Charles City Permeable Streetscape Phase 1—Charles City, IA
Methodology for Landscape Performance Benefits

Prepared By:
Research Fellow: Bo Yang, PhD, Assistant Professor, Utah State University
Research Assistant: Yue Zhang, MLA candidate, Utah State University
Research Assistant: Pamela Blackmore, BLA candidate, Utah State University
Firm Liaisons: Thomas Price and Sarah Alward, Conservation Design Forum
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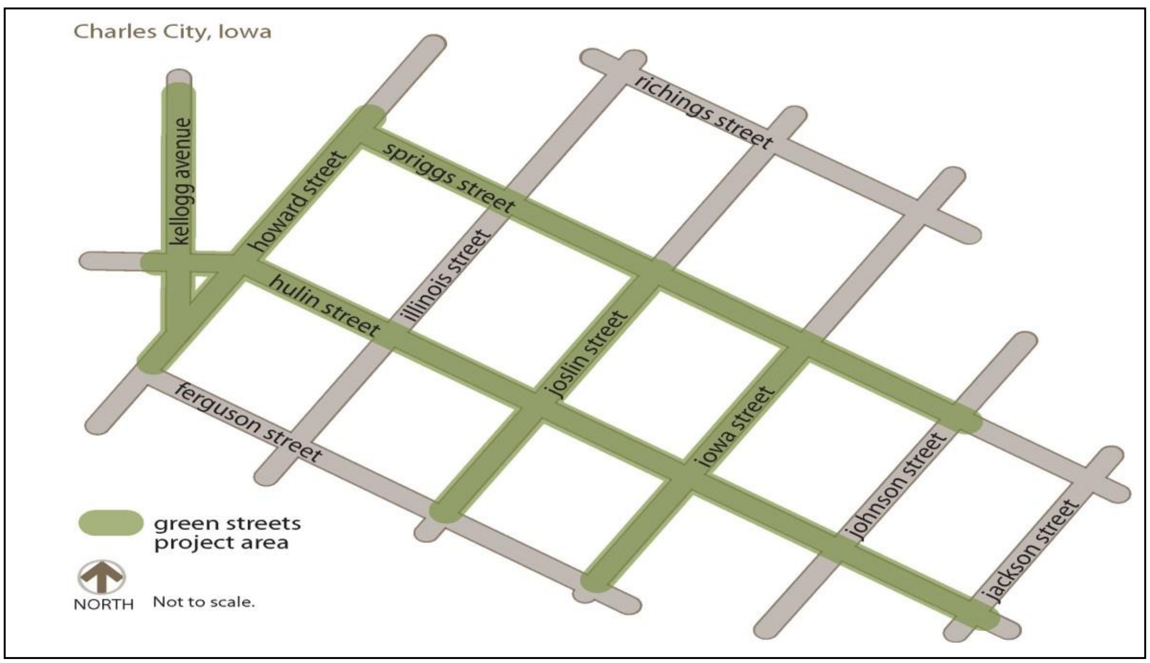
Environmental

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.

Economic

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:

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

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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