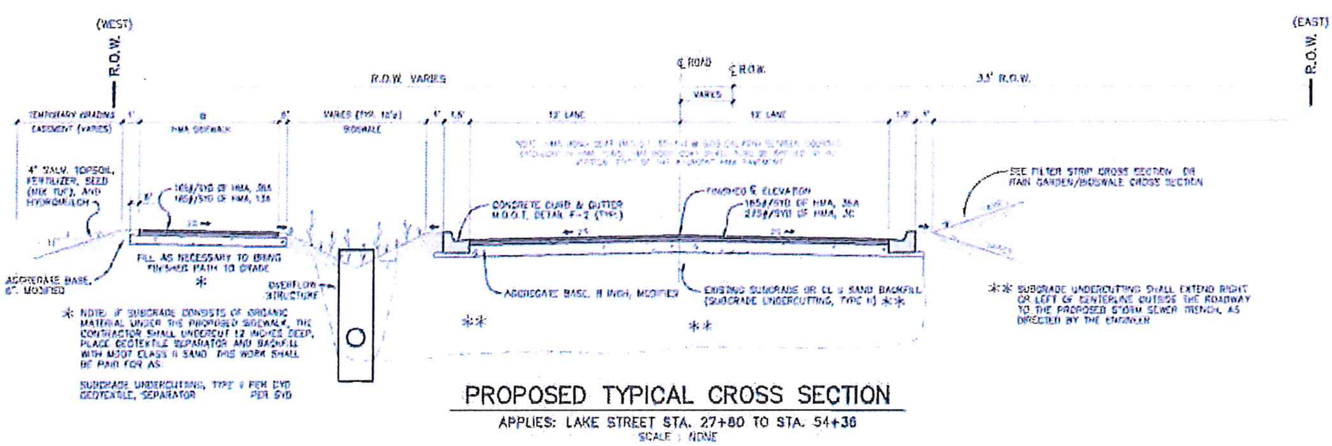
Construction costs
$350,000

Key design features
- Design Event: 10-year rain event
- Drainage Area: 1-5 acres

Project benefits
Water quality
Runoff reduction
Groundwater recharge
Community aesthetics

Project challenges
High material costs

Contact information
Jason M. Washler
P.E. Prein & Newhof
jwashler@preinnewhof.com



Bioretention or Bioswale: Local Road

10

Luna Pier Boulevard, City of Luna Pier, Monroe County, MI

Project sponsor
City of Luna Pier

Project designer
Poggemeyer Design Group, Inc.
Nowak and Fraus Engineers

Key design features
- Design Event: 2-year; 24-hour event
- Drainage Area: 1-acre
- Runoff Reduction: 1,400 cubic feet
- Annual Pollutant Loading Reduction: 200 lbs total suspended solids; 1 lb total phosphorus; 2 lbs total nitrogen

(Above) Luna Pier Boulevard bioretention.
(Right) Tree planter box.

The Luna Pier Boulevard green streets retrofit included techniques such as bioretention, a tree planter box, and porous paver blocks. The road retrofit was part of a larger project that included improvements to the pier and beach area. Luna Pier Boulevard is a major thoroughfare exit from Interstate-75 that ends at Lake Erie. The reconstruction was a component of the community's long-term vision of being a "welcome center" for Monroe County and the State of Michigan. The City of Luna Pier is the southernmost Michigan tourism community located in the vicinity of the International Wildlife Refuge that includes 48 miles of shoreline. It is home to the only public beach in the urban area of Monroe County. Luna Pier was awarded a $490,000 grant from the Michigan Natural Resources Trust Fund for the pier and beach improvements. The green infrastructure techniques were funded through a $100,000 EPA Great Lakes Restoration Initiative grant with SEMCOG. Monroe County was also a partner in the green streets project.

Project benefits
Water quality
Runoff reduction
Community aesthetics

Project challenges
High material costs
High maintenance

Contact information
Randy Mielnek, AICP
mielnikR@poggemeyer.com

Native Plant Grow Zone: County Road

11

Metropolitan Parkway, Macomb County, MI

Median along Metropolitan Parkway designated as a grow zone.

Macomb County Department of Roads implemented a native plant grow zone within the median along Metropolitan Parkway. The stormwater runoff from this parkway is directly tributary to Lake St. Clair and is the primary transportation corridor leading to Lake St. Clair Metropark. This project links to other Great Lakes Restoration Initiative Projects, including the wetland restoration at Lake St. Clair Metropark as well as the parking lot renovation at the park that incorporates Low Impact Development. The St. Clair River, Lake St. Clair, and the Detroit River connect Lake Huron and Lake Erie. Macomb County developed a Blue Economy Strategic Plan focusing on the ecotourism benefits provided by Lake St. Clair. A healthy Lake St. Clair ecosystem is critical to the success of this effort. Funding was provided by the EPA Great Lakes Restoration Initiative through the Southeast Michigan Council of Governments (SEMCOG). Additional supporting partners included Oakland County and Huron-Clinton Metroparks.

Project sponsor
Macomb County

Project designer
Macomb County Department of Roads

Project contractor
Natural Community Services
Michigan Wildflower Farms

Design cost
$6,000

Construction costs
$56,000

Key design features
- Design Event: 2-year; 24-hour event
- Drainage Area: 5 acres
- Runoff Reduction: 8,000 cubic feet

Project benefits
Water quality
Runoff reduction

Project challenges
Design timing
Site preparation

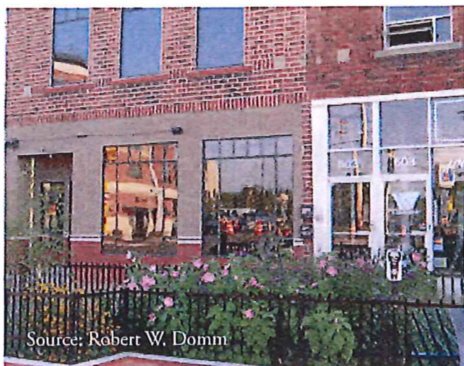
Maintenance
Basic mowing will be conducted annually rather than more frequently through the growing season.

