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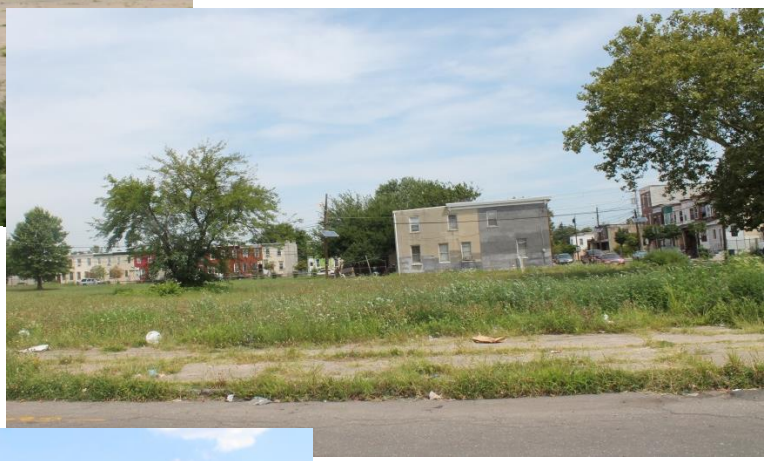
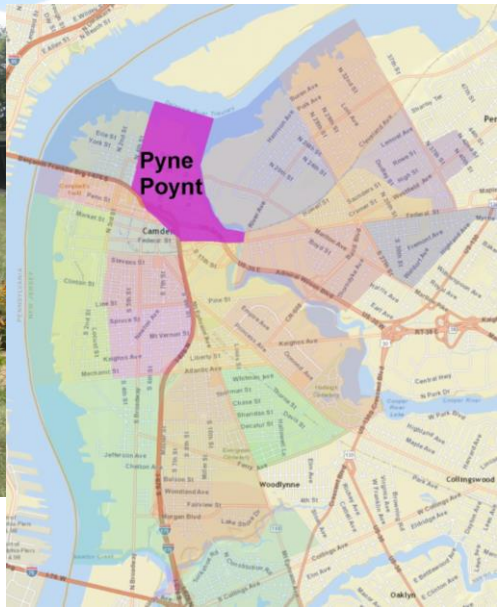
Neighborhood-Wide Green-Infrastructure Planning:

A Pilot Study to Optimize Stormwater Management Benefits for Camden





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Acknowledgements

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Background

The City of Camden, like many older cities in the U.S., is served by combined sewer systems (CSS) that date back to the mid-1800s/early 1900s. CSS collect wastewater and stormwater in the same pipe network and were not designed to handle large volumes of stormwater. During (usually) medium to high intensity storm events, there are combined sewer overflows (CSOs) when the system exceeds capacity and overflows, releasing untreated water into streams and bays and compromising their water quality. The city of Camden is comprised of 28 CSS sewersheds with outfalls to the Delaware River, to the Cooper River, and to Newton Creek. CSS are frequently susceptible to flooding and surcharging (overload of the system beyond its design capacity causing water to flow backwards). During these events, sewage and stormwater back up into buildings' basements and streets, causing serious health problems. In recent years, streets flooding and CSO issues have been aggravated by increasing runoff volumes (due to highly compacted urban soils and impervious surfaces) and by more frequent and intense storm events (due to climate change).

The federal Clean Water Act requires municipalities served by CSS to control their CSOs to ensure attainment of applicable water quality standards and protection of designated water uses. Green infrastructure (GI), such as bioswales and rain gardens, has the potential to mitigate floods and CSOs while providing multiple environmental, economic, and social benefits. GI is an ideal solution for some of the neighborhoods in Camden that present serious stormwater management issues and contain a large number of vacant and slightly contaminated (brownfields) properties that are publicly owned and can potentially be converted into GI. Many of these properties have no current plan or much pressure for redevelopment, so installing GI projects would not compete with other uses and would provide valuable green space that has environmental, economic, and social benefits for the nearby area.

Pilot Study

Our study demonstrates the benefits of strategically (instead of opportunistically, or randomly) placing multiple small- scale GI projects for 1.) flood reduction and 2.) CSO control. The final product of this study is a GI site priority list produced based on maximizing the "return on investment" (benefits/cost) for flood and CSO control.

