Part 1: Task B-E Summary Report

Stormwater Retrofit Plan for the College Street Storm Drain System

October 22nd, 2013

Presented To:
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I. Project Progress Summary

Watershed Consulting Associates, LLC, (WCA) in partnership with Lakeside Environmental Group (LEG), Waite-Heindel Environmental Management (WHEM), SMM Engineering (SMM), and Urban Rain Design (URD), was hired under ERP contract # SW-1-2013 to assess the College St. storm drain watershed for stormwater retrofit opportunities and prepare designs for the top priority BMPs within the allotted project budget. The following report summarizes the methods and results of the work completed to date for the following tasks including;

- Task B: Field Investigation and Existing Data review
- Task C: Hydrologic & Hydraulic/Water Quality Modeling
- Task D: Retrofit Options Assessment and GI Tool Kit Development
- Task E: Retrofit Alternatives Ranking and Feasibility Analysis

The initial phase of the project was initiated with a kick-off meeting on April 9th, 2013 at which time the project schedule, goals, and available data was reviewed with the team and City personnel. The project team then completed a field investigation of the site, to verify the watershed boundary and collect an initial survey of BMP opportunities. The project team then completed a thorough review of the existing GIS mapped infrastructure database for discrepancies and omissions from existing record drawings and field verified structure locations.

Figure 1: Project team discusses BMP feasibility at ICV site

WHEM initiated a soils evaluation which involved the selection of five test pit sites where a BMP would be followed by infiltration testing at each site to characterize the soil. Infiltration rates at the five sites were between 2-12 in/hr all of which exhibited infiltration feasible on site, with the exception of BS#1, where stormwater infiltration would be possible but not ideal.

Figure 2: LEG partner, S. Smith, completing the site survey to collect spot elevations

WCA reviewed the City's existing SWMM model for the College Street watershed, including parameter inputs, model assumptions, subwatershed delineations, and selection of junction points. The existing model junction inverts were estimated based on 2-ft contours and an assumed roadway slope, therefore a topographic survey was conducted to collect rim elevations at key junction structures along the stormline (Figure 2). Water quality inputs were also added to the model to estimate TSS and Phosphorus loading in the watershed. A revised existing conditions model was then developed, which estimated a peak flow for the WQ storm of 5.45 cfs.

Once the infrastructure and soils data was assessed the project team completed a thorough survey of the watershed for BMP opportunities (Figure 1). BMPs were considered of all scales ranging from small

LID bioretention systems within existing green space, to more-intensive streetscape changes involving traffic re-routing and/or parking realignment, with a focus on sites West of Battery St.

A Green-Infrastructure (GI) toolbox was also developed to highlight several strategies available for implementation in the watershed, including bioretention filters in the median, bump out filters, green gutters, etc. A map was prepared to show the location of possible retrofit opportunities and the type of BMP, based on the tool-box.

A retrofit screening matrix was developed to initially prioritize all possible BMPs. The ranking matrix was then reviewed with the City to complete the first two screening phases. The third screening phase involved input of the top ranked BMPs (37 sites) into the SWMM model, to assess the watershed-wide impact of the BMP's.

Through the screening process, the team identified three primary focus areas each with a collection of BMPs, including the Bank St./Pine St. area, the College/Pine intersection, and the City of Burlington/Hilton parking garage area. The final screened BMP list included two large-scale infiltration BMPs which both are connected to a collection of upstream BMPs. A full-build out of the BMPs within the three focus areas was estimated to decrease the WQ-storm peak flow by 31% at the outfall, and 52% at the last junction point downstream of a proposed BMP (Junction 4).

II. Methods and Results by Task

Task B: Field Investigation, Existing Data Revisions (PM 3)

Completion of Task B involved a soils evaluation, field verification of existing stormwater infrastructure and revisions to the GIS existing infrastructure mapping database. Infrastructure and subwatershed mapping revisions were completed based on information collected from a series of site visits in the watershed, review of all existing GIS data, as well as available historical site plans and record drawings. A total station survey was completed on 5-16-2013 to collect primary storm manhole and catch basin rims along the main stormline. A base map was prepared for the watershed including the surveyed structures (A-1-1). WHEM completed a review of available soils information for the watershed and conducted an initial soils site characterization at five sites. Several sites suitable for infiltration were identified and are discussed below.

Figure 3: Project Team reviews site plan in field to verify drainage mapping.