Contact information
John Crumm
Macomb County Department of Roads
JCrumm@RCMCWeb.org

Bioretention or Bioswale: Local Road

12 Michigan Avenue, Lansing, MI

The Michigan Avenue Streetscape Bioretention Facilities project consists of landscape planters and sidewalk paving improvements including new concrete sidewalks and accenting clay pavers, ornamental fences, rain garden plants, and site furnishings. In addition, a series of bioretention facilities were designed as part of a Michigan Avenue corridor enhancement project. Bioretention was developed in conjunction with the city's controlled sewer overflow work as a means to control, clean, and dispense stormwater in an urban environment. The rain garden is designed to remove sediment, nutrients, heavy metals, and other pollutants, as well as reduce water temperature, promote infiltration, evaporation, and transpiration of the stormwater runoff, thereby reducing the overall impact to the Grand River.



(Above) Michigan Avenue bioretention and (right) curbcut to bioretention.

Project sponsor
City of Lansing

Project designer
Tetra Tech, C2AE, Wildtype Design, Native Plants & Seed, Ltd.

Project contractor
Aggregate Industries/Eastlund Concrete, Inc.

Construction costs
$2,993,000 total costs

$1,000,000 green infrastructure costs

Key design features
- Ultra-urban application
- Extends over 4 city blocks
- 30 planter box bioretention gardens
- Designed for approximately 1-inch of runoff
- 4.1 acre tributary area
- Adaptable design to meet community needs

Project benefits
Water quality • Runoff reduction • Community aesthetics • Traffic calming
Pedestrian safety • Community education through interpretive signage

Project challenges
High material costs (decorative fence, retaining wall & metal plates were significant cost increase) • High maintenance needs due to litter

Contact information
Dan Christian, PE

Dan.Christian@tetratech.com

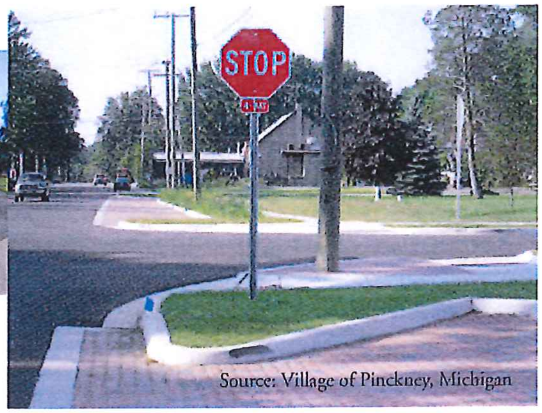
Post-construction monitoring
75% average annual runoff volume reduction • 55% to 85% reduction of peak flow rates

Lessons learned
In this urban setting, litter comes from wind-blown trash, washes down the gutter pan, and is thrown directly into the rain gardens. It consists of cigarette butts, cups, fast food wrappers, pet waste, bottles, etc. While the bioretention areas keep the litter out of the river, a high level of regular maintenance is necessary to keep the rain gardens visually appealing. Design alternatives could include trash basket collection systems along with sediment traps. Additional maintenance would be required to empty the trash collection basket, however the trash would be concentrated to key locations. Maintenance challenges with litter of this type and quantity are common with bioretention systems in ultra-urban settings.

Bioretention/Permeable Pavement: Local Road

13 Mill Street, Village of Pinckney, MI

Mill Street was reconstructed as a two-lane roadway with on-street parking and a variety of green infrastructure techniques. Green street elements include porous pavement, bioretention systems, perforated storm sewer, infiltration trenches, and native plantings. Funding was provided through the Michigan State Revolving Fund (SRF) and the American Recovery and Reinvestment Act (ARRA).



(Above) Before reconstruction and (right) after reconstruction.

Source: Village of Pinckney, Michigan

Project sponsor
Village of Pinckney

Project designer
OHM Advisors

Project contractor
TCI of Michigan, Inc.

Design cost
$100,000

Construction costs
$900,000

Key design features
- Design Event: 0.5 inches of runoff
- Drainage Area: 6 acres
- Runoff Reduction: 5,000 cubic feet

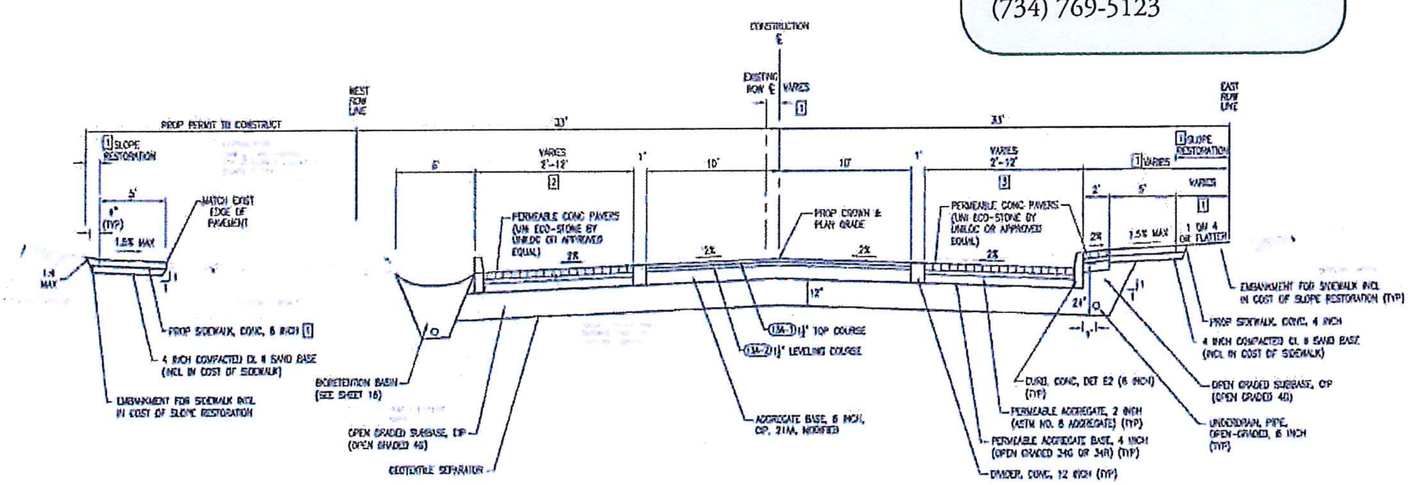
Project benefits
Water quality
Runoff reduction
Public education (interpretive signage)