The pilot study was developed for one sewershed (C15) located within the Pyne Poynt neighborhood (population ~5,800) in Camden. The area was selected in conjunction with partners of the Camden Collaborative Initiative (CCI), Land and Brownfields working group, based on multiple criteria, including: neighborhood needs, large number of available vacant properties, high frequency of

surcharge, floods, and CSO events, and the fact that it overflows to the Cooper River, which has a smaller drainage area than the Delaware River (and thus local alterations can result in higher benefits to the overall water quality of the river).

We selected lots that are owned by the city or that are flagged as brownfields by the Camden Redevelopment Agency (CRA). The Pyne Poynt neighborhood contains a total of 125 city-owned sites. From this list, we discarded all sites defined as "Utility Building" or with monetary improvement values based on the parcel dataset. We analyzed a total of 108 city-owned small-scale lots that can be potentially converted into bioswales/rain gardens. We applied the EPA-SWMM model (version 5) to quantify the benefits of GI for flood and CSO control. We then developed tools in Python to automate the simulation of multiple scenarios, including different: 1) rainfall events (3-months to 5 years flood return period and long term simulations); (2) tidal effects (low and high tide, with and without sea level rise), and (3) green-infrastructure implementation (one project site up to multiple GI sites). To be able to prioritize under different scenarios, we ran more than 2,000 simulations and selected high-performing sites from all of those scenarios.

Since all the sites have very similar properties, we assumed that the GI implementation cost is just a function of the site area (size). We quantified the benefits and the benefits-to-cost ratio for flood and CSO reduction for each site and defined a list of project priorities based only on maximizing benefits (Figure 1) and on maximizing return on investment (benefits/cost) (Figure 2). Because some of the sites collect stormwater from similar areas, we selected the sites providing the highest benefits and/or return on investment that do not treat the same areas so as to achieve the widest-spread impact instead of redundant benefits in the same area. Table 1 presents the list of available sites for GI with detailed information for each site, including the rank order of priority of each site based on maximizing benefits or return on investment (amongst all sites ("Priority" column in Table 1) and after the filter to remove duplicate treated areas ("SW Priority" column in Table 1)).

We also demonstrate the cumulative benefits of implementing green infrastructure in multiple small scale sites and prove that the sites identified as very high priority result in the maximum overall cumulative benefit, much higher than randomly selected sites. Figure 3 shows plots of cumulative benefits for flood reduction and CSO control for strategically versus randomly (opportunistic) selected sites. The benefits for strategically selected sites are shown in blue (based on benefits) and red (based on the benefits/cost ratio). We selected the sites by evaluating the combined benefits for flood and CSO volume reduction.

Applicability

In this study, we developed a flexible approach that allows for the evaluation of multiple scenarios to convert small-scale brownfield sites into GI for stormwater management. The tools developed in this study can be used to replicate this approach and apply to other areas. With the tools developed, we quantified a number of stormwater-related benefits of converting brownfield sites into GI but focus here primarily on the flood and CSO control benefits because of their value to both communities and river health (water quality). Our list of priority sites was generated based on maximum benefits and maximum return on investment taking into consideration CSO and flood control together. It is important to point out that priorities can also be defined in conjunction with other benefits, such as infiltration, or social and economic values. Because one of the strengths of GI is the multiple social and economic benefits it provides, future work should focus on quantifying these benefits so they also can be taken into consideration when prioritizing projects.