Soils Evaluation

The soil borings and infiltration testing was conducted by WHEM on May 22-23, 2013. The testing sites had been pre-selected by WHEM with input from the team, and had been cleared by DIGSAFE and by two private property owners (Peoples Bank and Investors Corporation of Vermont) as displayed in A-2-1. The five (5) borings were installed using a post-hole digger followed by a 3.5-in diameter stainless steel bucket auger, resulting in a 3.5-in diameter boring. Once installed to the depth of interest, an infiltration test was conducted by filling the borings with 24 in of clean water. The infiltration testing process was similar to the process outlined in Appendix D1 of the Vermont Stormwater Management

Manual (VSMM), with the following modifications: 1) the testing zone varied in depth, as there was not an established STP bottom; 2) a solid 2-inch diameter casing was used initially, then we decided to remove the casing and add water directly to the borehole (see discussion below); and 3) water drop was measured at 1 hr intervals for the borings, but we also decided to measure the drop every 10 minutes for two of the borings (we have called the 1 hr interval "long term" and the 10 minute interval "short term"). The short term test with open borehole is similar to the Percolation Test Procedure as per Appendix 4-A of the Chapter 1 Wastewater System and Potable Water Supply Rules (WSPWS). Also, for the evaluation of the infiltration test data, rather than use the average drop or value of the last drop as recommended in the VSMM, we graphed the drop data on a log-log plot and forecasted the drop rate at 24 hours, as recommended in the WSPWS Rules.

The results for the five borings (BS #1, 2, 3, 4 & 5) are shown on the attached boring logs (A-2-2). The stratigraphy was generally noted to be a thin veneer of sandy loam/fill over fine sand. The fine sand extended to at least a depth of 11 ft where a silt zone was encountered, and was loose-friable to approximately 6 ft, where it became firmer. In the eastern-most boring (BS#5), the sand had a gravel content down to approximately 4 ft. In general, the sand between 2-6 ft appears to be ideal for stormwater infiltration.

Table 1: Summary Infiltration Test Data

Boring	Infiltration Test Zone (in)	Measure-ment Interval	Open Borehole or PVC Pipe	Soil in Test Zone	Infiltration Rate in/hr	Infiltration Rate min/in
BS #1	72-96"	Long (1 hr)	Open Borehole	Medium Sand, firm	2	30
BS #2	48-72"	Long (1 hr)	PVC Pipe	Fine Sand, loose	10	6
BS #3	28-52"	Long (1 hr)	Open Borehole	Fine-Medium Sand, firming	7	9
BS #4	53-77"	Long (1 hr)	Open Borehole	Fine Sand, firming	5	12
BS #4	53-77"	Short (10 min)	Open Borehole	Fine Sand, firming	8	8
BS #5	49-73"	Short (10 min)	Open Borehole	Fine Sand with Fine Gravel Layer	12	5

***May 22-23, 2013, College Street Stormwater Study, Burlington, Vermont, Prepared by WHEM**

The infiltration testing results are shown in the attached graphs (A-2-2) and summary table 1 (above). The results show an infiltration rate between 2 and 12 in/hour. The results for BS #2, which is the only test done using PVC casing, can be considered vertical infiltration capacity, as it utilized a 2 ft water head exposed to the sand at a depth of 72 in (Figure 4). This was clearly the fastest vertical infiltration rate; the tests at both BS #1 and BS #3 utilized the PVC casing for the first hour, and had essentially no drop, so the PVC was removed. Hence, the results for BS #1, 3, 4 & 5 can be considered both vertical and horizontal infiltration capacity, as the 2 ft water head was exposed to the 24 in borehole. Based on the test at BS #1, the firm sand between 72-96 in had the slowest drop

Figure 4: Soil sample collected 5-22-13 exhibiting sandy soil

rate, suggesting this is too deep for stormwater infiltration. Based on the test at BS #5, the fastest drop rate was in the fine-medium sand with some gravel. Lastly, comparison between the long-term and short-term test at BS #4 shows a faster drop rate for the short-term test indicative of faster infiltration into the upper zone (4-5 ft) sand than the lower zone (5-6 ft) sand. In conclusion, the sand in the 4-6 ft zone under this portion of College Street has a conservative horizontal/vertical infiltration rate of 5 in/hour.

Task C: Hydrologic & Hydraulic/Water Quality Modeling (PM3)

The WCA project team completed revisions to the City's existing SWMM model for the watershed as well as the addition of a baseline water quality analysis in completion of Task C. In order to develop a true existing conditions model, WCA completed several site visits to verify drainage mapping and reviewed all available existing site plans and record drawings of the watershed to verify stormsewer infrastructure mapping. Subcatchment delineations and junctions were refined based on revised drainage boundaries and stormsewer infrastructure mapping. In addition, a total station survey was completed on May 16th, 2013 to obtain true manhole rim elevations for input into the revised model.

Model Revisions Summary:

Initially, WCA reviewed the existing SWMM 5 models for the College St. Storm Drain watershed, developed in 2007. Two models were provided for review—1)"college_swmm.inp", 2) "college_swmm2_inp". It was confirmed by Steve Roy who developed of the models, that the model "College_SWMM2.inp" was the most up to date. This model was reviewed for variable entries to determine which entries were defaults versus site-specific values. It was our understanding that invert elevations for junctions (storm manholes) were based on 2 foot contours developed from LIDAR data and the assumption that pipes were laid to grade with a consistent burial depth, and not based on survey data. A consistent manhole sump depth was assumed to be 7 feet for all stormwater junctions included in the model and a maximum depth (pipe size) was assumed for all conduits to be 1.25 feet.