Project challenges
High material costs

Contact information

Ron Cavallaro, PE
OHM Advisors
Ronald.Cavallaro@ohm-advisors.com

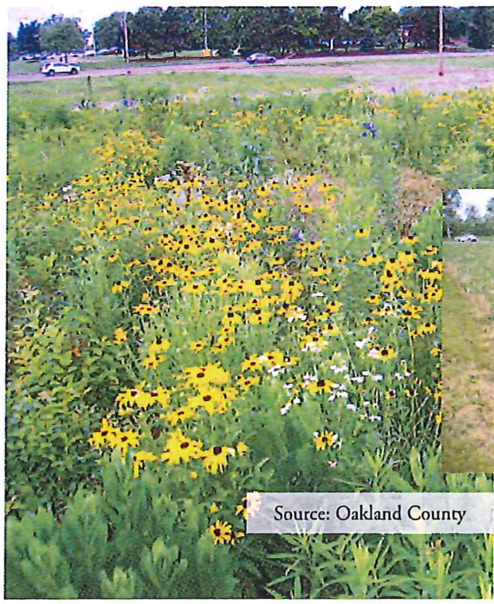
Rebecca Foster
HRWC
(734) 769-5123



14 Native Plant Grow Zone: County/State Road

Oakland County Sustainable Green Streets Campus, Oakland County, MI

The Oakland County Campus project constructed approximately 16 acres of native plant grow zones within the open space areas that receive a majority of the county campus and adjacent roadway runoff. Located within Pontiac, Michigan, stormwater runoff from two roadways, County Center Drive under Oakland County jurisdiction and Telegraph Road, under the Michigan Department of Transportation jurisdiction is managed through these green infrastructure techniques. Runoff from the county campus discharges into the Mainland Drain a tributary to the Clinton River upstream from Lake St. Clair, part of the Great Lakes system.



Oakland County Campus grow zone (above) before and (left) after.

Project sponsor
Oakland County

Project designer
Oakland County Planning & Economic Development Services

Project contractor
Oakland County Facilities Management

Design cost
$26,000

Construction costs
$178,000

Key design features
- Design Event: 2-year; 24-hour
- Drainage Area: 141 acres
- Runoff Reduction: 75,000 CF
- Annual Pollutant Loading Reduction: 27,000 lbs total suspended solids; 44 lbs total phosphorus; 290 lbs total nitrogen

Project benefits
Water quality • Runoff reduction • Stormwater peak rate reduction
Community aesthetics • Public education

Project challenges
High material costs • Availability of native plant materials
Upredictable weather

Maintenance
- First year - Mow and maintain grow zones at 6" - 12"
- Second year and beyond - Early spring mowing and/or prescribed burning, remove previous year's dead plant material
- Ongoing - Monitor all areas, manually weed, and selectively pull problematic plants as needed

Contact information

Jim Keglovitz
LEED Green Associate, Senior Planner, Oakland County
keglovitzj@oakgov.com

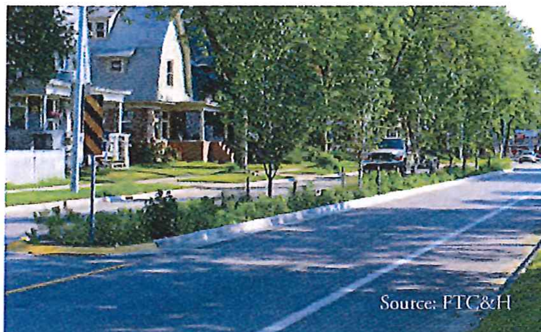
Phil Goulding
Grounds Division Chief
gouldingp@oakgov.com

Bioretention or Bioswale: Local Road

15

Plainfield Avenue, Grand Rapids, MI

Plainfield Avenue, an arterial roadway in Grand Rapids, was resurfaced and the design was upgraded to include enhanced stormwater management within seven linear bioretention islands in the center of the road. The islands reduce roadway stormwater runoff from the first flush event that would otherwise drain directly into the Grand River. This project is an example of how public agencies and the private sector can effectively work together to accomplish green initiatives. Federal, local, and private funds were utilized to finance street improvements that included innovative stormwater management techniques. Larger rain events bypass the island and enter the existing storm sewer system. Funding was provided through the Michigan Department of Transportation (MDOT) Enhancement Grant, the Creston Neighborhood Association, and the Creston Business Association. Other partners included Fishbeck, Thompson, Carr & Huber, Inc. and the West Michigan Environmental Action Council. Multiple outcomes were achieved including stormwater runoff reduction, increased pedestrian safety, traffic calming, and community aesthetics. A YouTube video was created to showcase this project.



(Above) Plainfield Island with traffic lane and bike lane. (Right) Stormwater structure within island.