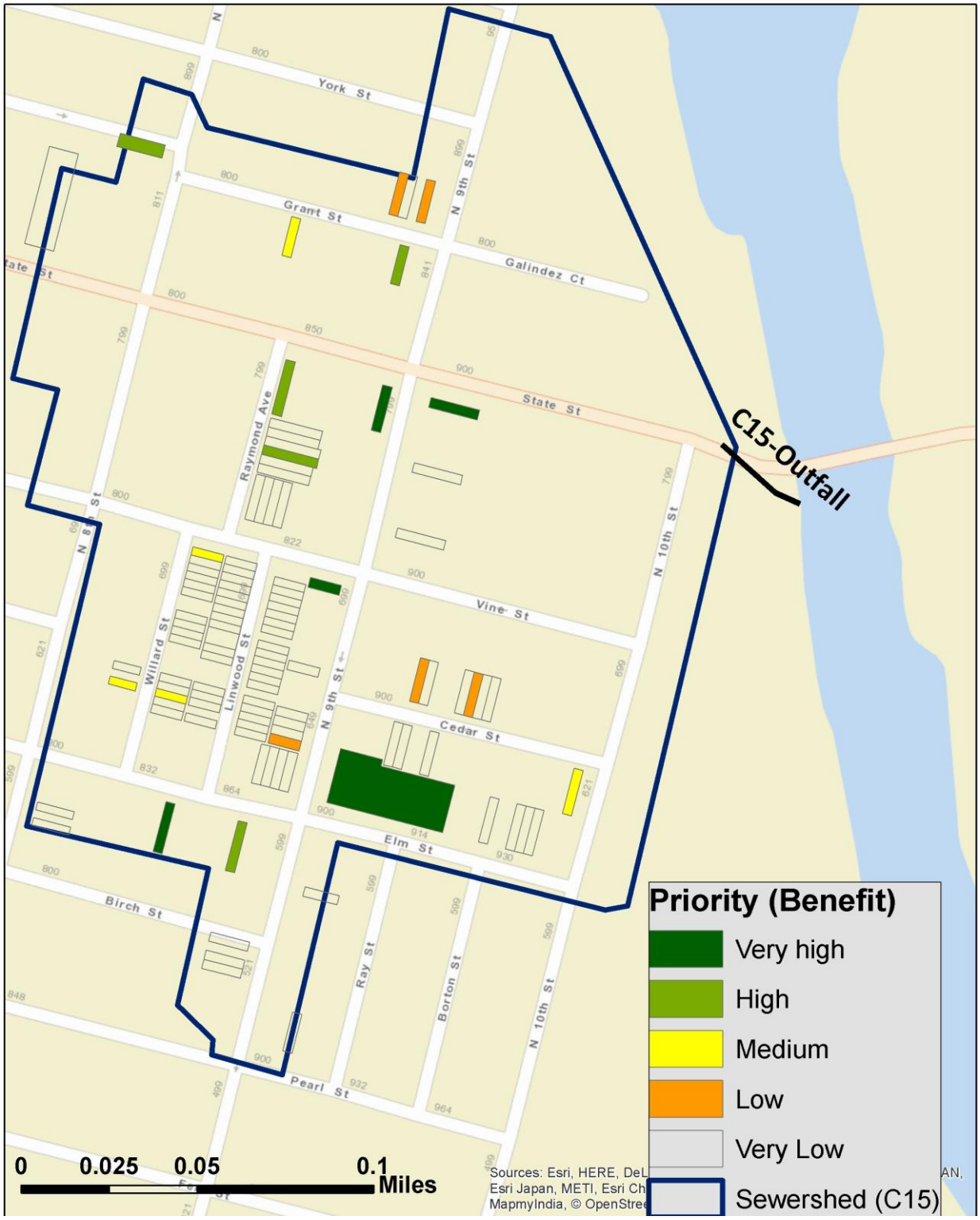

Figure 1: Priority green infrastructure sites for stormwater control (based on maximizing benefits, i.e., selecting the places with highest flood and CSO reductions among all scenarios run). With this prioritization, the implementation of the 10 highest priority sites (very high and high priority) has an expected cost of $328,000 (based on an average price of $20/ft^2 – see the City of Camden Green Infrastructure Design Handbook) and results in 1.35 million gallons reduction of flood volume per year, 10.8 million gallons CSO volume reduction per year, 63.8 million gallons increase in infiltration, and 4.4 million gallons increase in evapotranspiration.