To develop a true, rather than relative existing conditions model for the watershed WCA completed the following:

- Identified critical junction locations (11) along the main storm line based on the most up-to-date stormsewer infrastructure mapping.
- Refined subcatchment mapping into ten (10) catchments based on revised mapping and junction locations.
- Developed revised entries for subcatchment properties including:
    - **Percent impervious**: Based on City's GIS impervious mapping layer for revised subcatchments
    - **Area:** Used SWMM auto-calculate tool using scaled basemap
    - **Width:** Divided the length of the longest overland flow path (not including channelized flow i.e. pipe or gutter flow) by the subcatchment area in accordance with the SWMM Applications Manual (SWMM 2009)
    - **Percent slope:** Slope of the longest overland flow path using LIDAR derived 2 ft contours

- Calculated true junction invert elevations based on surveyed rim elevations and rim tape downs (City Manhole Inventory sheets completed on 5-21 and 5-31).

- Revised conduits and roughness (n) entries based on field verified pipe sizes and materials (City Manhole Inventory sheets completed on 5-21 and 5-31).

Baseline Model Results ("WCA_College_6-7.inp):

The previous model was run using 24-hr design storm intensity distributions based on the SCS Type II intensity-duration-frequency (IDF) curve. The Northeast Regional Climate Center developed storm-specific IDF curves based on Burlington rainfall data. Therefore, 24-hr intensity distributions were developed using the VT-Burlington IDF curves for the WQ (0.9") event and 10-yr (3.10") event. The model was run for the water quality (0.9") and 10-yr (3.1") 24-hr design storms and assessed at the outfall as summarized in Table 1. The pollutant loading estimates were modeled using a general initial build-up (lbs/acre) for all the subcatchments and pollutant washoff based on pollutant specific event mean concentrations (EMCs).

Table 2: Baseline SWMM model results at Outfall node

Model: WCA_college_SWMM_6-7
Run Duration: 24 hours

Outfall Node	Storm Event	Avg. Flow (cfs)	Peak Discharge (cfs)	Total Volume (acft)	Total TSS (lbs)	Total Phosphorus (lbs)
Out1	WQ (0.9")	0.68	5.45	1.332	25.563	0.247
	10-yr (3.1")	2.59	20.99	4.910	27.609	0.468

The total water quality volume estimate for the existing model is within 1% of the water quality estimate using the empirical methodology as outlined in the VSWMM (Table 2).

Task D: Retrofit Options Assessment (PM4)

The project team completed a GIS desktop and field assessment of potential retrofit locations as well as the development of a GI tool box specific to the College St. watershed in completion of Task D.

Initially, WCA completed a desktop assessment of the watershed for site identification considering WHEM's soils evaluation, revised infrastructure data, and overall knowledge of the watershed. After an initial set of retrofits were identified, a site visit with the project team's green infrastructure expert, Kevin Perry of Urban Rain|Design and project team staff was completed on June 10th, during which the entire watershed was assessed for additional retrofit opportunities. In addition to identifying individual BMP sites, boarder redevelopment goals for the City's pedestrian core as outlined in Burlington's "Plan BTV" were considered. An inventory sheet was completed for each retrofit site identified in the field, recording feasibility criteria including land ownership (i.e. private vs. public), utility conflicts, transportation, pedestrian safety, collateral benefits, and ease of operation/maintenance (Example sheet- A-3-1).

A green infrastructure tool box was prepared to highlight over 19 different strategies which would work at various sites throughout the watershed (A-3-2). A short description of each strategy along with an existing conditions photo and proposed condition example photo is included in the attached tool box sheets (Figure 5). The focus of the various strategies was to target the first flush and water quality storm event (0.9" design storm), however several of the practices have the potential to reduce peak discharges from higher flow rain events (1-yr, 2-yr storm events).

Figure 5: Theoretical Before and After in front of Peoples Bank property

A map was prepared to show the location of all possible retrofit sites, with an identification of the BMP(s) best suited for the site from the attached green infrastructure tool box (A-3-3).

Task E: Retrofit Alternatives Ranking and Feasibility Analysis (PM5)

The College St. project team completed a three phase BMP screening process in completion of Task E from which we developed a final list of the top selected retrofit sites for design (Table 3 below). In addition to the final screening list of flow-mitigation BMP's, additional sites were identified for erosion control which will be included in the final design phase (Figure 10 below).

WCA prepared a retrofit ranking matrix, which involved ranking each BMP based on a series of criteria including treatment method (e.g. infiltration, filtration), land ownership (private vs public), infiltrative capacity, upstream vs downstream location in watershed, cost, water quality benefits (i.e, phosphorus treatment), collateral benefits (aesthetics), and site constraints (e.g. utilities, permitting). A range of values were assigned each ranking criteria depending on the weighting of the criteria. The BMP opportunities identified in Task D were ranked from 25 (highest) to 11 (lowest score) (A-4-1).

