Landscape Architecture Foundation

Charles City Permeable Streetscape Phase 1

Landscape Peformance Benefits

- Reduced stormwater peak flows by at least 75% for 10-year storm events and 40% for 100-year storm events.
- Reduced the runoff volume by over 60% up to the 10-year 24-hour storm event, and over 30% for the 100-year 24-hour storm event. This eliminated the need to replace downstream storm sewers, thereby reducing infrastructure costs and neighborhood disruption.
- Expected to improve water quality by reducing the need for winter salt application by up to 75% because snowmelt and stormwater can infiltrate. This should also lead to savings in the city's winter operations budget.
- ï»¿Saved $57,000 by preserving 192 street trees instead of removing them and installing new trees.
- ï»¿Secured $731,000 in additional funding to implement this major street reconstruction project -- funding that would not be available for conventional street reconstruction.

Designer
Conservation Design Forum

Land Use
Residential
Retrofit

Project Type
Streetscape
Transportation

Location
Hulin Street and N. Joslin Street
Charles City, Iowa 50616

Size
5 acres (16 blocks of street ROW)

Budget
$3.7 million

Completion Date
2009

Overview

The Charles City, Iowa, Green Street project addressed serious issues with street deterioration and nuisance street and adjacent yard flooding for a 16-block residential area. The project combines durable permeable paving materials with sustainable stormwater Best Management Practices, while maintaining the historical character of the neighborhood. By integrating stormwater management, the City was able to leverage additional funding that would not be available for conventional street reconstruction. Because of the success and the lessons learned in design and maintenance, the project has spurred additional phases in adjacent neighborhoodsand serves as an important blueprint for others considering similar sustainable stormwater systems.

Sustainable Features

- The permeable roadway surface consists of interlocking precast concrete unit pavers on a gravel bed. Water infiltrates between the pavers at a rate of 2 inches per hour, to the gravel storage below.
- A 24-inch deep layer of gravel with 36% porosity provides water storage below the pavement. In the center of the roadway, the gravel deepens to approximately 42 inches with a 6-inch perforated pipe running through it at a depth of 24 inches. Directly beneath the gravel is a layer of geotextile filter fabric, a layer of silty-sand subgrade soil, and then a 36-inch layer of sugar sand subgrade soil. During large storm events, as the water level rises in the gravel storage, it enters the pipe through the perforations and is conveyed to the existing storm sewer system.
- ï»¿Cobble infiltration areas are used at the corners of all intersections. Excess water from the permeable street runs down the gutter and is channeled into the cobble infiltration area through a curb cut. The water infiltrates through the layer of cobble then an 8-inch layer of gravel before entering the gravel storage below the permeable pavement system. The cobble infiltration areas have a design infiltration capacity of 100 inches per hour. If water accumulates in the cobble infiltration areas, it will enter an elevated storm inlet and be conveyed to the existing storm sewer system.ï»¿

- Amended soil infiltration areas were added in the space between the curb and sidewalk along all of the streets to capture and infiltrate runoff from adjacent yards and sidewalks. Lined with turf and sloped to 4 inches below the top of the curb, the infiltration areas detain water and allow it to infiltrate into the amended soil, a mix of topsoil, sand, and compost. The gravel storage below the permeable pavement of the roadway extends beneath the amended soil infiltration areas. Excess water flows over the curb to the gutters, where it is conveyed to the cobble infiltration areas.ï»¿
- Alley trench grates were installed across alley aprons on Spriggs Street and Hulin Street to infiltrate runoff and prevent sediment from backyards and the unpaved alleys from clogging the permeable pavement of the roadway. Water flows from the alley into the metal trench grate, through a 4-inch deep gravel filter layer, and then into the gravel storage layer, which extends from under the street.ï»¿
- The roadway was narrowed from 44 to 31 feet. This design reduced the pavement surface, increased vegetated area, and increased the volume of soil available for trees.

Challenge

Landscape maintenance was a major concern for the design team as the long-term maintenance budget would be limited. Ideally, a wider range of vegetated stormwater management features such as roadside bioretention swales, intersection curb extensions, and rain gardens would be used. However, substantial maintenance would then be needed to weed, supplement plantings, and remove leaves and other debris to prevent clogging. The permeable unit pavers would also require diligent maintenance to remain functional for their design life.

Solution

Rather than typical rain garden plantings of perennial grasses and forbs, amended soil infiltration areas were planted with turf so that they can be mowed by residents, just as they were prior to the street reconstruction. For the intersections, cobblestone infiltration areas were selected instead of rain gardens due to the lower maintenance requirements. A strict maintenance regime was developed to maintain the permeability of the pavement, with guidelines that include no use of sand and minimal use of salt for winter maintenance.

Cost Comparison

- The project uses permeable interlocking concrete unit pavers as a high-performance, cost-effective pavement, which saves approximately $395,000 in construction and permitting costs when compared to cast-in-place porous concrete for the 5,670 linear feet of streets that were replaced.ï»¿
- By preserving 192 of the existing street trees, the City saved $57,000 over the cost of removing them and installing new trees.ï»¿

Lessons Learned

- The cobble infiltration areas used in this first phase collected debris, which reduced the effectiveness of the system. Because they were deemed to require too much maintenance, these infiltration areas were discontinued in the second phase and an alternative system was utilizedï»¿ with curb intakes at the back of the curb. Instead of having a direct connection between the storm sewer system and the intake, storm water runoff enters the intake structure and is directed into the rock sub base where it infiltrates into the soil. During large rain events when runoff exceeds the infiltration rate, there is an overflow connection to the storm sewer system. Weep holes in the bottom of each intake structure allow water to empty out of the structure and into the soil to eliminate standing water at the bottom of the intake.