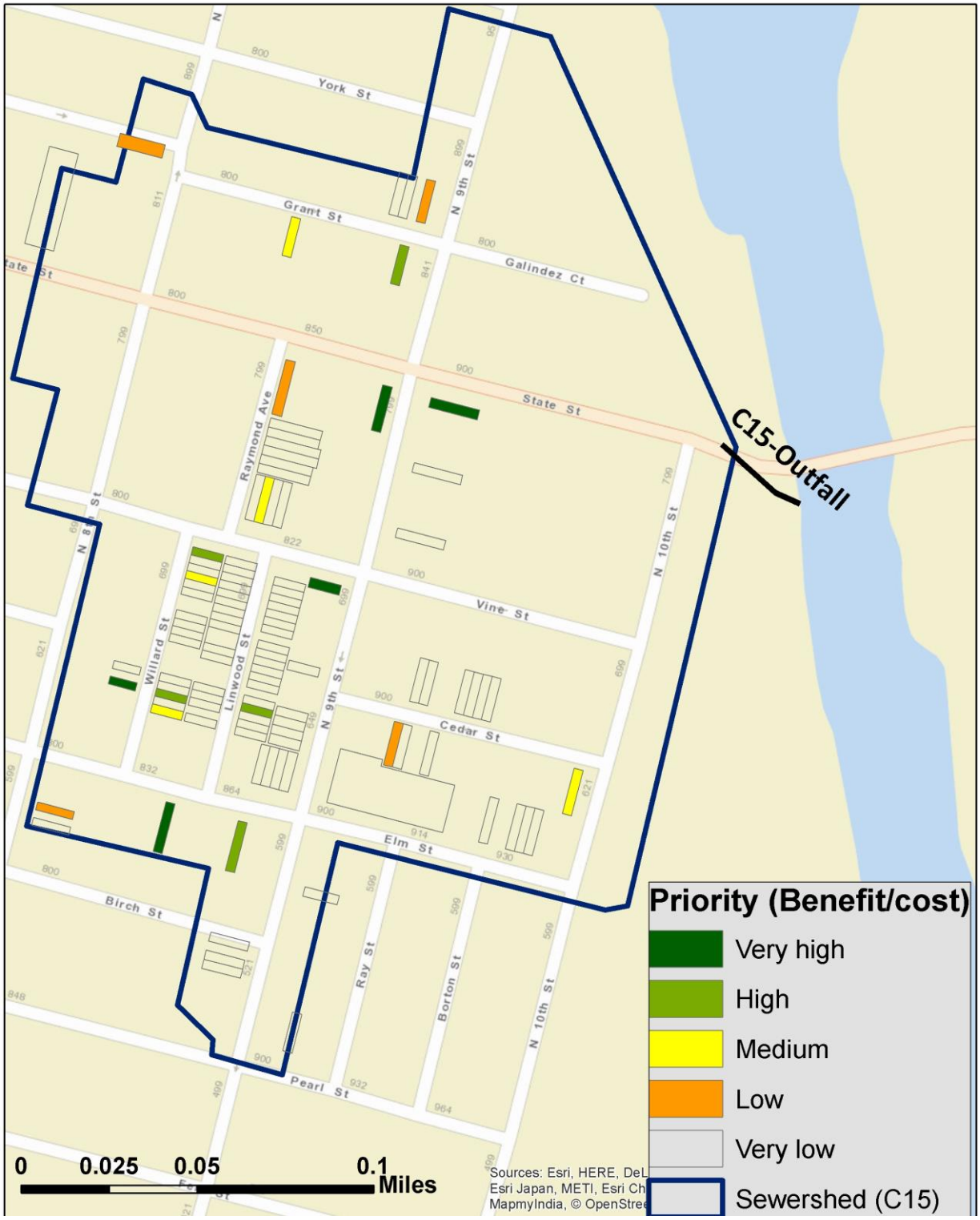

Figure 2: Priority green infrastructure sites for stormwater control (based on maximizing the return on investment, i.e., selecting the places with the highest benefit/cost ratios among all scenarios run). For this scenario, the implementation of the 10 highest priority sites (very high and high priority) sites has an expected cost of $172,000 (based on an average price of $20/ft^2 – see the City of Camden Green Infrastructure Design Handbook) and results in 0.85 million gallons reduction of flood volume per year, 6.8 Million gallons CSO volume reduction per year, 21.3 million gallons increase in infiltration, and 1.5 million gallons increase in evapotranspiration.

