Ann Arbor Municipal Center – Ann Arbor, MI
Methodology for Landscape Performance Benefits
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Environmental

Reduces the post-redevelopment site runoff quantity by 87.5% for a 1-year, 24-hour design storm and 87.3% for a 2-year, 24-hour design storm.

The following is CDF's memorandum to USGBC – LEED summarizing their analysis methods and results for the stormwater management system as it relates to LEED NC v2.2 SS 6.1 Stormwater Design Quantity Control.

Pre-development Conditions
The pre-development site consists of a building and associated parking lots, and small, perimeter landscape areas. A majority of the pre-development site is impervious surface (pavement or building roof).

To determine the 1- and 2-yr, 24-hr stormwater runoff rates and quantities, the following land cover areas and curve numbers were used with the NRCS Curve Number and unit hydrograph methods in HydroCAD, a proprietary stormwater modeling software title (www.hydrocad.net).

Land Cover Areas
Impervious Surfaces: 63202 sf
Pervious Surfaces: 22038 sf

Curve Numbers
Impervious Surfaces: 98 (NRCS TR-55 – Paved parking lots, roofs, driveways, etc.)
Pervious Surfaces: 74 (NRCS TR-55 – Open space, good condition)

Post-development Conditions
The post-development site consists of a building with partial green roof, permeable pavement parking lots and pedestrian plazas, and landscaped areas (planting beds, raingardens, and bioretention planters).

A majority of the post-development site is impervious surface (pavement or building roof). It is important to note, that for hydrologic modeling, permeable pavements are considered impermeable surfaces, as they generate runoff that must be detained per the City's stormwater ordinance. However, the permeable pavement overlies storage in the gravel base of the pavement. As described below, the gravel storage is used as temporary storage for infiltration and detention and this is where the runoff reduction benefit is accounted for in the analysis. From this gravel storage, runoff can infiltrate into the subgrade or be released to the storm sewer system via the underdrains.

To determine the 1- and 2-yr, 24-hr stormwater runoff rates and quantities, the following land cover areas and curve numbers were used with the NRCS Curve Number and unit hydrograph methods in HydroCAD, a proprietary stormwater modeling software title (www.hydrocad.net).

Land Cover Areas
Impervious Surfaces: 41881 sf
Permeable Pavement: 12326 sf
Greenroof: 19928 sf
Pervious Surfaces: 11105 sf
(85,240 sf total area)

Curve Numbers
Impervious Surfaces: 98 (NRCS TR-55 – Paved parking lots, roofs, driveways, etc.)
Permeable Pavement: 98 (NRCS TR-55 – Paved parking lots, roofs, driveways, etc.)
Greenroof: 83
Pervious Surfaces: 74 (NRCS TR-55 – Open space, good condition)

Stormwater Infiltration and Detention
All the runoff from the site is directed to permeable paving or bioretention areas. Gravel storage is located beneath the permeable paving and bioretention areas. The gravel temporarily stores the runoff allowing time for infiltration into the subgrade and/or slow release to the existing storm sewer system located in the Right of Way adjacent to the site. Discharge to the storm sewer system is controlled by outlet control structures such that the discharge does not exceed the allowable release rate specified by the Washtenaw County Drain Commissioner.

The gravel storage was modeled using HydroCAD as a "Pond" in a similar manner as a conventional detention basin. However, the pond has two outlets – one is the infiltration out of the bottom of the pond and the other is the controlled release to the existing storm sewer.

Based on the geotechnical report, the subgrade soils are predominantly sands and gravels, with a permeability of 2.98 in/hr. For design and analysis purposes, a permeability of 1.50 in/hr was assumed for the infiltration rate through the bottom of the "ponds".

Although gravel similar to being used for the temporary storage had been tested and shown to have a porosity of 40%, the allowable porosity used for design was specified as 30% by the Drain Commissioner.