Project Team

Landscape Architect/Civil Engineer: Conservation Design Forum
Installation Contractor: Wick's Construction

Role of the Landscape Architect

The landscape architect/civil engineer worked with Charles City to develop a comprehensive plan that addressed the crumbling streets and flooding problems. They prepared models and evaluated the exisiting and proposed roadway designs to determine the expected performance of the permeable streetscape. ï»¿

Case Study Brief Prepared By:
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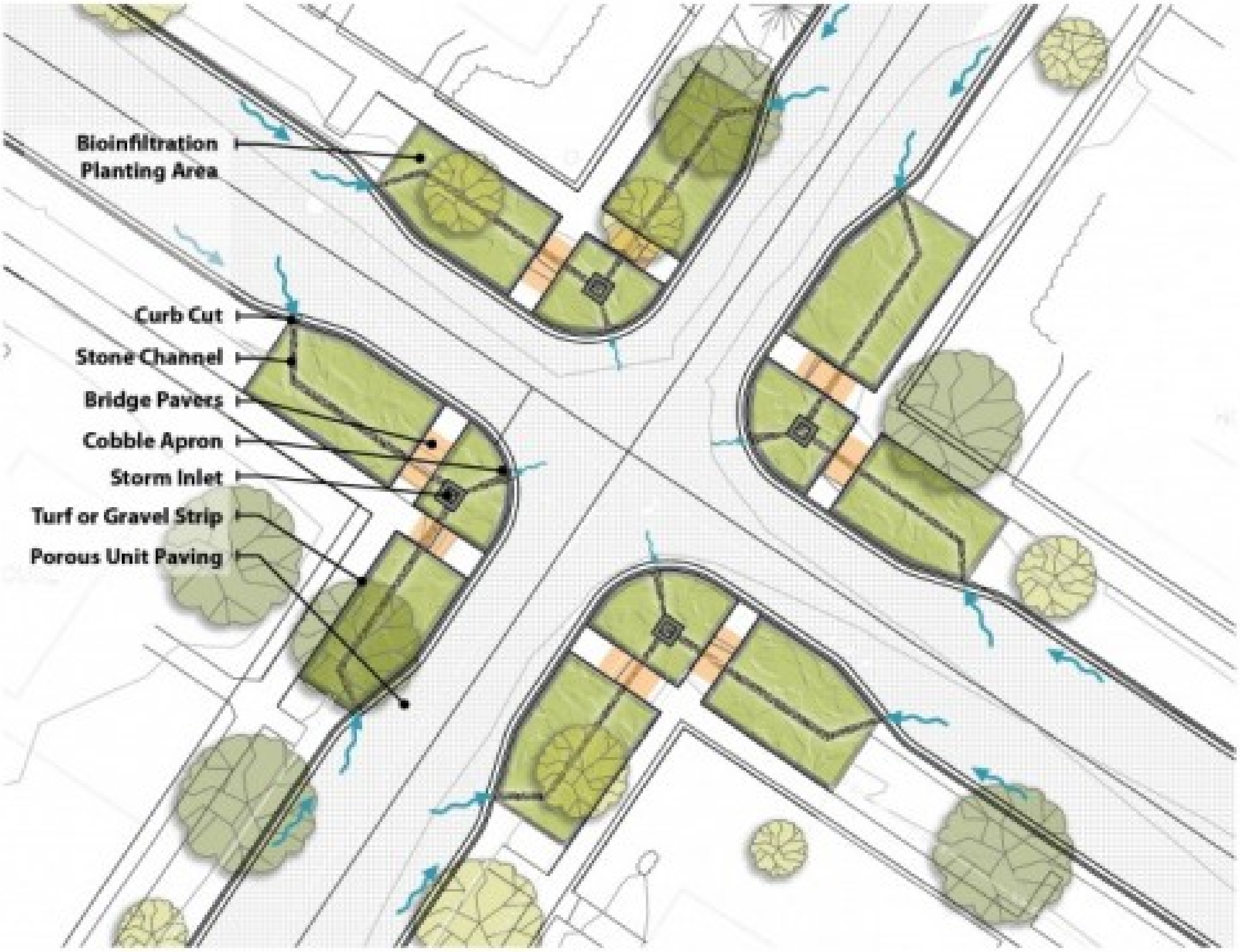
Research Assistant: Yue Zhang, MLA candidate, Utah State University
Research Assistant: Pamela Blackmore, BLA candidate, Utah State Universityï»¿
Firm Liaisons: Thomas Priceï»¿ and Sarah Alwardï»¿ï»¿, Conservation Design Forum
August 2012