Table 1: GI priority list in terms of maximum benefits and maximum benefits/cost

LID info			Property Info				Priority (Benefits)			Priority (Benefits/cost)		
Site ID	LID Area	SW	Address	Block	Lot	Type	Priority	Priority SW	Priority Class	Priority	Priority SW	Priority Class
0	588.0	S55	521 NO 9TH ST	802	93	VACANT LAND	107		Very low	107		Very low
1	436.8	S49	609 LINWOOD ST	797	88	VACANT LAND	25		Very low	26		Very low
2	504.0	S48	609 NO 9TH ST	798	132	CITY PROPERTY 115	49	19	Low	50		Very low
3	504.0	S49	643 NO 9TH ST	798	119	CITY PROPERTY 126	1	2	Very High	1	1	Very High
4	409.6	S49	636 LINWOOD ST	798	97	CITY PROPERTY 128	20		Very low	22		Very low
6	652.1	S70	918 CEDAR ST	800	68	CITY PROPERTY 127	95		Very low	95		Very low
7	681.3	S67	950 CEDAR ST	800	85	VACANT LAND	17	11	Medium	18	12	Medium
10	784.0	S44	716 RAYMOND AVE	786	47	CITY PROPERTY 114	50		Very low	49		Very low
11	478.8	S50	534 NO 8TH ST	801	8	VACANT LAND	62	25	Very low	63		Very low
12	409.9	S48	610 LINWOOD ST	798	112	VACANT LAND	45		Very low	44		Very low
13	735.0	S84	840 STATE ST	786	69	LIST #167	4	5	Very High	4	4	Very High
14	882.0	S42	820 STATE ST	786	59	VACANT LAND	52	8	High	52	18	Low
17	357.2	S46	617 WILLARD ST	796	34	VACANT LAND	6		Very low	6		Very low
18	408.2	S47	640 WILLARD ST	797	47	VACANT LAND	59		Very low	60		Very low
19	630.0	S48	841 ELM ST	798	140	VACANT LAND	94		Very low	94		Very low
20	478.8	S50	538 NO 8TH ST	801	6	VACANT LAND	69		Very low	62	19	Low
21	754.6	S60	822 ELM ST	801	37	CITY PROPERTY 120	3	3	Very High	3	3	Very High
22	980.0	S18	823 NO 8TH ST	777	49	VACANT LAND	48	6	High	32	16	Low
23	652.1	S70	912 CEDAR ST	800	64	VACANT LAND	51		Very low	51		Very low
24	588.0	S55	515 NO 9TH ST	802	95	VACANT LAND	105	27	Very low	105	27	Very low
25	652.1	S74	913 CEDAR ST	799	44	CITY PROPERTY	91	20	Low	92	24	Very low
27	408.2	S49	625 LINWOOD ST	797	68	VACANT LAND	18		Very low	21		Very low
28	754.6	S59	838 ELM ST	801	45	CITY PROPERTY 119	10	7	High	8	7	High
31	408.2	S47	628 WILLARD ST	797	55	VACANT LAND	79		Very low	86		Very low
32	637.0	S5	841 GRANT ST	765	37	VACANT LAND	88		Very low	88		Very low
33	9614.0	S70	600 NO 9TH ST	800	3	VACANT LAND	103	4	Very High	103		Very low
34	681.3	S67	941 ELM ST	800	93	CITY PROPERTY 120	56		Very low	57		Very low