Project sponsor
City of Grand Rapids

Project designer
Fishbeck, Thompson, Carr & Huber, Inc. and the City of Grand Rapids

Project contractor
Dykema Excavators

Design cost
$23,000

Construction costs
$241,000

Maintenance costs
Initial $30,000 endowment (at 5% return) created by Creston Business Association provides $1,500/year for maintenance

Key design features
- Design Event: 0.5 inch of runoff
- Drainage Area < 1 acre
- Runoff Reduction 420,000 cubic feet annually
- Pollutant Load Reduction: 60% sediment reduction and 65% phosphorus reduction

Design and construction unique specifications

Existing cross slopes of the road were maintained for this mill and pave project. Stormwater enters the the island area under closed conduit conditions. Deep reinforced curbheads are provided to resist snowplow damage and movement.

Project benefits

Water quality • Runoff reduction • Community aesthetics • Traffic calming
Pedestrian safety • Reduced atmospheric CO_2

Project challenges

Selection of best management practices and materials to withstand harsh urban environment • Filling in funding gaps on short timeline • Funding outside of city funds through the local community • Balancing the level of service of the roadway with the desire for greenspace and parking

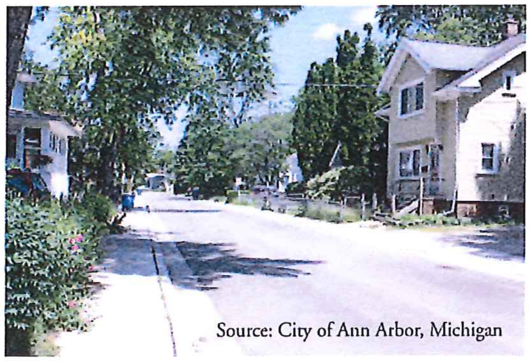
Contact information

Breese Stam, PE
City of Grand Rapids
bstam@grcity.us

Permeable Pavement: Local Road

16 Sylvan Avenue, Ann Arbor, MI

The Sylvan Avenue project utilized permeable pavement technology to manage stormwater runoff. The permeable pavement allows rainwater to pass through the pavement and into the ground, where it is filtered, cleaned, and temporarily stored until it can be absorbed or gradually enter the storm sewer system. The project used permeable asphalt as the road surface material, and was one of the first projects in southeastern Michigan to use this particular technology on a public street. The project makes use of an underdrain system to collect water below the street that is not absorbed into the ground. Swirl concentrators provide pretreatment to stormwater entering the storm sewer from the gutter. A curb drain system was incorporated to provide homeowners a place to connect sump pump discharges rather than discharging to the ground surface. Funding was provided by the Michigan Department of Environmental Quality State Revolving Fund; Washtenaw County was an additional partner in the project.


Source: City of Ann Arbor, Michigan

Sylvan Avenue after paving.

Project sponsor
City of Ann Arbor

Project designer
Fishbeck, Thompson, Carr & Huber, Inc.

Project contractor
ABC Paving

Design cost
$70,000

Construction costs
$495,000

Key design features
- Design Event: Storage for 100-year
- Drainage Area: < 1-acre

Project benefits
Water quality • Runoff reduction • Stormwater peak rate reduction

Project challenges
High material costs • Limited accessibility • High maintenance
Low water quality benefits

Maintenance
Semi-annual pavement sweeping

Lessons learned
Communicate maintenance requirements during design phase

Contact information
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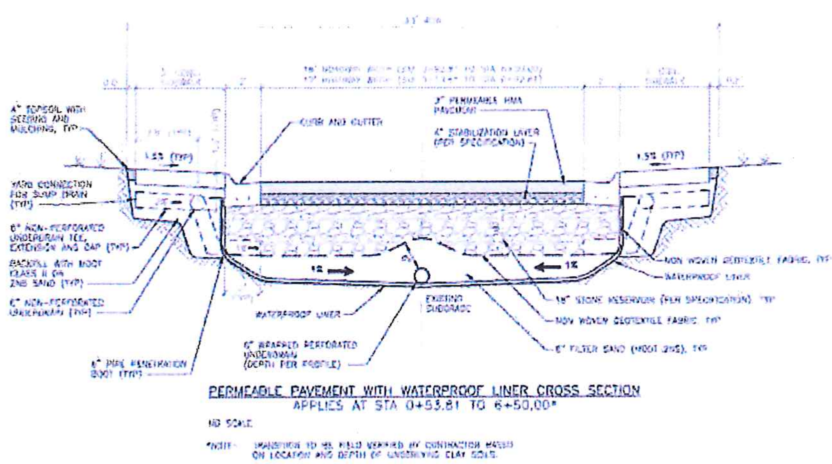


Bioretention or Bioswale: Local Road

17 Washington Square, Lansing, MI

Washington Square Streetscape includes a two-way local road with parking and bioretention systems. This streetscape project converted a former concrete pedestrian mall that traversed the entire area between buildings to a two-way local road with additional parking, but which also incorporated bioretention to manage the runoff from the roadway and parking surfaces. Additionally, the project reduced the overall quantity of impervious surfaces. Funding was provided by the Michigan Department of Transportation Enhancement Grant and the City of Lansing.

Re-opened Washington Square.