The project team then met with the City in early August to review the ranking matrix and initial list of possible retrofit sites. Site specific constraints were discussed as well as overall goals of the project. A follow up meeting was held on August 16th, 2013 with the project team, City personnel, Sandrine Thibault, Principal Planner for Comprehensive Planning, and the Assistant Director of economic development at CEDO, Nick Wildfire, to further discuss and prioritize the identified retrofit opportunities within the context of broader redevelopment goals for the City and potential funding opportunities.

The second screening involved synthesizing the comments, concerns, and observations from the past meetings with the feasibility ranking information to develop a prioritized list of sites. Subwatersheds were developed for the screened BMPs and entered into the existing conditions SWMM model, in order to assess various BMP collection scenarios.

The final screening list presented in Table 3 below was based on a combination of factors, including the BMP's impact on the overall College St. subwatershed peak discharge (cfs), volume capture of the individual BMP, visibility within the watershed, and feasibility ranking using the ranking matrix (See A-4-2 Final Screening Map). The BMPs presented in the final screening list are designed for flow mitigation. The final list presented includes more sites than will be moved to the design phase because there are land ownership constraints and/or conflicting redevelopment goals with the sites on private lands that need to be resolved. The alternative sites allow for the flexibility to continue evaluating other projects in the event that one or both of the larger storage BMPs (PS2-A, CS4-A) are determined to be infeasible.

Table 3: BMP list after final screening

BMP Subwatershed	Zone	Screen 1 Ranking (25-max, 11-min)	BMP Type
BNK1-A	Bank	24	Curb Bump Out
BNK1-B			Green Gutter
BNK1-C			Curb Bump Out
PS2-A	Peoples Bank	25	Infiltration Unit
PS1-A	Pine East	20	Bioretention
PS1-F			Curb Bump Out
PS1-G			Curb Bump Out
PS1-H			Burb Bump Out
BTC2-A	Mall Alley	15	Terraced Planters
BTV1-A	Parking Garage South	23	Roof top planter box
BTV1-B			Roof top planter box
BTV1-C			Bioretention (2 units)
CS1-A	College St. 1	22	Curb Bump Out
CS1-C			Curb Bump Out
CS2-A	College St. 2	24	Curb Bump Out
CS2-C			Curb Bump Out
CS4-A	College St. 4/ICV	23	Large Infiltration Unit

The watershed-wide impact of the final screened list of BMPs was assessed at the outfall, as well as the upstream junction, J4 (corner of Battery St and College St), below which there are no proposed BMPs. It was estimated that the full-build out of the Final Screened BMPs presented here would reduce the WQ-storm peak discharge by 52% at J4, and an overall reduction of 31% at the outfall.

FLOW MITIGATION FOCUS AREAS:

The approach of selecting the top retrofits involved identifying priority focus areas (discussed below) where a collection of several flow mitigation BMPs could be implemented. The motivation for this approach was due to the typical size for a green infrastructure BMP in the ROW. This type of BMP is inherently limited in size and capacity, and therefore a subcatchment can be managed more properly with a collection of smaller BMPs. In addition, there was interest from the City to focus on one area within the College St. watershed as a demonstration of a more comprehensive green street redevelopment project which could be implemented elsewhere in the City.

Focus Area 1: College St./ Pine St. Intersection Redevelopment

The intersection of College St. and Pine St. (Figure 6) is a priority focus area for redevelopment because the road width is currently wider than necessary and is along the pedestrian byway connecting the waterfront to Church St. The excess width and visibility of the intersection along College St. make the site a primary candidate for a focused green infrastructure improvement area. The concept attached (A-4-3) shows a possible BMP layout with seven (7) bump-out planters and an alteration of parallel to angular parking on the East side of Pine St. north and south of the intersection. The parking alteration would allow the space for a bump out BMP in the ROW, and reduce the road width which would slow traffic and improve pedestrian safety. Flow through planters with infiltration wells would be implemented within the bump outs to address the first-flush and peak discharge, as well as safe overflow during high-flow events.

Figure 6: College St/Pine St Vignette demonstrating BMP placement and parking alterations (URD 92613)

Focus Area 2: Bank St. / Pine St.

Bank St. is a visible highly trafficked area with a continual erosion issue due to heavy pedestrian traffic through the ROW medians. In addition, the back entrance to the Church St. Mall is located along this portion of Bank St. which the Mall ownership would like to improve. Therefore, Bank St./Pine St. is a focus area for implementation of several BMPs. A concept is attached (A-4-4) demonstrating an approach that would provide aesthetic and functional improvements without impacting on-street parking. The BMPs would include a bump out flow-through planter at the top of Pine St, a green gutter along the South side of Bank,

Figure 7: Example of Stormwater planters with on street parking proposed for Bank St.

and a bioretention planter connected to a bump out on the North side. In addition, hardscapes would be proposed at each parking meter to create intentional pedestrian pathways (See project example in Figure 7). Overflow from the planters would enter the pipe network, which would connect to a large infiltration unit located in front of Peoples Bank. The People's Bank BMP would capture runoff from the upstream BMPs as well as surface runoff from the roadway. The City however has identified this site for potential housing redevelopment, which may conflict with the proposed BMP. There is potential to incorporate the People's Bank BMP with the possible redevelopment plan, however the redevelopment goals are still in the planning phase. This BMP would provide a large benefit to the College Street storm drain basin, and therefore is still on the priority list for design.