LID info			Property Info				Priority (Benefits)			Priority (Benefits/cost)		
Site ID	LID Area	SW	Address	Block	Lot	Type	Priority	Priority SW	Priority Class	Priority	Priority SW	Priority Class
38	652.1	S74	915 CEDAR ST	799	45	TAX LIEN FORECLOSURE	93		Very low	93		Very low
40	436.8	S52	610 WILLARD ST	797	63	VACANT LAND	27	22	Very low	29	15	Medium
41	408.2	S49	613 LINWOOD ST	797	84	VACANT LAND	74		Very low	77		Very low
42	357.2	S46	613 WILLARD ST	796	37	VACANT LAND	5	14	Medium	5	5	Very High
44	588.0	S10	844 GRANT ST	783	59	FORECLOSURE #163	7	10	High	7	6	High
46	519.4	S58	534 NO 9TH ST	803	6	CITY PROPERTY 143	72		Very low	75		Very low
47	408.2	S47	634 WILLARD ST	797	55	VACANT LAND	80		Very low	85		Very low
48	600.0	S56	905 PEARL ST	803	42	CITY PROPERTY 123	86	21	Very low	80	21	Very low
49	408.2	S58	612 WILLARD ST	797	63	VACANT LAND	12		Very low	12		Very low
50	408.2	S58	614 WILLARD ST	797	63	VACANT LAND	8	13	Medium	9	8	High
51	408.2	S58	616 WILLARD ST	797	63	VACANT LAND	34		Very low	31		Very low
52	408.2	S58	618 WILLARD ST	797	63	VACANT LAND	35		Very low	30		Very low
53	784.0	S44	714 RAYMOND AVE	786	52	VACANT LAND	64		Very low	61		Very low
54	754.8	S88	720 NO 9TH ST	787	19	CITY PROPERTY 142	100		Very low	100		Very low
55	409.6	S48	622 LINWOOD ST	798	105	VACANT LAND	43		Very low	43		Very low
56	681.3	S67	931 ELM ST	800	90	VACANT LAND	63		Very low	69		Very low
57	408.2	S49	615 LINWOOD ST	797	84	VACANT LAND	32		Very low	48		Very low
59	652.1	S73	929 CEDAR ST	799	49	VACANT LAND	90		Very low	91		Very low
60	754.8	S88	706 NO 9TH ST	787	26	CITY PROPERTY 121	99	24	Very low	99	25	Very low
61	637.0	S5	845 GRANT ST	765	40	VACANT LAND	82	17	Low	79	20	Low
62	588.0	S32	820 GRANT ST	783	46	CITY PROPERTY 128	24	12	Medium	17	11	Medium
63	588.0	S48	837 ELM ST	798	140	CITY PROPERTY 119	84		Very low	82		Very low
64	588.0	S48	835 ELM ST	798	140	CITY PROPERTY 119	83		Very low	83		Very low
65	682.8	S44	829 VINE ST	786	53	CITY PROPERTY 137	26		Very low	25		Very low
66	408.2	S47	630 WILLARD ST	797	55	VACANT LAND	73		Very low	76		Very low
67	408.2	S47	632 WILLARD ST	797	55	VACANT LAND	81		Very low	87		Very low
68	681.3	S67	939 ELM ST	800	93	VACANT LAND	78		Very low	78		Very low
69	681.3	S67	937 ELM ST	800	93	CITY PROPERTY 119	68		Very low	68		Very low