References & Resources

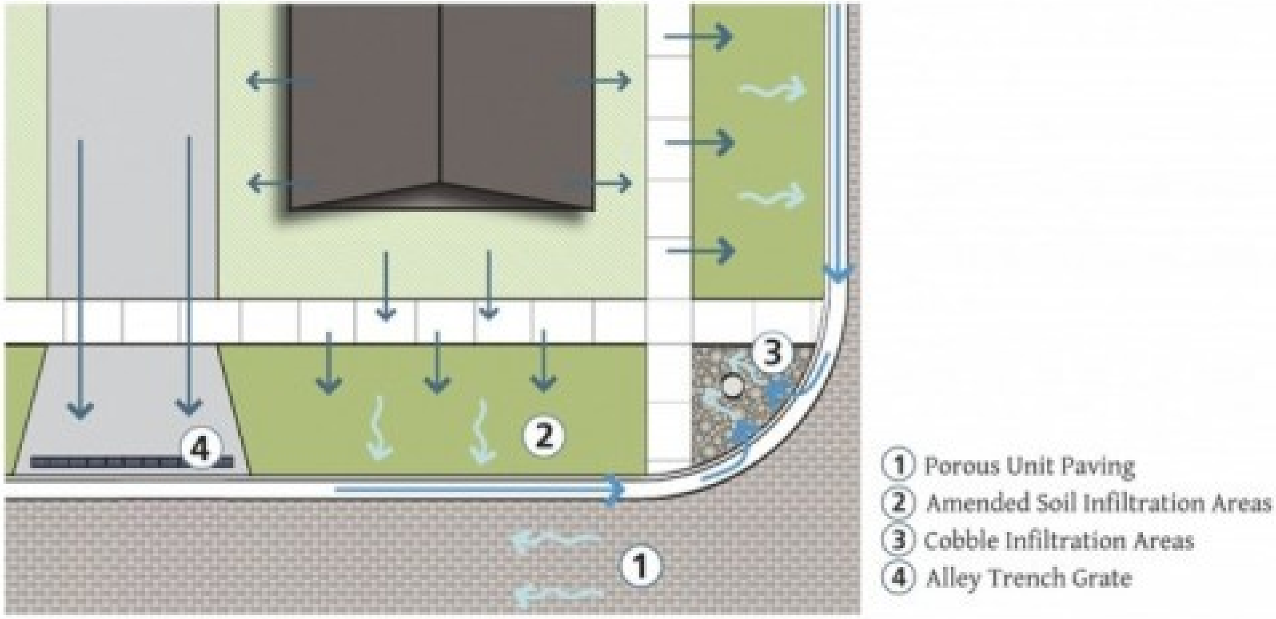
Conservation Design Forum: Charles City Permeable Streetscape
Charles City Green Streets Green Infrastructure Guide ï»¿
ASLA Green Infrastructure & Stormwater Management Case Study
Iowa Environmental Focus: Charles City- Paving a more sustainable Iowa (2011)
Governor's Environmental Excellence Award for Water Quality, 2011