Results

	Pre-development site runoff rate (cfs)	Pre-development site runoff quantity (cf)	Post-development site runoff rate (cfs)	Post-development site runoff quantity (cf)
1-yr, 24-hr rainfall event	4.88	9060	0.125	1133
2-yr, 24-hr rainfall event	6.17	11674	0.130	1481

Reduction in runoff quantity is calculated as follows:
1-year, 24-hour design storm = (1 - (1133 / 9060)) * 100 = 87.5%
2-year, 24-hour design storm = (1- (1481 / 11674)) * 100 = 87.3%

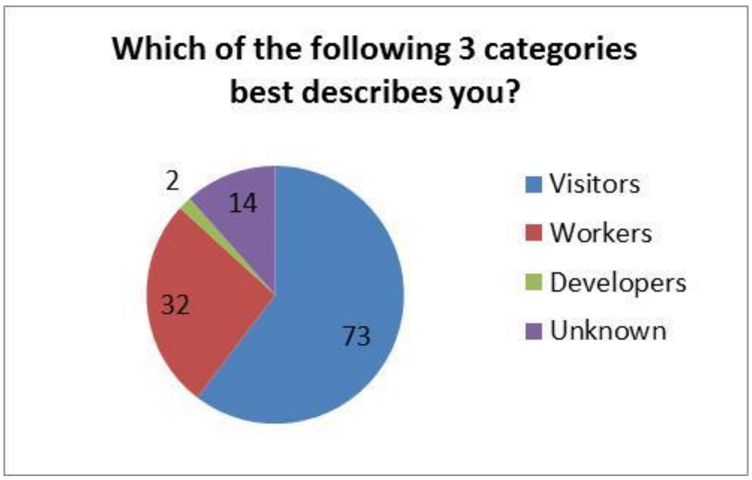
To calculate the equivalent in gallons:
9060-1133 = 7927 cf = 59,300 gallons

11674-1481 = 10193 cf = 76,200 gallons

By infiltrating a vast majority of the 1- and 2-yr, 24-hr rainfall events into the subgrade soils, the reductions in post-development runoff rates and volumes is drastic. To a lesser extent, the use of green roof, rain gardens, and bioretention planters reduced post-development runoff rate and volume by reducing the imperviousness of the site.

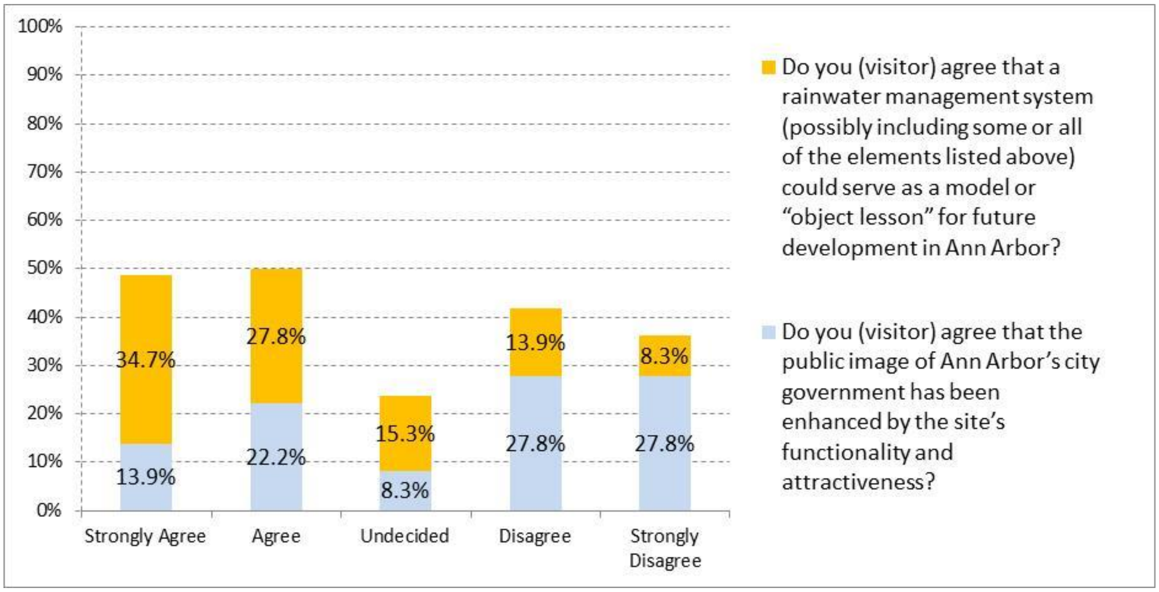
Social

Social Benefits were measured by a voluntary on-line survey of adult visitors, employees, and developers/builders in Ann Arbor and Washtenaw County, Michigan using the Survey Monkey® platform to solicit responses. 120 people participated in the survey including 73 visitors, 32 city employees, 2 professional developers and 14 participants of unknown description. Some participants did not answer all questions so the results may or may not reflect the views of all participants. The pie chart below shows the categories of participants:



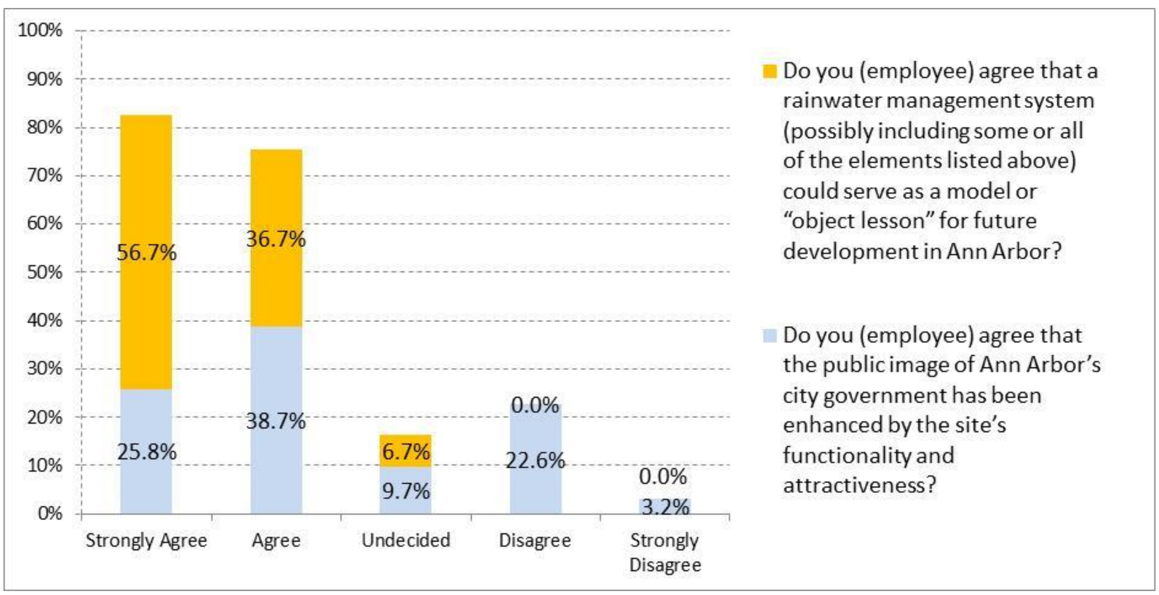
Demonstrates sustainable stormwater management with 93% of city employees and 63% of visitors surveyed agreeing that the stormwater management features could serve as a model for future development in Ann Arbor. The green roof captures the most interest (70% of survey respondents), while the sculpture, rain gardens, native plants, and permeable walkways are the most noticeable stormwater features.

While the public is divided on the municipal government for political or other reasons beyond this study they are mostly supportive of the rainwater management system. 34.7% of visitors strongly agree and 27.8% agree (total of 63% in agreement). Whereas 56% of visitors strongly disagree or disagree (27.8% + 27.8%) that the public image of city government has been enhanced. The following chart shows this relationship.