LID info			Property Info				Priority (Benefits)			Priority (Benefits/cost)		
Site ID	LID Area	SW	Address	Block	Lot	Type	Priority	Priority SW	Priority Class	Priority	Priority SW	Priority Class
70	652.1	S73	927 CEDAR ST	799	49	CITY PROPERTY 118	89		Very low	89		Very low
71	652.1	S73	925 CEDAR ST	799	49	VACANT LAND	85	16	Low	81	22	Very low
72	652.1	S70	910 CEDAR ST	800	64	CITY PROPERTY	46		Very low	45	17	Low
73	409.6	S48	630 LINWOOD ST	798	105	VACANT LAND	37		Very low	37		Very low
74	652.1	S73	923 CEDAR ST	799	49	CITY PROPERTY 112	92		Very low	90		Very low
75	588.0	S55	517 NO 9TH ST	802	95	VACANT LAND	106		Very low	106		Very low
78	637.0	S11	839 GRANT ST	765	37	CITY PROPERTY 119	87	18	Low	84	23	Very low
79	409.6	S48	632 LINWOOD ST	798	105	VACANT LAND	42		Very low	40		Very low
80	409.6	S48	612 LINWOOD ST	798	112	VACANT LAND	41		Very low	41		Very low
81	409.6	S48	614 LINWOOD ST	798	112	CITY PROPERTY 112	19		Very low	20		Very low
82	409.6	S48	616 LINWOOD ST	798	112	CITY PROPERTY 112	14		Very low	13	10	High
83	409.6	S48	618 LINWOOD ST	798	112	CITY PROPERTY 120	15		Very low	14		Very low
85	474.6	S48	625 NO 9TH ST	798	128	CITY PROPERTY 123	65		Very low	64		Very low
86	474.6	S48	611 NO 9TH ST	798	132	CITY PROPERTY 115	61		Very low	65		Very low
87	474.6	S48	613 NO 9TH ST	798	132	VACANT LAND	67		Very low	67		Very low
88	408.2	S49	633 LINWOOD ST	797	68	VACANT LAND	54		Very low	54		Very low
89	408.2	S49	635 LINWOOD ST	797	68	VACANT LAND	13		Very low	15		Very low
90	816.5	S49	629 LINWOOD ST	797	68	VACANT LAND	102		Very low	102		Very low
91	588.0	S48	839 ELM ST	798	140	CITY PROPERTY 135	96		Very low	98		Very low
92	408.2	S49	617 LINWOOD ST	797	84	VACANT LAND	55		Very low	56		Very low
93	408.2	S47	642 WILLARD ST	797	47	VACANT LAND	33		Very low	46		Very low
94	408.2	S47	644 WILLARD ST	797	47	CITY PROPERTY 128	22		Very low	23	14	Medium
95	408.2	S47	646 WILLARD ST	797	47	CITY PROPERTY 128	23	23	Very low	24		Very low
96	408.2	S47	648 WILLARD ST	797	47	VACANT LAND	57		Very low	59		Very low
97	408.2	S36	812 VINE ST	797	47	VACANT LAND	11	15	Medium	10	9	High
98	408.2	S49	627 LINWOOD ST	797	68	CITY PROPERTY 112	31		Very low	35		Very low
99	409.6	S48	626 LINWOOD ST	798	105	VACANT LAND	38		Very low	39		Very low
100	409.6	S48	628 LINWOOD ST	798	105	VACANT LAND	44		Very low	42		Very low
101	408.2	S49	637 LINWOOD ST	797	68	VACANT LAND	71		Very low	70		Very low

LID info			Property Info				Priority (Benefits)			Priority (Benefits/cost)		
Site ID	LID Area	SW	Address	Block	Lot	Type	Priority	Priority SW	Priority Class	Priority	Priority SW	Priority Class
102	408.2	S49	639 LINWOOD ST	797	68	VACANT LAND	36		Very low	34		Very low
103	408.2	S49	641 LINWOOD ST	797	68	VACANT LAND	30		Very low	33		Very low
104	833.0	S44	718 RAYMOND AVE	786	47	CITY PROPERTY 135	53	9	High	53		Very low
105	474.6	S48	615 NO 9TH ST	798	132	VACANT LAND	66		Very low	66		Very low
106	4724.9	S20	721 STATE ST	777	2	VACANT LAND	104	26	Very low	104	26	Very low
107	833.0	S44	720 RAYMOND AVE	786	47	VACANT LAND	101		Very low	101		Very low
108	784.0	S42	722 RAYMOND AVE	786	47	VACANT LAND	97		Very low	96		Very low
109	784.0	S42	724 RAYMOND AVE	786	47	VACANT LAND	98		Very low	97		Very low
110	682.8	S44	827 VINE ST	786	53	CITY PROPERTY 137	28		Very low	27		Very low
111	682.8	S44	825 VINE ST	786	53	CITY PROPERTY 137	21		Very low	19	13	Medium
112	682.8	S44	823 VINE ST	786	53	CITY PROPERTY 137	29		Very low	28		Very low
113	408.2	S49	643 LINWOOD ST	797	68	VACANT LAND	70		Very low	71		Very low
114	409.6	S49	644 LINWOOD ST	798	97	CITY PROPERTY 143	60		Very low	55		Very low
115	409.6	S49	646 LINWOOD ST	798	97	CITY PROPERTY 143	40		Very low	36		Very low
116	409.6	S49	648 LINWOOD ST	798	97	CITY PROPERTY 143	47		Very low	47		Very low
118	409.6	S48	624 LINWOOD ST	798	105	VACANT LAND	39		Very low	38		Very low
119	408.2	S49	645 LINWOOD ST	797	68	VACANT LAND	58		Very low	58		Very low
120	408.2	S49	647 LINWOOD ST	797	68	CITY PROPERTY 112	16		Very low	16		Very low
121	408.2	S49	649 LINWOOD ST	797	68	CITY PROPERTY 112	9		Very low	11		Very low
122	409.6	S49	638 LINWOOD ST	798	97	CITY PROPERTY 143	76		Very low	74		Very low
123	409.6	S49	640 LINWOOD ST	798	97	CITY PROPERTY 123	75		Very low	72		Very low
124	409.6	S49	642 LINWOOD ST	798	97	CITY PROPERTY 123	77		Very low	73		Very low
125	787.5	S87	734 NO 9TH ST	787	5		2	1	Very High	2	2	Very High