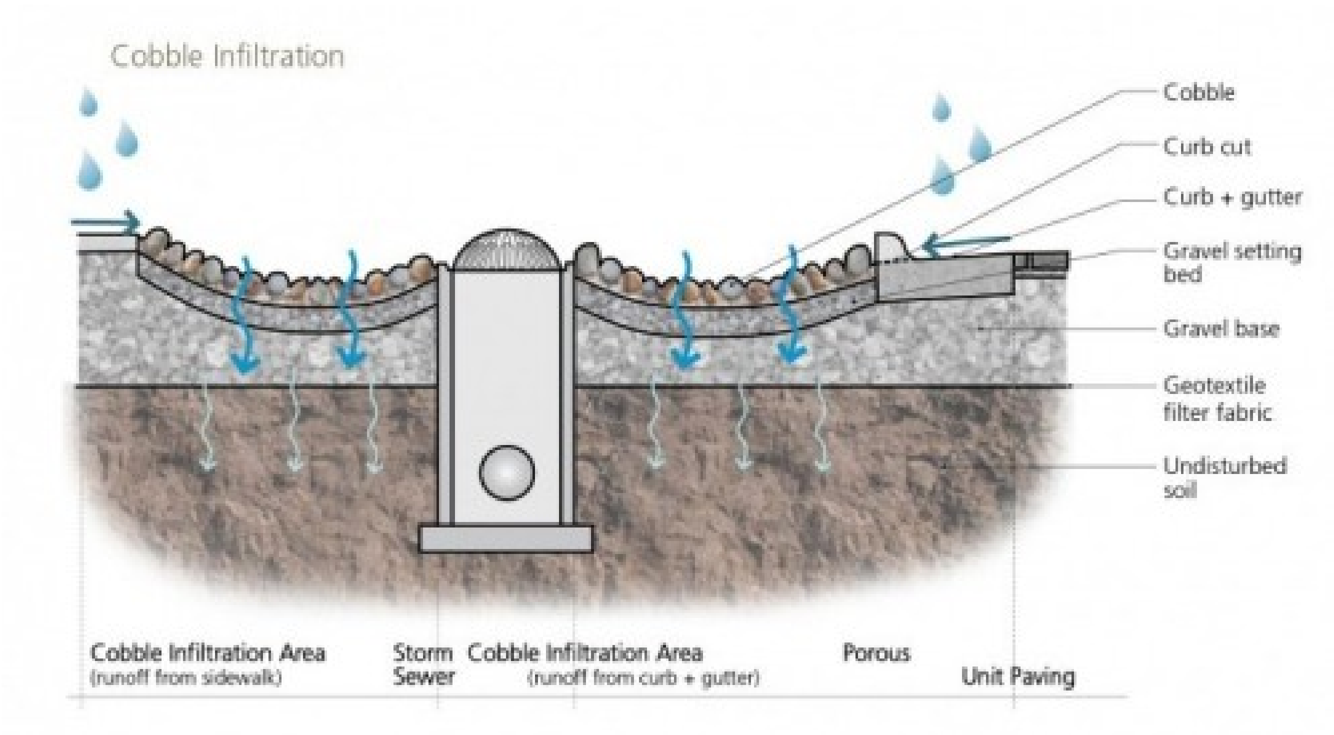
Additional Images

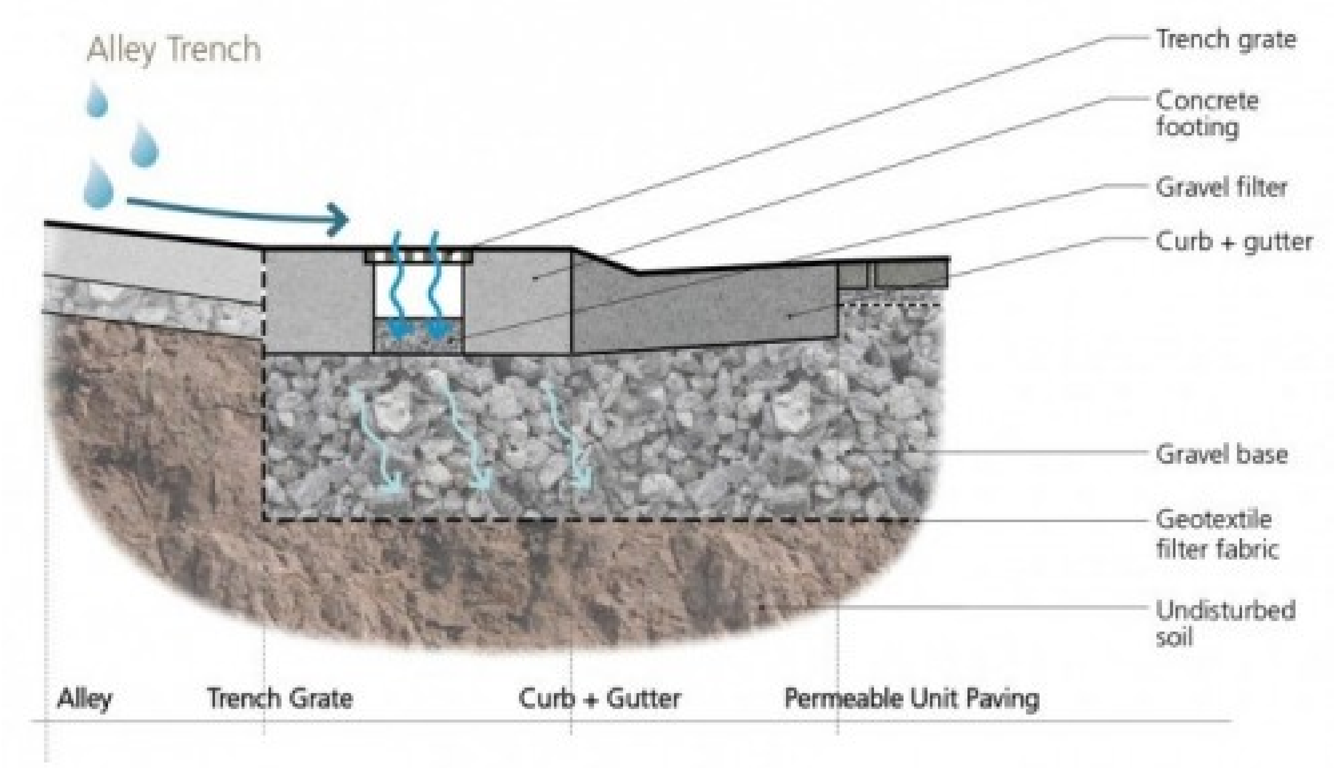


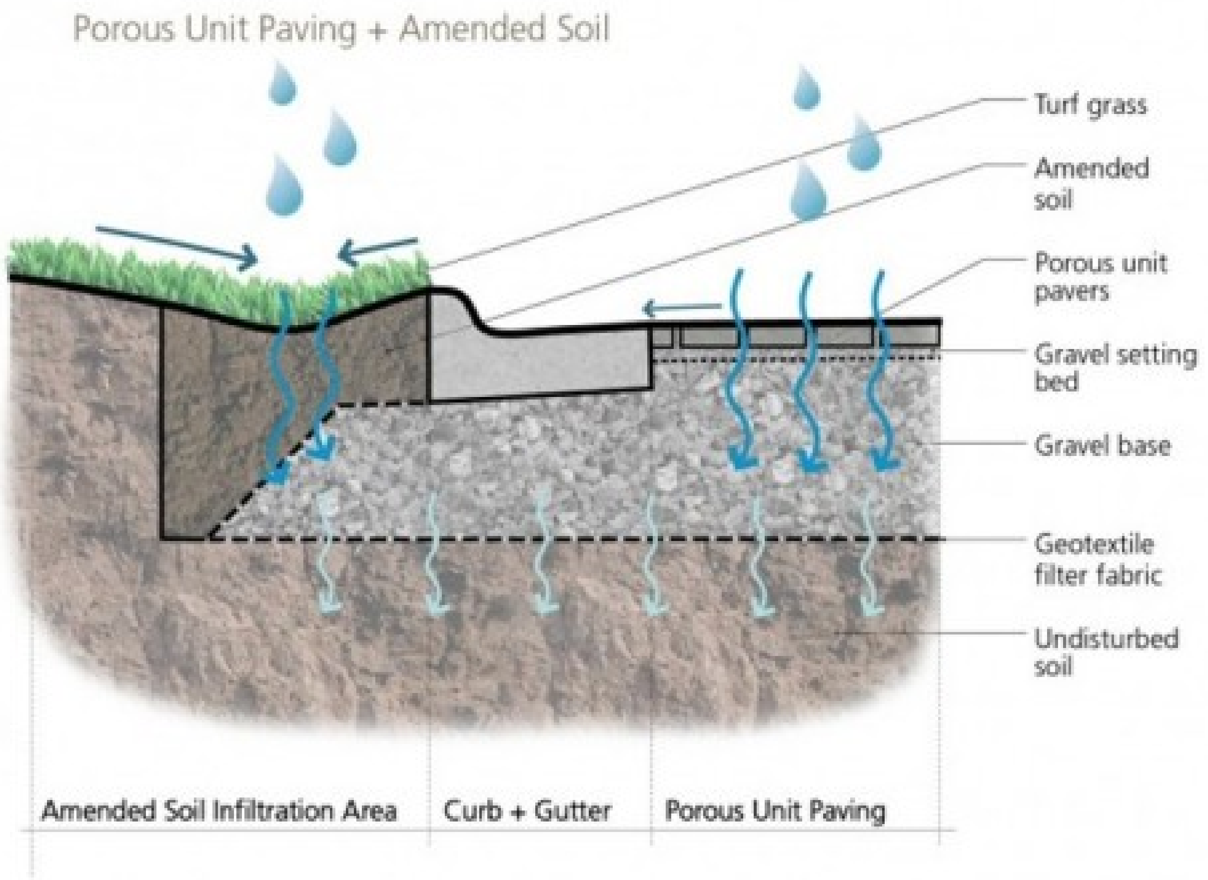
Charles City Green Streets *Rainwater Treatment System Overview*