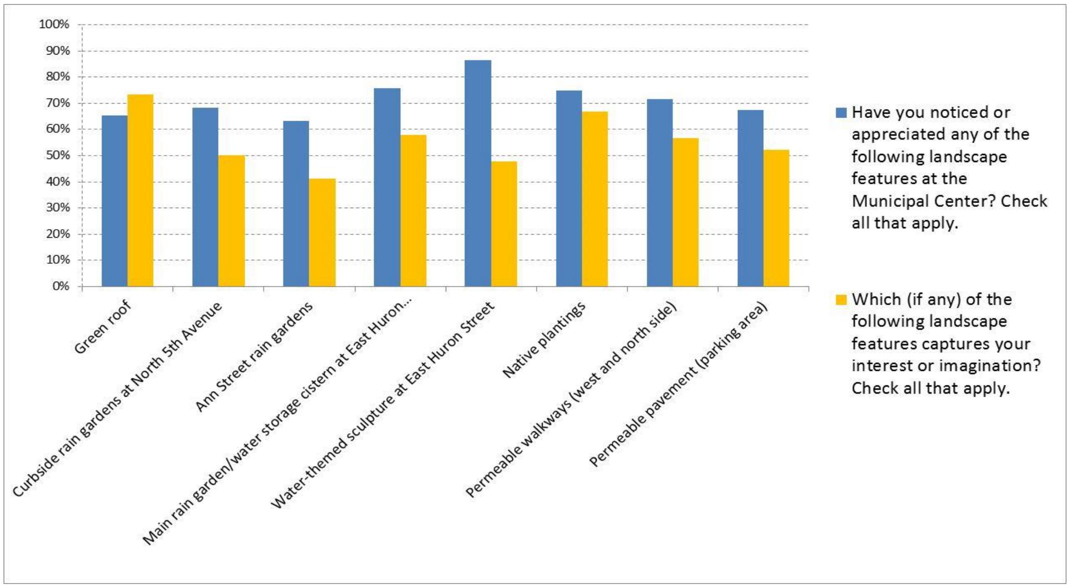
Survey responses from visitors to the Municipal Center.

The majority 93% (56.7%+36.7%) of employees agree that the rainwater system could serve as a model for future development. 65% (25.8% + 38.7%) of city employees that work at the Municipal Center agree that the public image of Ann Arbor's city government has been enhanced. These results are reasonable assuming employees that work the Municipal Center likely interact and with the stormwater features more frequently then visitors. The following chart shows this relationship.



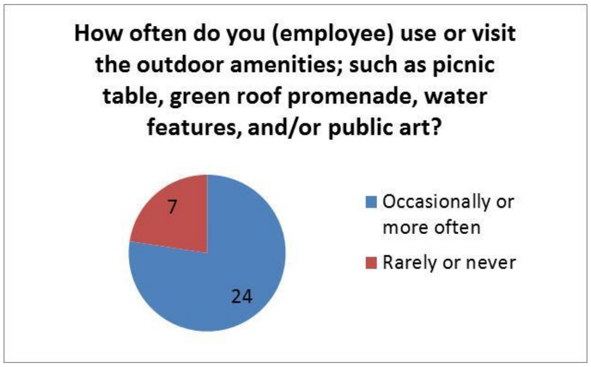
Survey responses from city employees that work at the Municipal Center.

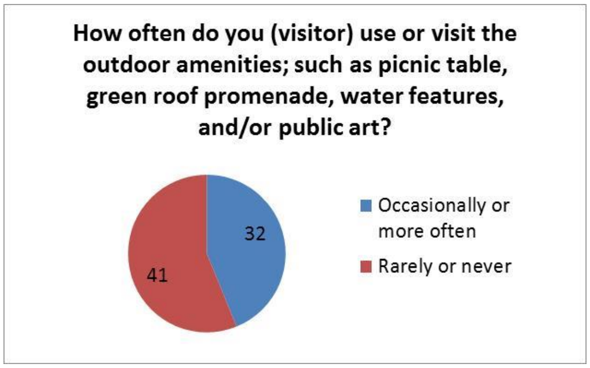
Over 70% (as shown in the chart below) of people notice or appreciate the sculpture, rain garden, native plants and permeable walkways. These features, while noticeable, do not capture the interest or imagination as much as the green roof.



Provides new outdoor amenities for the 400 city employees who work at the Municipal Center, with 77% of those surveyed saying that they visit or use the picnic tables, green roof promenade, water features and/or public art occasionally or more often.