Focus Area 3: City of Burlington/ Hilton Parking Garage

The third focus area within the College St. Watershed is the City of Burlington and Hilton parking garage. The subcatchment is almost 95% impervious located in the upper portion of the watershed and almost all the flow is directly connected to the pipe network. The goal for this area would be to utilize the existing green space, primarily the center median in the garage entrance (Figure 8) for stormwater mitigation. The collection would include two roof-top planters, a vegetated swale, and a bioretention cell within the exiting median. The bioretention cell would be designed to infiltrate flow on-site, and overflow would enter the pipe network as before. While this collection is not as visible as the other focus areas, addressing runoff within this subcatchment area allows for a more comprehensive spread of the treatment within the College St. Watershed.

Figure 8: City of Burlington/Hilton Garage conceptual layout

ICV Property BMP:

The ICV property was identified as an opportune location for implementation of a large-scale infiltration BMP due to the availability of open space and good natural soil ideal for infiltration. In addition, the location of the site, at the bottom of College St., would allow the main stem of the College St. stormwater network to be rerouted through the BMP, reducing the need for many smaller BMPs along College St. The Team will be working with the City and the Property owners to understand the availability of the site for implementation of a stormwater BMP.

EROSION MITIGATION FOCUS AREAS:

The reduction of sediment loading due to erosion from stormwater flows is one of the strategies for improving water quality at the College St. basin outfall. In addition stabilizing exposed soil areas improves the aesthetics of the area and reduces the Cities ongoing maintenance responsibilities. WCA conducted a hotspot assessment of the watershed and found that erosion due to destabilized open space was the primary hot spot of concern (ie. versus dumpster spillage, illicit discharge, etc).

Figure 9: Erosion trench along E-W walking path (Site BTV3-C)

The East-West walking path between the Mall East Entrance/Cherry St. Parking garage and Peoples Bank property (Figure 10-Subcatchments BTV3-A and BTV3-C) was selected as a priority site for erosion mitigation. The pathway is steep, along which a six (6) inch trench has formed on the south edge along the concrete (Figure 9).

The WCA team proposes to include a design for mitigating the erosion along the walking path, through a type of armoring and/or hardscape, which can be applied at other sites in the watershed as well. Site BTC2-A, the north-south alleyway connecting to Cherry Street, is also a site where erosion mitigation is a priority. This site will be addressed with a flow-mitigation BMP as well as erosion control, and therefore is included in the final screening list (Table 3).

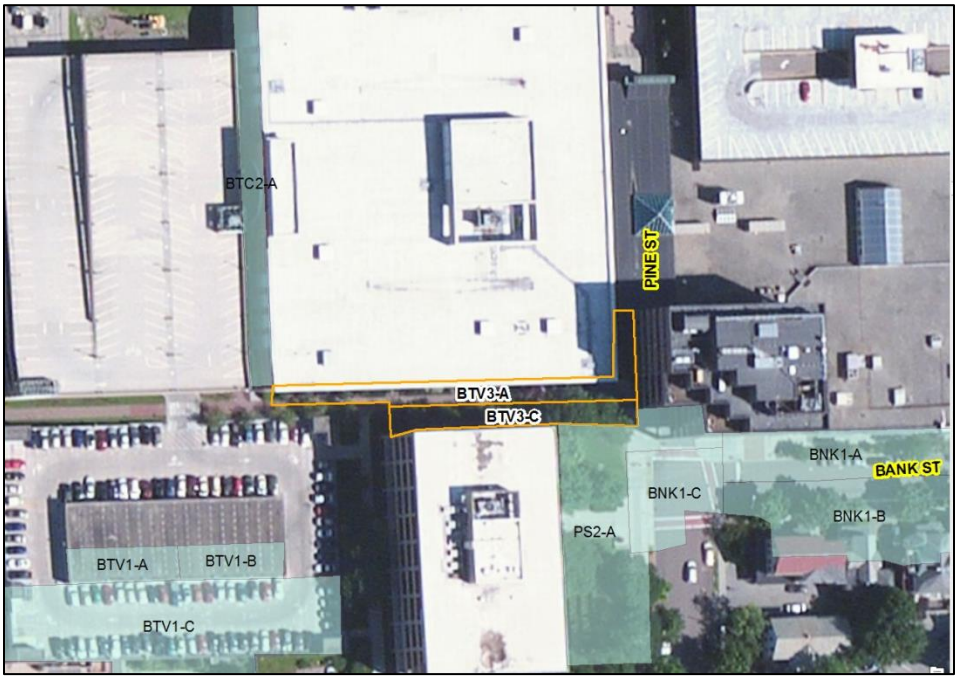


Figure 10: Erosion mitigation sites BTV3-A and BTV3-C, along walking path.