a. Rainwater Diagram




Cobble Infiltration
Cobble
Curb cut
Curb + gutter
Gravel setting bed
Gravel base
Geotextile filter fabric
Undisturbed soil
Cobble Infiltration Area
(runoff from sidewalk)
Storm Sewer
Cobble Infiltration Area
(runoff from curb + gutter)
Porous Unit Paving


Alley Trench
Trench grate
Concrete footing
Gravel filter
Curb + gutter
Gravel base
Geotextile filter fabric
Undisturbed soil
Alley
Trench Grate
Curb + Gutter
Permeable Unit Paving


Porous Unit Paving + Amended Soil
Turf grass
Amended soil
Porous unit pavers
Gravel setting bed
Gravel base
Geotextile filter fabric
Undisturbed soil
Amended Soil Infiltration Area
Curb + Gutter
Porous Unit Paving

LANDSCAPE PERFORMANCE SERIES

Charles City Permeable Streetscape Phase 1

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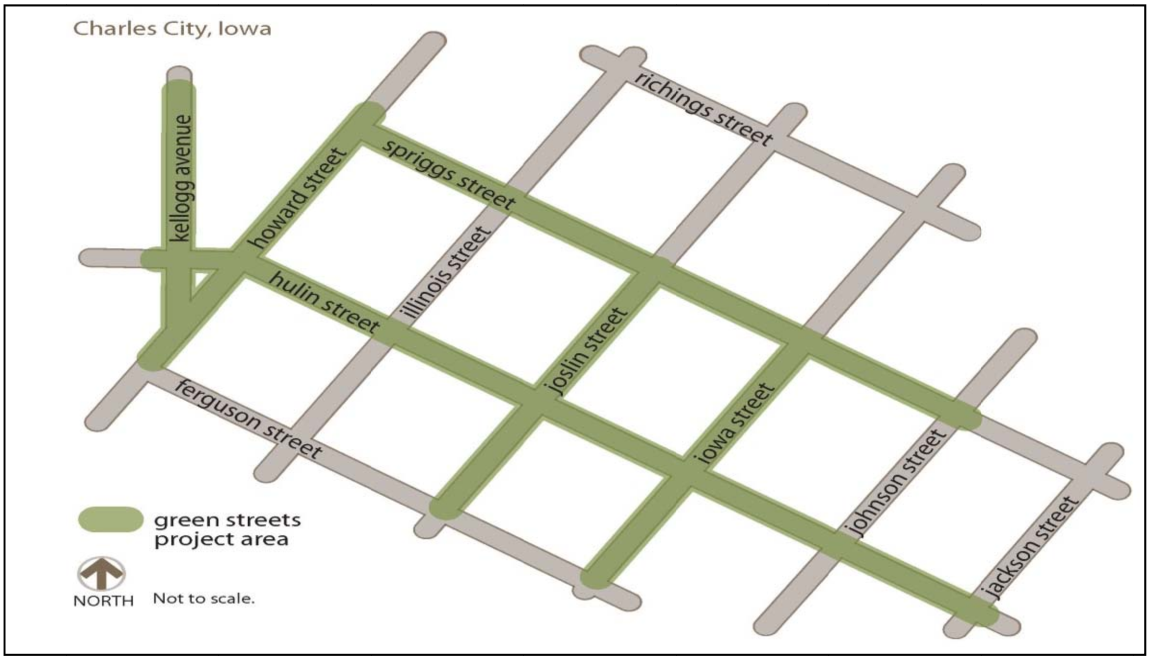
Landscape Performance Benefits and Methods

- ***Reduced stormwater peak flows by at least 75% for 10-year storm events and 40% for 100-year storm events.***