Project sponsor
City of Lansing

Project designer
DC Engineering, P.C.
& Linsemier and Associates

Project contractor
Abbott Construction Company

Total project cost
$2.8 million

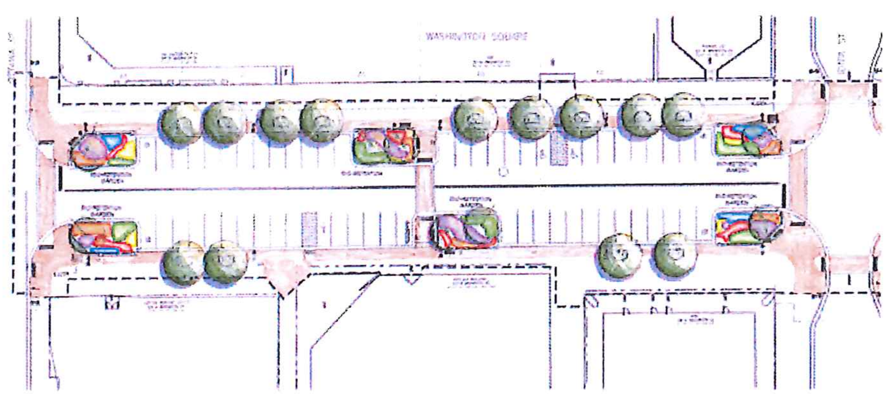
Key design features
- Design Event: 1-inch rain event
- Drainage Area: 2 acres
- Runoff Reduction: 8,300 cubic feet

Design & Construction Unique Specifications
The bioretention systems consisted of three feet of engineered soil mix. The soil mix was comprised of 30% 2NS fin aggregate, 30% topsoil, 30% aged municipal compost, and 10 percent coir fibe. The soil mix was placed and maintained in a non-compacted state. Additionally, triple shredded hardwood mulch was selected to minimize floating.

Contact information
Jane Dykema, PE
jdykema@lansingmi.gov

Project benefits
Water quality
Runoff reduction
Community aesthetics

Project challenges
Utility conflicts and relocation



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Other: Road Diet – Pavement Reduction: Local Road

West Stadium Boulevard Complete Streets Project, Ann Arbor, MI

Project sponsor
City of Ann Arbor

Project designer
Hubbell, Roth & Clark, Inc.
InSite Design Studio, Inc.

Project contractor
Hoffman Bros.

Design cost
$774,000

Construction costs
$3.7 million

Key design features

- Design Event: 10-year; 12-hour storm
- Drainage Area: 175 acres
- Annual Pollutant Loading Reduction: 2,100 lb/year of Total Suspended solids

The City of Ann Arbor West Stadium Boulevard Complete Streets Project won the American Public Works Association/ Michigan 2010 Project of the Year Award in the Transportation $5-10 Million Category. At an average daily two-way traffic volume of over 15,000 per day, West Stadium Boulevard was one of most heavily traveled corridors in the city. Design included a lane reduction from four lanes to three lanes of approximately one mile as well as water-main replacement, an in-line detention and stormwater treatment system, nearly 80 decorative LED streetlights, and bicycle lanes for nonmotorized travel in both directions. The project was partially funded through the Michigan Department of Environmental Quality State Revolving Fund Loan for its Best Management Practices linked to the local watershed management plan. Funding was also provided through American Recovery and Reinvestment Act (ARRA). Partnerships included the Washtenaw County Water Resources Commissioner's Office, Michigan Department of Transportation, Ann Arbor Transit Authority, McKenna Associates Insite Design Studio, Inc., and Huron River Watershed Council. In addition to the lane reduction, over 140 trees were planted to promote stormwater infiltration in structural free-draining soil with underdrains.

West Stadium Boulevard (top) before and after construction.

Project benefits
Water quality

Project challenges
High material costs

Contact information
Laura Gruzwalski
lgruzwalski@hrc-engr.com

Permeable Pavement: Local Road

19 Willard Street, Ann Arbor, MI

Willard Street during final paving.

Willard Street in Ann Arbor, Michigan was reconstructed between East University and South Forest using permeable asphalt technology. The permeable pavement allows rainwater to pass through the pavement and infiltrate back into the ground, creating a more environmentally friendly roadway. The construction included the complete removal of the existing pavement, removal and replacement of subgrade soil below the existing pavement, and replacement of all the curb and gutter, sidewalks, and curb ramps. Funding was provided through the Michigan Department of Environmental Quality State Revolving Fund program; the Washtenaw County Water Resources Commissioner's Office was a project partner.

Project sponsor
City of Ann Arbor

Project designer
City of Ann Arbor

Project contractor
E.T. MacKenzie

Design cost
$49,000

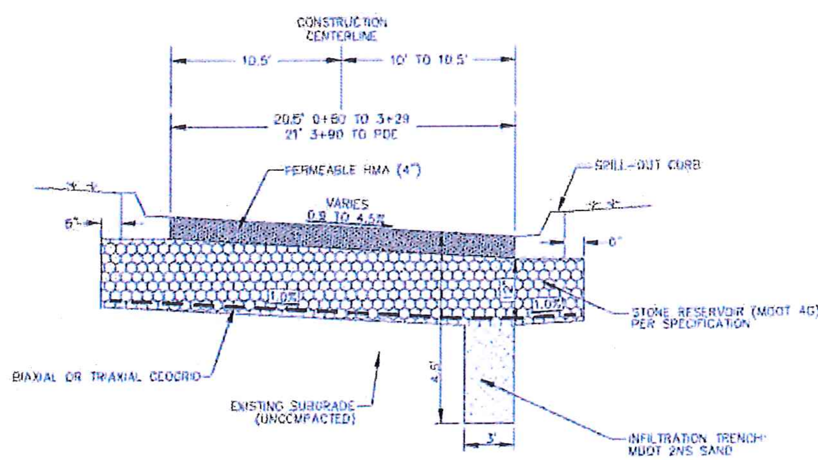
Construction costs
$243,000

Key design features
- Design Event: 10 year; 24-hour
- Drainage Area: 1-5 acres
- Runoff Reduction: 670 cubic feet

Contact information
Nick Hutchinson, PE
NHutchinson@a2gov.org

Project benefits
Water quality
Runoff reduction
Stormwater peak rate reduction
Groundwater recharge

Maintenance
Semi-annual pavement sweeping



PERMEABLE ASPHALT TYPICAL CROSS-SECTION
0+80 TO POE
(NTS)

20 Bioretention or Bioswale: Local Road

Maywood Avenue, Toledo, OH

Maywood Avenue includes a series of bioswales to reduce stormwater runoff into the city's collection system and work towards both frequency and volume reduction of combined sewer overflows. An aggregate reservoir was placed under the sidewalks to maximize the temporary stormwater storage volume and surface area for infiltration. The bioswale was planted with buffalo grass and street trees. In locations where residents agreed to maintenance responsibilities, additional native vegetation plantings were provided.