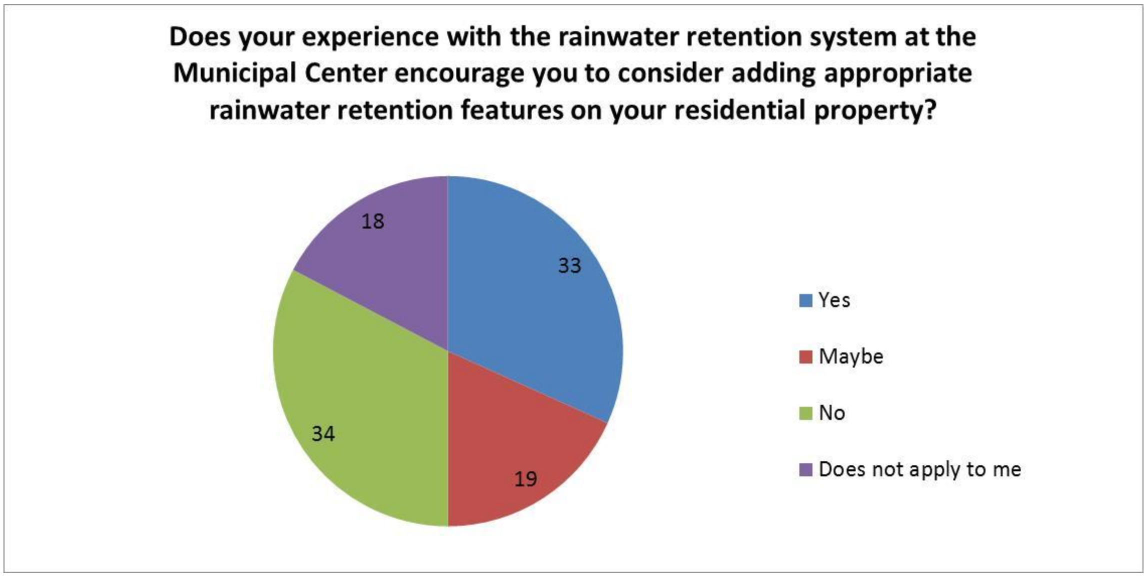
Survey results show that out of 31 employees that responded to the question *"How often do you use or visit the outdoor amenities; such as picnic table, green roof promenade, water feature and/or public art"* 24 (77%) indicated they use the outdoor amenities occasionally or more often. This is in contrast to the results from only the visitors that show a lesser percentage (44%) or 32 out of 73 visitors indicated they use the outdoor amenities. This expected since employees are assumed to spend a far greater amount of time passing through the features on their way to the building entrances and may have opportunities at lunch time to enjoy the landscape features.





Encourages city employees and visitors to consider adding rainwater retention features on their residential properties. One-third of survey respondents reported being encouraged by their experience at the Municipal Center.

The pie chart below illustrates the survey response results.



Economic

Saves an estimated $1,000 in annual heating and cooling costs due to the added insulation from the green roof.

A green roof can save on heating and cooling costs by providing additional insulation, which helps maintain a constant temperature inside the building. Quantification of the savings is achieved by using the methodology detailed in The Center for Neighborhood Technology's "The value of Green Infrastructure". The amount of energy saved is determined by calculating the differential in the amount of energy consumed by a conventional and green roof as follows:

annual number of cooling degree days (°F days) * 24 hrs/day * ΔU = annual cooling savings (Btu/SF)

annual number of heating degree days (°F days) * 24 hrs/day * ΔU = annual heating savings (Btu/SF)

Where:
U = heat transfer coefficient, or 1/R; and
R = heat transfer coefficient

$$\Delta U = \left[\frac{Btu}{R(conventional\ roof)}\right] - \left[\frac{Btu}{R(green\ roof)}\right]$$

The calculation is a function of the average heating degree days (both heating and cooling) and the change in heat transfer coefficient or ΔU. Typical R values are used for the conventional roof (R = 11.34*SF*F*hrs) and green roof (R = 23.4*SF*F*hrs).