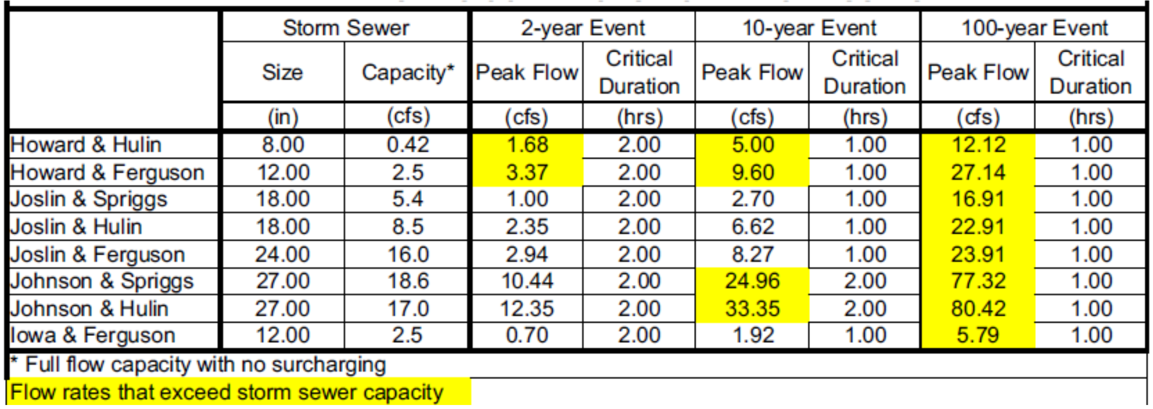
Note: The figure below shows the location of the permeable streets and the intersections. All the streets mentioned in this Methodology section are indicated on this figure.



Poor drainage and ponding are the major issues in this project. In most of the intersections, the capacity of the dilapidated, existing storm sewer system cannot meet its targeted design capacity. Additional runoff was intended to drain into the gutters along the streets. The intersection of Joslin and Hulin is a low spot. Surface runoff drains toward this intersection and it often times causes ponding in this area. In large storms, excessive runoff eventually reaches the high point on Joslin Street, between Hulin and Ferguson. This was the case in 2008 that the entire intersection was inundated and some private yards were also severely flooded.

The existing peak flow rates and storm sewer capacities are shown in Table 1. A Hydro CAD model was developed by using the NRCS Curve Number (CN) method and the unit hydrograph methodology. The soil type in the study area is Hydrologic Soil Group B. The rainfall amount and frequency information is derived from the Midwest Climate Center Research Report 92.03. As shown in Table 1, two existing storm sewers could not meet the capacity of 2-year design storms; four of them could not meet the capacity of 10-year design storms and none of them presents a 100-year storm capacity.

Table 1. Modeling results of existing storm sewers at street intersections (Source: Charles City Green Streets Evaluation and Design Report, 2009, P.4).



	Storm Sewer		2-year Event		10-year Event		100-year Event	
	Size	Capacity*	Peak Flow	Critical Duration	Peak Flow	Critical Duration	Peak Flow	Critical Duration
	(in)	(cfs)	(cfs)	(hrs)	(cfs)	(hrs)	(cfs)	(hrs)
Howard & Hulin	8.00	0.42	1.68	2.00	5.00	1.00	12.12	1.00
Howard & Ferguson	12.00	2.5	3.37	2.00	9.60	1.00	27.14	1.00
Joslin & Spriggs	18.00	5.4	1.00	2.00	2.70	1.00	16.91	1.00
Joslin & Hulin	18.00	8.5	2.35	2.00	6.62	1.00	22.91	1.00
Joslin & Ferguson	24.00	16.0	2.94	2.00	8.27	1.00	23.91	1.00
Johnson & Spriggs	27.00	18.6	10.44	2.00	24.96	2.00	77.32	1.00
Johnson & Hulin	27.00	17.0	12.35	2.00	33.35	2.00	80.42	1.00
Iowa & Ferguson	12.00	2.5	0.70	2.00	1.92	1.00	5.79	1.00

* Full flow capacity with no surcharging

Flow rates that exceed storm sewer capacity

Focusing on this issue, Conservation Design Forum developed a new green street system, which consists of permeable pavements, cobble infiltration at intersections, and engineered parkway bioretention swales. The green street system increases substantially the overall infiltration capacity. As a result the system captures excess runoff and mitigates the flooding problem of Charles City.

The Hydro CAD model was used to evaluate the influence of the proposed permeable pavement design on the existing stormwater sewer system. The permeable pavement and bioretention systems were tested in the model. The CNs that were used for the proposed conditions are presented below (Charles City Green Streets Evaluation and Design Report, 2009):

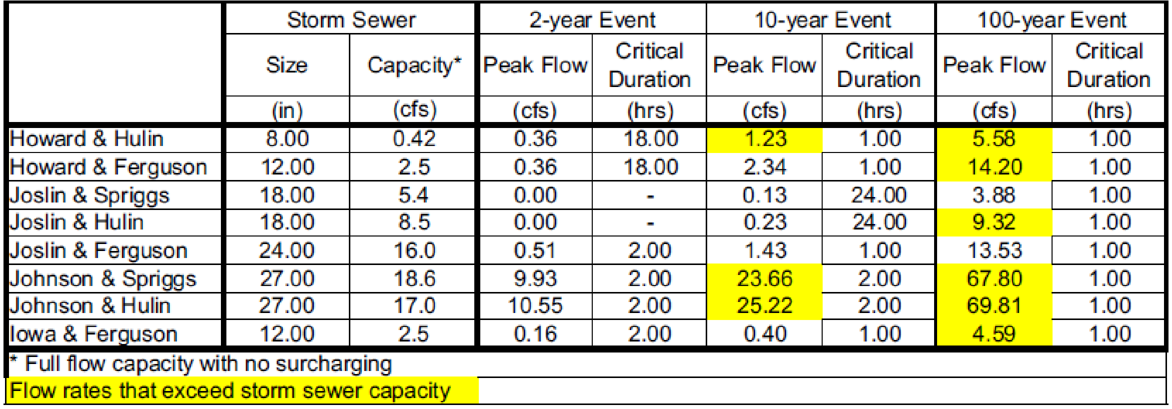
Permeable Pavement Surface:	98 (NRCS TR-55, paved parking lots, roofs, driveways)
Unconnected Impermeable Surface:	98 (NRCS TR-55, unconnected impervious surfaces)
Open Space:	61 (NRCS TR-55, lawns, grassy open areas)