(Above) Maywood Avenue after construction and (right) Maywood Avenue before construction.

Project sponsor
City of Toledo

Project designer
Tetra Tech, American Rivers, Biohabitats, Northwest Consultants

Project contractor
Crestline Paving & Excavating, Co.

Design cost
$48,000

Construction costs
$622,000 total costs

$278,000 green infrastructure costs

Key design features
- Design objective to maximize storage volume
- Achieved stored volume is 0.5-inch over the watershed
- Drainage Area: > 8 acres
- Valve installed on underdrain

Project benefits
Water quality
Runoff reduction
Peak rate reduction
Reduced street flooding and basement backups
Low maintenance with turf grass and street trees

Post Construction Monitoring
64% average annual runoff volume reduction
60% to 70% reduction of peak flow rates

Lessons Learned
The turf design has worked very well and has demonstrated that high levels of runoff reduction can be accomplished without the use of native plants. Some residents chose native plants as an option offered by the designer and agreed to maintain them while others chose the simpler turf design.

Contact information
Dan Christian, PE
Dan.Christian@tetratech.com

Permeable Pavement/Bioswale: Local Roads

21 CSO 60 Green Street Pilot, Buffalo, NY

In lieu of a planned sewer separation, three green street technologies were implemented as pilot projects on five streets within Buffalo's CSO 60 basin in 2012. Two residential streets received rain gardens, two residential streets received pervious asphalt, and one commercial street received stormwater planters. Funding was provided through the Buffalo Sewer Authority's Long Term Control Plan implementation effort as well as the New York State Environmental Facilities Program Green Infrastructure Grant Program. Partners included the Buffalo Sewer Authority, City of Buffalo Department of Public Works, Elmwood Village Association, Buffalo Niagara Riverkeeper, and local block groups.

New rain garden along one of the residential streets.

Project sponsor
Buffalo Sewer Authority

Project designer
URS

Project contractor
Mark Cerrone, Inc.

Design cost
$999,750

Key design features
- Design Event: 0.9" runoff as per the NYS Stormwater Design Manual
- Drainage Area: 8.3 acres
- Runoff Reduction: 13,600 cubic feet

Project benefits
Water quality
Runoff reduction
Groundwater recharge
Stormwater peak rate reduction
Community aesthetics

Project challenges
High material costs
High maintenance
Codes/ordinances
Lack of public support
Lack of regulatory support

Maintenance
Contractor maintains for 2 years
Sewer Authority inspections/maintenance semiannually
Semi-annual street sweeping

Contact information
David Comerford
dcomerford@sa.ci.buffalo.ny.us

Permeable Pavement: Local Road

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North James Street, Rome, NY

(Below) Before and (left) after streetscape improvements.

The City of Rome, New York utilized Community Development Block Grant (CDBG) funding to support streetscape improvements on North James Street in the streetscape target area and on East Dominick Street at the Mill Street intersection. Improvements included the use of Flexi®-Pave materials facilitating infiltration of stormwater runoff from the sidewalk area between the buildings and roadway. Additionally, Flexi®-Pave was also used as a technique to allow infiltration of rooftop runoff and reduce the quantity of that rooftop drainage from entering the sewer system.

Project sponsor
City of Rome

Project designer
City of Rome Engineering Department

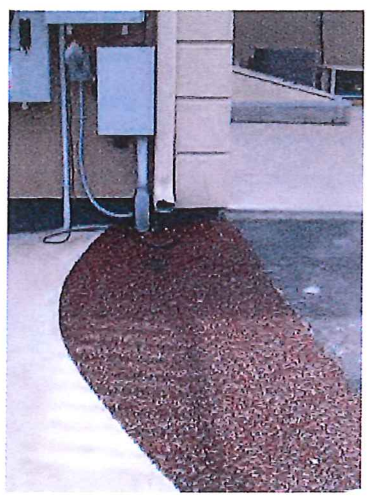
Project contractor
L.P. Trucking

Total project cost
$357,700 - Funding provided by Housing and Urban Development, Community Development Block Grant

Key design features
- Design Event: 1-inch of runoff
- Drainage Area: < 1 acre
- Soil Modifications with Crushed Stone Base at 95% compaction per AASHTO T-180

Project benefits
Water quality
Stormwater runoff reduction
Stormwater disconnection
Community aesthetics
Urban heat island effect reduction

Project challenges
High material costs



Contact information
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City of Rome
jguiliano@romecitygov.com

Permeable Pavement: Local Road

23 Sawdey Way, Rochester, NY

(Above) Sawdey Way before construction and (left) after construction.

Sawdey Way in Rochester, New York is a new city street connecting Emerson Street to Locust Street. The project achieves multiple outcomes including stormwater runoff reduction, access for emergency responders, enhanced nonmotorized safety features such as mid-block crossings, and enhanced community aesthetics. The roadway is constructed of porous asphalt with a pervious concrete sidewalk. To reduce the impervious footprint of the project, the roadway is narrower than standard and the sidewalk is located on only one side of Sawdey Way. Additional bioretention rain gardens further manage stormwater runoff and provide community aesthetic benefits. Funding was provided by the City of Rochester with support from the New York State Department of Environmental Conservation grant program.

Project sponsor
City of Rochester

Project designer
Stantec

Project contractor
Villager Construction, Inc.