The calculation for the annual cooling cost savings is:

$$691°F\ days * \frac{24hrs}{day} * \left[\left[\frac{Btu}{11.34*SF*°F*hrs}\right] - \left[\frac{Btu}{23.4*SF*°F*hrs}\right]\right] = \text{annual cooling savings}$$

$$16{,}584\ °\mathrm{F} * hrs * \left[\left[\frac{Btu}{11.34*SF*°\mathrm{F}*hrs}\right] - \left[\frac{Btu}{23.4*SF*°\mathrm{F}*hrs}\right]\right] = \text{annual cooling savings}$$

$$\left[\left[\frac{16{,}584\ Btu}{11.34 * SF * °\mathrm{F} * hrs}\right] - \left[\frac{16{,}584\ Btu}{23.4 * SF * °\mathrm{F} * hrs}\right]\right]$$

$$\left[\left[\frac{1{,}462\ Btu}{SF}\right] - \left[\frac{709\ Btu}{SF}\right]\right] = \text{annual cooling savings}$$

753 Btu/SF = annual cooling savings

In order to find how cooling savings results in electricity savings (kWh), the Btu units should be converted to kWh using the conversion rate of 1 kWh/3412 Btu. By converting Btu to kWh, annual cooling savings becomes:

$$753\,\frac{Btu}{SF} * \frac{1kWh}{3{,}412}\,Btu = 0.221\ \text{kWh/SF} = \text{annual cooling savings}$$

Thus for the 10,318 SF green roof the annual cooling savings is 10,318 * 0.221 kWh/SF = 2,280 kWh. The 2012-2013 average cost of electricity in the USA according the Bureau of Labor Statistics was $0.130 per kWh therefore the cost savings in annual cooling is 2,280 kWh * $0.13/kWh = **$296**

The calculation for the annual heating cost savings is:

$$6{,}503°\mathrm{F}\ days * \frac{24hrs}{day} * \left[\left[\frac{Btu}{11.34*SF*°\mathrm{F}*hrs}\right] - \left[\frac{Btu}{23.4*SF*°\mathrm{F}*hrs}\right]\right] = \text{annual cooling savings}$$

$$156{,}072\ °\mathrm{F} * hrs * \left[\left[\frac{Btu}{11.34*SF*°\mathrm{F}*hrs}\right] - \left[\frac{Btu}{23.4*SF*°\mathrm{F}*hrs}\right]\right] = \text{annual cooling savings}$$

$$\left[\left[\frac{156{,}072\ Btu}{11.34*SF*°\mathrm{F}*hrs}\right] - \left[\frac{156{,}072\ Btu}{23.4*SF*°\mathrm{F}*hrs}\right]\right] = \text{annual cooling savings}$$

$$\left[\left[\frac{13{,}763\ Btu}{SF}\right] - \left[\frac{6{,}670\ Btu}{SF}\right]\right] = \text{annual cooling savings}$$

7,093 Btu/SF = annual cooling savings

Assume heating is with natural gas (Btu), the savings in heating for the 10,318 SF green roof is 10,318 SF * 7,093 Btu/SF = 73,185,574 Btu.

The 2012-2013 average cost of natural gas in the USA according the Bureau of Labor Statistics was $0.130 per kWh therefore the cost savings in annual cooling is 73,185,574 Btu * $0.964/100,000Btu = **$705**

The total heating and cooling annual cost savings is $296 + $705 = **$1,001**

<u>Source</u>
www.lwf.ncdc.noaa.gov/oa/documentlibrary/hcs/hcs.html – Heating and cooling degree days
www.bls.gov – Average annual energy prices (2012-2013) for the United States
www.cnt.org/repository/gi-values-guide.pdf – "The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Social and Environmental Benefits"

Cost Comparison Methodology

The permeable unit pavers installed in the vehicle parking area north of the Larcom Building saves an estimated $7,429 or 16% compared to the cost of a conventional concrete pavement over a 30-year service life cycle.

The methodology used to estimate the life cycle cost of the parking area north of the Larcom Building considers two pavement types; the as-built permeable unit paving and a conventional concrete. Formulating a cost comparison with the two designs is a complex issue with many variables beyond the scope of this study; however a simplistic approach has been taken here based on key inputs gathered form industry literature and software produced by the Interlocking Concrete Pavement Institute (ICPI). The life cycle cost analysis is based on the following assumptions:

- 4.0 percent discount rate (discount rate = interest rate – inflation rate)
- Analysis period (30 years)
- Parking lot area (7,191 sq. ft., considers only the area trafficked by vehicles)
- Unit costs (includes material, labor and equipment costs)
- Pavement thickness
- Timing and types of maintenance and rehabilitation activities and quantities

To simplify the calculations, the salvage value or the remaining value of the pavement after 30-years of service is not considered in this method neither is the cost of excavation. The cost and frequency of periodic sweeping and/or power washing is assumed to be the same for ether scenario and is left out of the analysis.