Runoff volume is generated based on the above CNs. Then runoff is treated and drains into the gravel beneath the permeable pavement system. Several assumptions were made to construct the model (Adapted from Charles City Green Streets Evaluation and Design Report, 2009, P.11):

- Amended soil infiltration areas: The designed infiltration capacity of the amended soil is 2 inches per hour. The swale surface is 4 inches below the top of curb to provide time for infiltration.
- Permeable pavement surface: The designed infiltration capacity is 2 inches per hour.
- Cobble infiltration area: The designed infiltration capacity of the gravel surface is 100 inches per hour and the gravel surface is 6 inches below the gutter line.
- Gravel storage: The gravel storage beneath the permeable pavement has a porosity ratio of 36%. Based on the permeability test, the average infiltration capacity of the sandy soils below the silty-sand surface is 1.4 inches per hour. This study used a conservative infiltration capacity of 0.88 inches per hour. The excessive runoff will drain along the street right-of-way that is covered by gravel. The hydraulic conductivity of the gravel storage layer is 0.13 ft/s. Drainage through the gravel storage space was modeled based on Darcy's Law.

Hydro CAD modeling was conducted based on the above assumptions. The proposed peak flow reduction is shown in Table 2.

Table 2. Modeling results of proposed condition after applying the permeable pavement on the street (Source: Charles City Green Streets Evaluation and Design Report, 2009, P.13).



	Storm Sewer		2-year Event		10-year Event		100-year Event	
	Size	Capacity*	Peak Flow	Critical Duration	Peak Flow	Critical Duration	Peak Flow	Critical Duration
	(in)	(cfs)	(cfs)	(hrs)	(cfs)	(hrs)	(cfs)	(hrs)
Howard & Hulin	8.00	0.42	0.36	18.00	1.23	1.00	5.58	1.00
Howard & Ferguson	12.00	2.5	0.36	18.00	2.34	1.00	14.20	1.00
Joslin & Spriggs	18.00	5.4	0.00	-	0.13	24.00	3.88	1.00
Joslin & Hulin	18.00	8.5	0.00	-	0.23	24.00	9.32	1.00
Joslin & Ferguson	24.00	16.0	0.51	2.00	1.43	1.00	13.53	1.00
Johnson & Spriggs	27.00	18.6	9.93	2.00	23.66	2.00	67.80	1.00
Johnson & Hulin	27.00	17.0	10.55	2.00	25.22	2.00	69.81	1.00
Iowa & Ferguson	12.00	2.5	0.16	2.00	0.40	1.00	4.59	1.00

* Full flow capacity with no surcharging

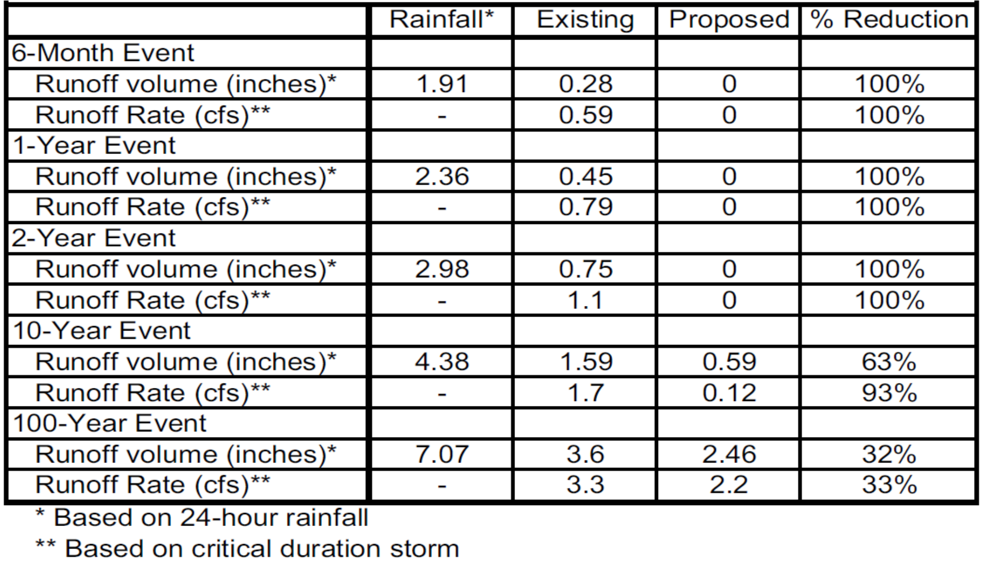
Flow rates that exceed storm sewer capacity

For the 2-year and 10-year storm events, peak flows are reduced at least 75% at all the locations except on Johnson (where most of the flow it receives actually comes from areas outside the project). The peak flow reduction is less for the 100-year events but reduction rates are at least 40% at all the locations except on Johnson and at the intersection of Iowa and Ferguson.