Design cost
$42,000

Construction costs
$300,000

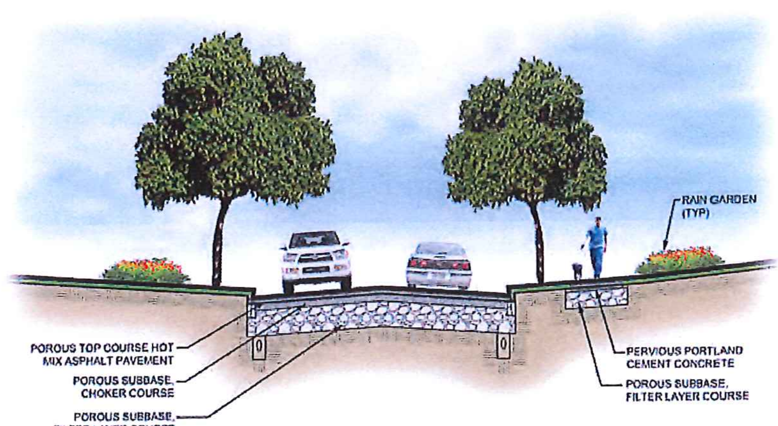
Key design features
- Design Event: 0.5-inch of runoff
- Drainage Area: < 1 acre

Contact information
James R. Hofmann, Jr.
jim.hofmannjr@stantec.com

Project benefits
Water quality
Stormwater peak rate reduction

Project challenges
High material costs

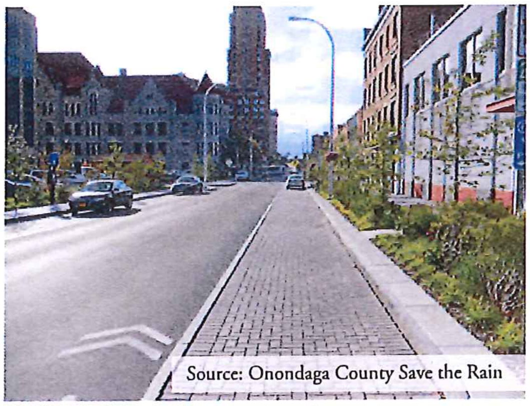
Maintenance
Semi-annual pavement sweeping



SAWDEY WAY IN ROCHESTER, N.Y

24 Bioretention/Permeable Pavement/Tree Trench/Planter Boxes: Local Road

Save the Rain - Water Street Green Gateway, Onondaga County, NY


Source: Onondaga County Save the Rain

E. Water Street after construction

The Water Street Green Gateway is a comprehensive green street application which incorporates several green infrastructure technologies into a complete renovation of the street and sidewalk along the 300 block of E. Water Street in downtown Syracuse. This is a signature project within Onondaga County's Save the Rain Program which manages stormwater runoff using green and gray infrastructure to prevent combined sewer overflows. Several green infrastructure elements were installed that will capture stormwater and enhance the urban landscape, including streetscape tree detail with enhanced tree plantings in the right-of-way; installation of porous pavers in parking lanes; installation of infiltration trenches and planters; and landscaping features throughout the footprint of the block. The project was developed in conjunction with the private renovation of 323, 325, and 327 E. Water Street, which was recently designated LEED platinum by the U.S. Green Building Council, in part due to the green infrastructure improvements to the public right-of-way on the 300 block of Water Street. Full project details are available on the Save the Rain Web site.

Partial grant funding was provided by the New York State Department of Environmental Conservation Water Quality Improvement Projects Program (WQIPP).

Project sponsor
Onondaga County, New York

Project designer
CH2M HILL

Project contractor
Davis Wallbridge

Total costs
$986,937

Key design features
- Design Event: 1-inch runoff
- Drainage Area: 53,000 square feet
- Runoff Reduction: 924,000 gallons/year

Project benefits
Water quality
Runoff reduction
Groundwater recharge
Stormwater peak rate reduction
Community aesthetics

Project challenges
Undocumented underground utility vault
Codes/ordinances (mid-street pedestrian crossing)

Maintenance
The porous pavers installed in the on-street parking lanes are vacuumed twice a year with a vacuum truck to prevent sediment accumulation that would reduce permeability. Catch basins and inlets are cleaned at least twice per year. The stormwater planters require basic landscape maintenance including removal of weeds and pruning of trees. For the three years after planting, the trees require watering in absence of rainfall.

Contact information
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Save the Rain Program
Onondaga County Dept. of
Water Environment Protection
MadisonQuinn@ongov.net

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Bioswale: Local Road

South 6th St.: W. Howard Ave. to W. Layton Ave., Milwaukee, WI

Project sponsor
City of Milwaukee

Project designer
City of Milwaukee

Project contractor
C.W. Purpero, Inc.

Construction costs
$430,000

Key design features

- Design Event: 1-year storm event
- Drainage Area: 92,000 square feet

South 6th Street bioswale

In 2011, 19 bioswales were constructed in the terrace areas behind the curbs of South 6th Street to collect roadway stormwater runoff. The 19 bioswales encompass approximately 8,400 square feet. The bioswales were constructed on a portion of South 6th Street known as the Green Corridor where the city, in partnership with private entities, and is implementing various green infrastructure projects. The bioswales were constructed with 12 inches of engineered soil over 12-inches of storage stones, and have a ponding depth of about 12-inches. The engineered soil mix is a combination of 50 percent sand, 25 percent topsoil, and 25 percent compost. Stormwater percolates through the engineered soil. Once the underlying soil matrix is saturated, excess stormwater discharges through the underdrain to a manhole or catch basin into the existing stormwater infrastructure. The funding for the project is from the city's capital budget.