III. Next Steps

As of now, the WCA project team has characterized the watershed, revised and developed SWMM models including the existing conditions and post condition with BMP's scenarios, and prioritized potential BMP opportunities, in order to identify the final list of screened BMPs for design consideration. The next phase of the project will involve the design and cost estimation for a collection of BMP's to meet the allotted budget of $200,000. The next steps will involve the following tasks:

- ✓ Continue follow-up with ICV and Peoples Bank property owners to confirm the potential use of the property for a stormwater retrofit.
- ✓ Develop rough cost estimates for BMP build out in the three proposed focus areas, to prioritize the design phase.
- ✓ Determine additional survey needs regarding soils, drainage paths utility conflicts, and other constraints needed for initial engineering design.
- ✓ Complete additional survey work as needed.
- ✓ Develop final basis of design for each BMP site.
- ✓ Quantify peak discharge reductions as well as TSS and Phosphorus loading reductions from each BMP.
- ✓ Develop concept design plans (20%) for each BMP site. Plans will be sufficient to confirm layout, sizing, elevation control, drainage flow paths, and other critical details needed to verify engineering feasibility and to prepare construction cost estimates.
- ✓ Prepare final cost estimate for each practice for the remaining design engineering required to implement the project as well as construction costs.

Appendices:

Appendix 1:
- A-1-1: Basemap with Rim Elevations

Appendix 2:
- A-2-1: Soils Testing Logs
- A-2-2: Soil Testing Map

Appendix 3:
- A-3-1: GI Inventory Sheet
- A-3-2: GI Toolkit for the College St. Storm Drain Basin
- A-3-3: GI Opportunities Map

Appendix 4
- A-4-1: Retrofit Ranking Matrix
- A-4-2: Final Screening Map
- A-4-3: College/Pine Intersection Design Concept
- A-4-4: BankSt/PineSt Design Concept