- ***Reduced the runoff volume by over 60% up to the 10-year 24-hour storm event, and over 30% for the 100-year 24-hour storm event. This eliminated the need to replace downstream storm sewers, thereby reducing infrastructure costs and neighborhood disruption.***

This result is achieved by applying the proposed project to a prototype model to determine the runoff volume and rate reduction of Hulin Street between Joslin Street and Iowa Street under the same assumption mentioned above. As shown in Table 3, the proposed permeable pavement system can achieve zero discharge up to the 2-year storm event. For the 10-year event, the runoff volume is reduced by over 60% and the peak discharge is reduced over 90%. Even for the 100-year event, the runoff volumes and rates can be reduced by over 30%.

Table 3. Prototype modeling results of Hulin Street between Joslin Street and Iowa Street (Source: Charles City Green Streets Evaluation and Design Report, 2009, P.12).



	Rainfall*	Existing	Proposed	% Reduction
6-Month Event				
Runoff volume (inches)*	1.91	0.28	0	100%
Runoff Rate (cfs)**	-	0.59	0	100%
1-Year Event				
Runoff volume (inches)*	2.36	0.45	0	100%
Runoff Rate (cfs)**	-	0.79	0	100%
2-Year Event				
Runoff volume (inches)*	2.98	0.75	0	100%
Runoff Rate (cfs)**	-	1.1	0	100%
10-Year Event				
Runoff volume (inches)*	4.38	1.59	0.59	63%
Runoff Rate (cfs)**	-	1.7	0.12	93%
100-Year Event				
Runoff volume (inches)*	7.07	3.6	2.46	32%
Runoff Rate (cfs)**	-	3.3	2.2	33%

* Based on 24-hour rainfall

** Based on critical duration storm

- ***Expected to improve water quality by reducing the need for winter salt application by up to 75% because snowmelt and stormwater can infiltrate. This should also lead to savings in the city's winter operations budget.***

This information is based on the University of New Hampshire Stormwater Center (UNHSC) research (2009). UNHSC found that permeable paving may reduce salt use by up to 75% compared to conventional paving, because permeable paving allows snowmelt and stormwater to infiltrate. No salt application is required for porous pavement to achieve an equivalent friction factor and traction as the normally treated conventional pavement. This is because porous pavement has a higher frictional resistance than conventional pavement (UNHSC, 2007).

Before construction, Charles City used salt for snow melt on the conventional asphalt in winter. The alternative permeable pavement will reduce the amount of salt that would be applied (and the associated costs) and will reduce the pollution level in runoff. Therefore, similar environmental and economic benefits are expected in this project, as shown in the UNHSC study.

- ***Saved $57,000 by preserving 192 street trees instead of removing them and installing new trees.***

In Phase I, the project preserved 192 trees onsite. Estimated by the project manager, the unit cost ranges from $250 to $350 for removing an existing tree and installing a new tree. This price doesn't include the cost of purchasing new trees from a nursery. Assuming an average cost of $300, the project saves more than $57,600 compared to installing new street trees.

$$\$300 \times 192 = \$57,600$$

- ***Secured $731,000 in additional funding to implement this major street reconstruction project — funding that would not be available for conventional street reconstruction.***

The project received $631,000 under the American Recovery and Reinvestment Act State Revolving Fund (ARRA-SRF) "green reserve" provisions. The project was also awarded $100,000 from the Iowa Department of Natural Resources (DNR) I-Jobs grant that assisted in design and construction of the permeable pavements (ASLA Green Infrastructure and Stormwater Management Case Study, Case 191).

Cost Comparison Methods

- ***The project uses permeable interlocking concrete unit pavers as a high-performance, cost-effective pavement, which saves approximately $395,000 in construction and permitting costs when compared to cast-in-place porous concrete for the 5,670 linear feet of streets that were replaced.***

Based on the Charles City Green Streets Evaluation and Design Report, the estimated unit cost of a permeable paver road is $530/LF to construct the road cross section proposed for Charles City. The estimated unit cost of porous concrete road is $590/LF. The above price includes removal of the existing pavement and installation of the stone base, required drainage, curbs, and the permeable pavers. The project covers 6 streets and the overall length in this project is 5,669 LF. The Contingency and Design and Permitting Fees rates are 10% and 6%, respectively. Therefore the overall costs savings are:

$$(\$590/\text{LF} - \$530/\text{LF}) \times 5669\ \text{LF} + (\$590/\text{LF} - \$530/\text{LF}) \times 5669\ \text{LF} \times 16\% = \$\ 395,000$$

- ***By preserving 192 of the existing street trees, the City saved $57,000 over the cost of removing them and installing new trees.***

See method for Landscape Performance Benefit #4.

References

1) ASLA Green Infrastructure and Stormwater Management Case Study, Case 191: Charles City Downtown Permeable Streetscape. Available online at: http://www.asla.org/uploadedFiles/CMS/Advocacy/Federal_Government_Affairs/Stormwater_Case_Studies/Stormwater%20Case%20191%20Charles%20City%20Downtown%20Permeable%20Streetscape,%20Charles%20City,%20IA.pdf
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5) National Menu for BMP Practices Post-Construction Storm Water Management. (2004). U.S. Environmental Protection Agency, Washington, D.C.
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7) University of New Hampshire Stormwater Center. (2009). Winter Maintenance Guidelines for Porous Asphalt. Available online at: http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/winter_maintenance_fact_sheet.pdf