Priority – Overall rank

Priority SW – Rank taking into consideration sites that cover the same drainage area

Priority Class – Rank 1-5: Very High; 6-10: High; 11-15: Medium; 15-20: Low; Lower than 20: Very low

Accumulated benefits for strategically versus randomly selected green-infrastructure sites

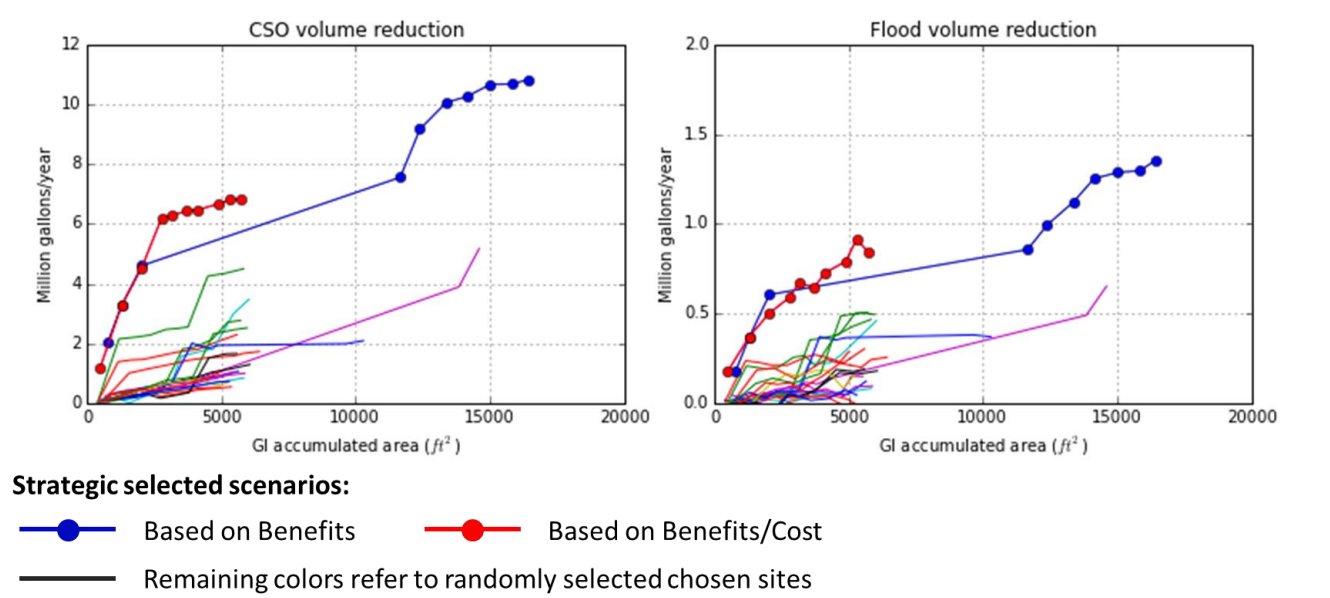

Figure 3: Accumulated benefits for strategically versus randomly chosen green-infrastructure sites. The benefits for sites selected based on maximizing benefits are shown in blue, and for sites selected based on maximizing benefits/cost are shown in red; all other colors represent scenarios with randomly selected sites. We selected the sites by evaluating the combined benefits for flood and CSO volume reduction. Note: in some instances, it is possible for the flood benefits (millions of gallons reduced per year) to actually decrease with the addition of acres of green infrastructure; these instances are because of nonlinearities in flood behavior, such as if water is held and released with sub-optimal timing, decreasing the amount of water that can be removed from the system.

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