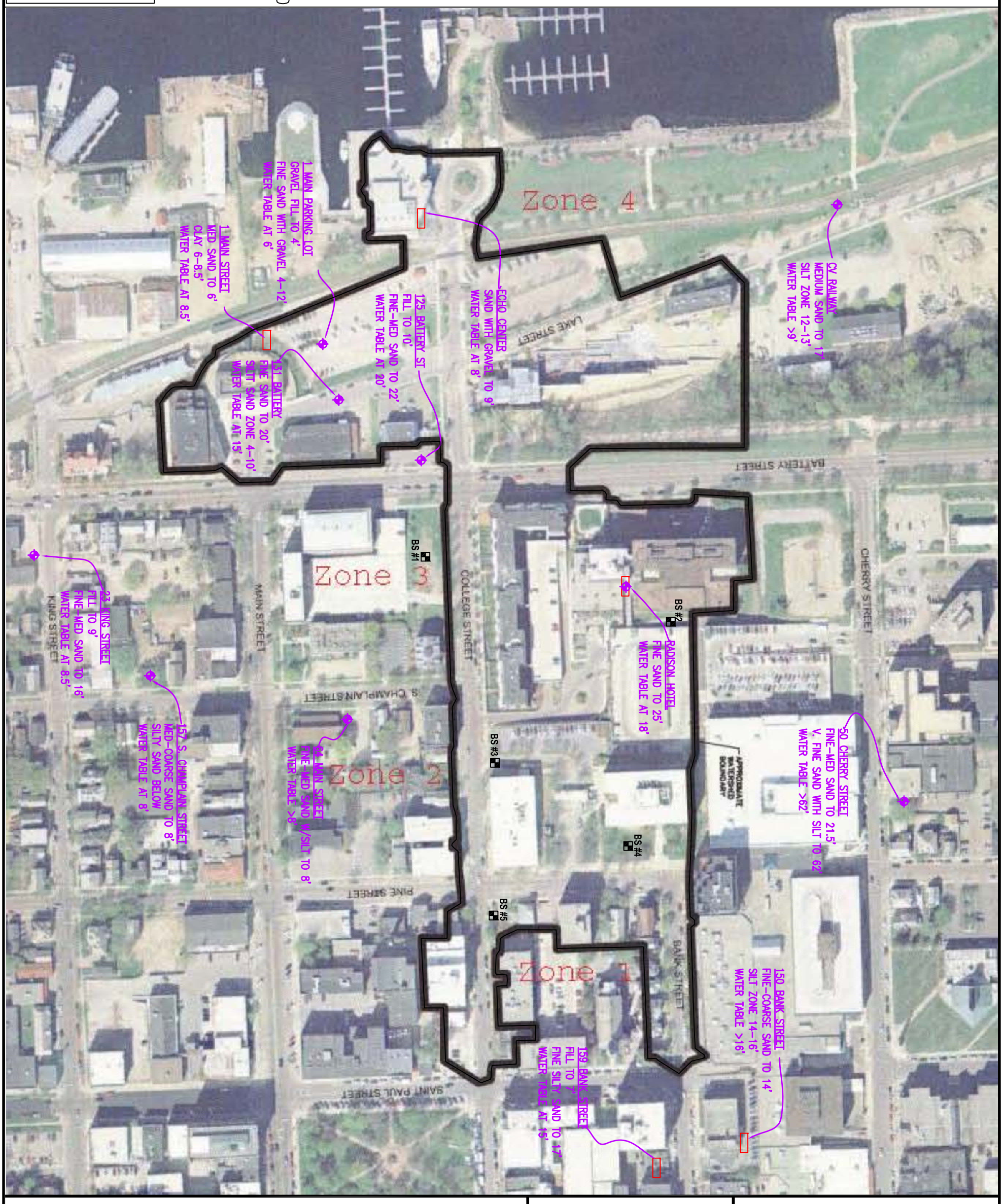
APPENDIX 1

GRAPHIC SCALE

60 0 30 60 120 240

(IN FEET)
1 inch = 60 ft.

APPENDIX 2



STUDY AREA WITH EXISTING DATA AND FIELD TESTING SITES	DATE: 05-28-13	Waite - Heindel Environmental Management
	PROJECT NO.	W H Waite - Heindel E M • Hydrogeology • Environmental Services • Water and Wastewater Design • Burlington, Vermont • (802) 860-9400
COLLEGE STREET STORMWATER STUDY BURLINGTON, VERMONT	DRAWN BY: MW	
	PROJ. MGR: WK	
	APPROVED: MW	
SCALE: 1" = 200'	FILE: Burlington Stormwater Plan.dwg	☒ DRAFT ☐ FINAL
		SHEET: 1

Soil Boring Logs

Boring Number:	**BS #1**
Site Name:	**College Street Stormwater Study** **ICV Property**

WEM Project # 2013-10
Installed by: Waite-Heindel Environmental Management
Logged by: MW, WK

Date Installed: 5/22/2013
Drilling Method: hand auger
Sampling Method: na
Development Method: na

Soil Boring	Depth Below Ground Surface	Color	Texture and Description
BS #1	0-4"	Dark Brown (7.5 YR 3/3)	Fine Sandy Loam, loose, roots
	4-10"	Red (7.5 YR 4/4)	Gravel Fill, firm
	10-60"	Yellowish Brown (10 YR 5/4)	Fine Sand, poorly graded, loose
	60-96"	Reddish Brown (2.5 YR 5/4)	Fine Sand, becoming Fine- Medium Sand below 72", firmer
	End of Boring		
	72-96"	*Infiltration Test Zone*	

Boring Number:	**BS #2**
Site Name:	**College Street Stormwater Study** **East of Hilton Hotel**

WEM Project # 2013-10
Installed by: Waite-Heindel Environmental Management
Logged by: MW, WK

Date Installed: 5/22/2013
Drilling Method: hand auger
Sampling Method: na
Development Method: na

Soil Boring	Depth Below Ground Surface	Color	Texture and Description
BS #2	0-9"	Very Dark Grayish Brown (10 YR 3/2)	Fine Sandy Loam, loose, roots to 6"
	9-30"	Brown (10 YR 3/4)	Fine Sand, poorly graded, granular, loose
	30-72"	Olive Brown (2.5 Y 4/3)	Fine Sand, poorly graded, granular, loose
	End of Boring		
	48-72"	*Infiltration Test Zone*	

Soil Boring Logs

Boring Number:	**BS #3**
Site Name:	**College Street Stormwater Study** **South of Peoples Bank Parking Lot at edge of College St.**

WEM Project # 2013-10 — Date Installed: 5/22/2013
Installed by: Waite-Heindel Environmental Management — Drilling Method: hand auger
Logged by: MW, WK — Sampling Method: na
Development Method: na

Soil Boring	Depth Below Ground Surface	Color	Texture and Description
BS #3	0-7"	Dark Brown (10 YR 3/3)	Fine Sandy Loam, loose, some gravel
	7-22"	Brown (10 YR 3/4)	Fine Sand with few gravel, loose, tree root at 17"
	22-35"	Dark Yellow Brown (2.5 Y 4/4)	Fine-Medium Sand, poorly graded, granular, loose
	35-38"	Dark Yellow Brown (2.5 Y 4/4)	Fine Sand, poorly graded, firmer
	38-51"	Brown (10 YR 4/3)	Fine Sand with Fine Gravel, mottled reddish brown
	51-63"	Brown (10 YR 4/3)	Fine Sand, iron staining
	63-67"	Brown (10 YR 4/3)	Very Fine Sand with Silt, no iron staining
	67-96"	Brown (10 YR 5/3)	Fine Sand, no iron staining
	96-130"	Brown (10 YR 5/3)	Very Fine Sand, iron staining
	130"-135"	Brown (10 YR 5/3)	Silt, damp
	End of boring		
	28-52"	*Infiltration Test Zone*	