A deterministic approach was used (as opposed to a more complex probabilistic approach) to examine the initial construction and future maintenance and rehabilitation costs over the analysis period. Future costs of maintenance and rehabilitation are brought back in time to the year of initial construction (2011) by applying the discount rate which results in 2011 net present values of these costs which allows for a direct dollar to dollar comparison. A 4.0% discount rate is based on typical values assuming the future economy in over the 30-year analysis period will follow past trends instead of the current conditions which would warrant a lower discount rate. The net present value is calculated as follows:

$$NPV = Initial\ Cost + \sum Future\,Cost * \left[\frac{1}{(1+i)^n}\right]$$

where:

NPV = net present value, $
i = discount rate, percent
n = time of future cost, years

The following tables summarize unit costs used in the analysis:

Permeable Unit Paver Costs*		
Activity	**Unit Costs ($)**	**Unit**
Bedding sand and paver installation	3.75	sq. ft.
Granular base	11.80	ton
Granular subbase	7.75	ton
Replace cracked pavers	3.75	sq. ft.
Replace worn/rutted pavers	5.60	sq. ft.

* Unit costs are ICPI typical values. Actual construction costs are not available.

Conventional Concrete Pavement Costs*		
Activity	**Unit Costs ($)**	**Unit**
Doweled and jointed concrete pavement (8 inch)	5.60	sq. ft
Granular base	11.80	ton
Reseal joints	0.60	ft

Concrete pavement restoration (patching)	14.85	sq. ft

* Unit costs are ICPI typical values. Actual construction costs are not available.

The projected expenditure stream for each pavement scenario is shown in the following tables:

Permeable Unit Paver Projected Expenditure Stream				
Year	**Activity**	**Amount**	**Cost ($)**	**Present Value ($)**
0	Install unit pavers and bedding sand	7,191 sq.ft.	26,966	26,966
0	Install 6 inch granular base	243 tons	2,864	2,864
0	Install 24 inch granular subbase	971 tons	7,524	7,524
	Subtotal (cost of initial construction)		37,354	–
8	Replace cracked pavers (2% of area)	144 sq.ft.	539	394
12	Replace worn and/or rutted pavers (5% of area)	360 sq.ft	2,013	1,258
28	Replace cracked pavers (2% of area)	144 sq.ft.	539	180
	Total (cost of initial construction and maintenance and rehabilitation)			**39,030**

Conventional Concrete Pavement Projected Expenditure Stream				
Year	**Activity**	**Amount**	**Cost ($)**	**Present Value ($)**
0	Install doweled and jointed 8 inch concrete pavement	7,191 sq.ft.	40,270	40,270
0	Install 6 inch granular base	243 tons	2,864	2,864
	Subtotal (cost of initial construction)		43,133	–
5	Reseal 5% of joints	99 ft.	59	49
15	Patch 2% of pavement area	144 sq.ft.	2,136	1,186
18	Reseal 15% of joints	297 ft.	178	88
25	Patch 5% of pavement area	360 sq.ft	5,339	2,003
30	Reseal 5% of joints	99 ft.	59	18
	Total (cost of initial construction and maintenance and rehabilitation)			**46,459**

A 24 percent savings is calculated from the 2011 net present values as follows:

$$Saving = 100 * \frac{(NPV_{Concrete} - NPV_{UnitPavers})}{NPV_{concrete}}$$

$$Saving = 100 * \frac{(46{,}459 - 39{,}030)}{46{,}459}$$

$$Saving = 15.99\%$$

Source
Interlocking Concrete Pavement Institute, www.icpi.org

Life-Cycle Cost Comparison for Municipal Road Pavements, 9th International Conference on Concrete Block Paving, Buenos Aires, Argentina, 2009