Project benefits

Water quality
Runoff reduction
Stormwater peak rate reduction
Community aesthetics

Contact information

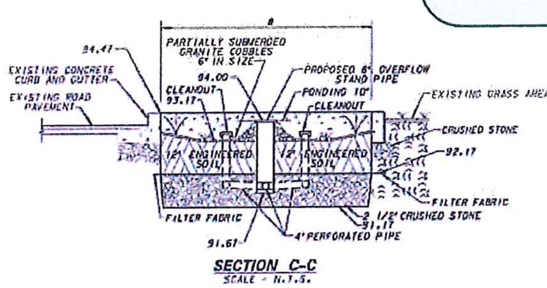
Tim Thur
City of Milwaukee
Timothy.Thur@milwaukee.gov

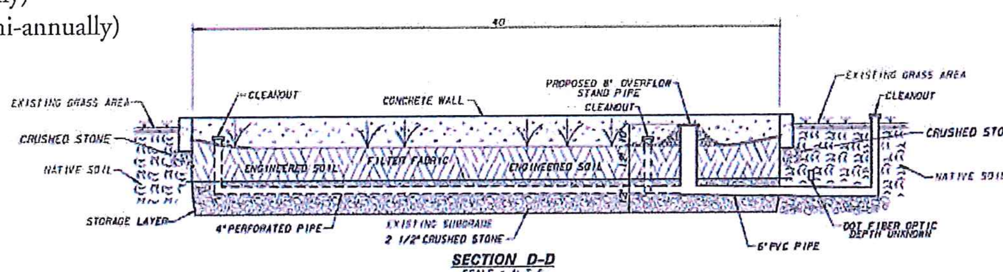
Project challenges

Existing utilities
Limited applicability – finding suitable tributary areas
Maintenance after construction
Low permeability native soils (clay)

Maintenance

Trash cleanout (semi-annually)
Weeding (semi-annually)
Native vegetation (semi-annually)





Bioswale: Local Road

26

West Grange Avenue from South Howell Avenue to I-94, Milwaukee, WI

West Grange Avenue bioswale

In 2012, 13 bioswales were created in the medians to collect roadway stormwater runoff. The contributing area was a mainly residential roadway totaling 93,000 square feet. The 13 bioswales totaled 8,700 square feet in area.

The bioswales were constructed with 12 inches of engineered soil over 18 inches of stones as a storage layer. Stormwater percolates through the engineered soil and as it fills up the storage volume underneath the beds, it rises up and discharges through the underdrain connected to a stormwater structure such as a manhole or a catchbasin. The beds also have a ponding depth of about 12-inches. The engineered soil mix is a combination of 50 percent sand, 25 percent topsoil, and 25 percent compost.

The project was partially funded by an Urban Nonpoint Source and Storm Water Management Program grant from the Wisconsin Department of Natural Resources. The grant was in the amount of $150,000. The funding for the project is from the City capital budget.

Project sponsor

Partner – Wisconsin Department of Natural Resources

Project designer

City of Milwaukee

Project contractor

C.W.Purpero, Inc.

Total costs

$400,000

Key design features

- Design Event: 1-year storm event
- Drainage Area: 93,000 square feet
- Runoff Reduction: peak flow and volume reduction

Project benefits

Water quality
Runoff reduction
Stormwater peak rate reduction
Community aesthetics

Project challenges

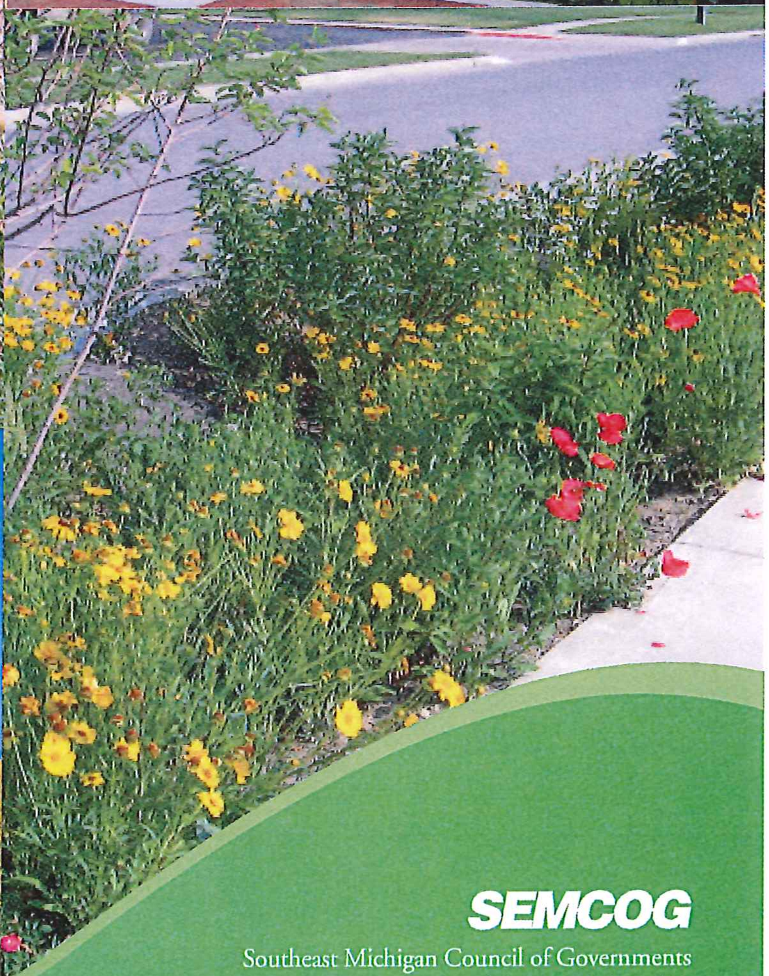
Existing utilities
Limited applicability – finding suitable tributary areas
Maintenance after construction
Low permeability native soils (clay)

Maintenance

Trash cleanout (semi-annually)
Weeding (semi-annually)
Native vegetation maintenance (semi-annually)

Contact information

Tim Thur
City of Milwaukee
Timothy.Thur@milwaukee.gov



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