Boring Number:	**BS #4**
Site Name:	**College Street Stormwater Study** **East of Peoples Bank**

WEM Project # 2013-10 — Date Installed: 5/23/2013
Installed by: Waite-Heindel Environmental Management — Drilling Method: hand auger
Logged by: MW, WK — Sampling Method: na
Development Method: na

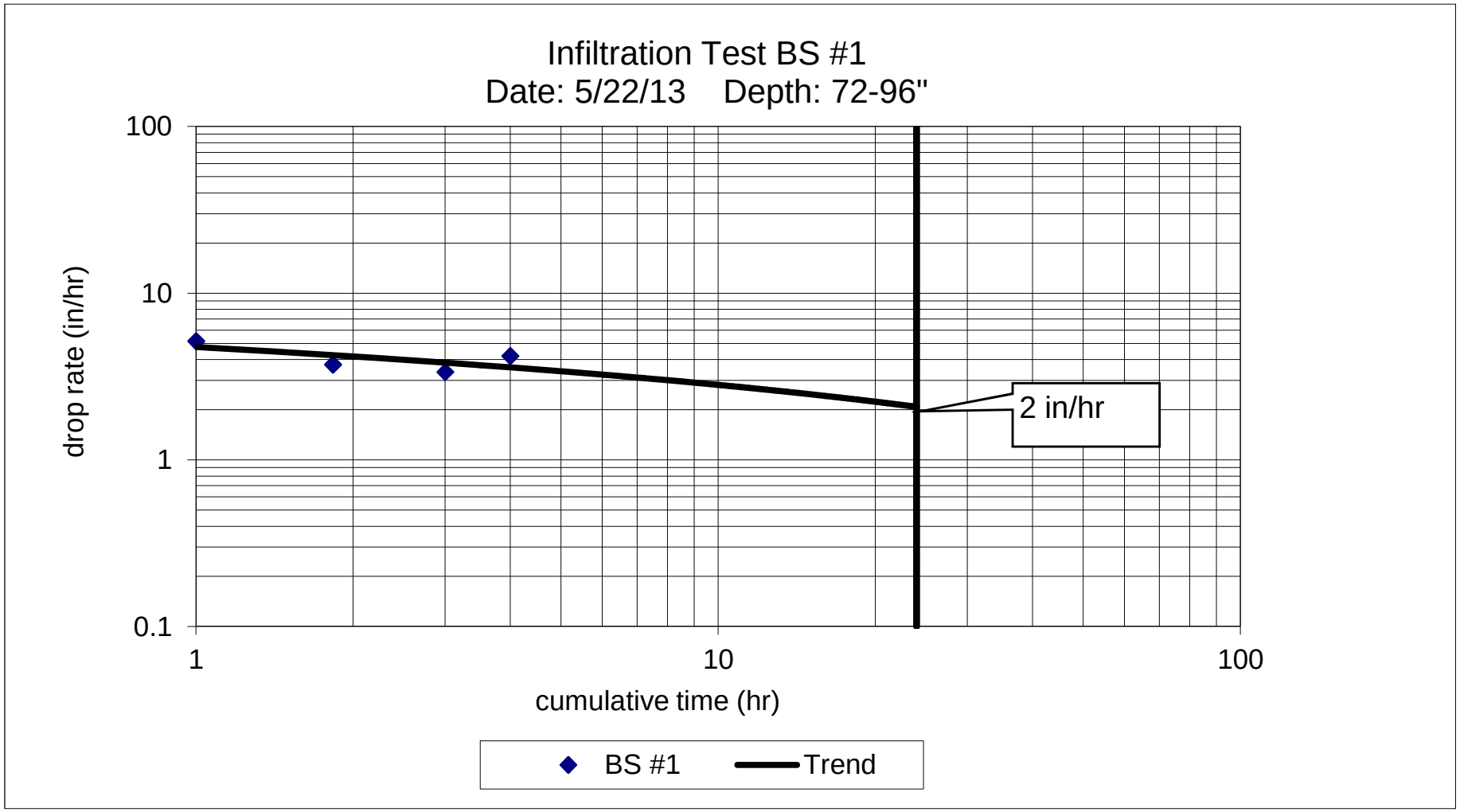
Soil Boring	Depth Below Ground Surface	Color	Texture and Description
BS #4	0-10"	Very Dark Grayish Brown (10 YR 3/2)	Fine Sandy Loam, loose, roots
	10-47"	Reddish Brown (2.5 YR 4/3)	Fine Sand, well graded, granular, loose
	47-48"	Reddish Brown (2.5 YR 4/3)	Fine Sand, light iron staining
	48-76"	Dark Reddish Brown (2.5 YR 5/3)	Fine Sand, no iron staining, firming
	End of boring		
	53-77"	*Infiltration Test Zone*	

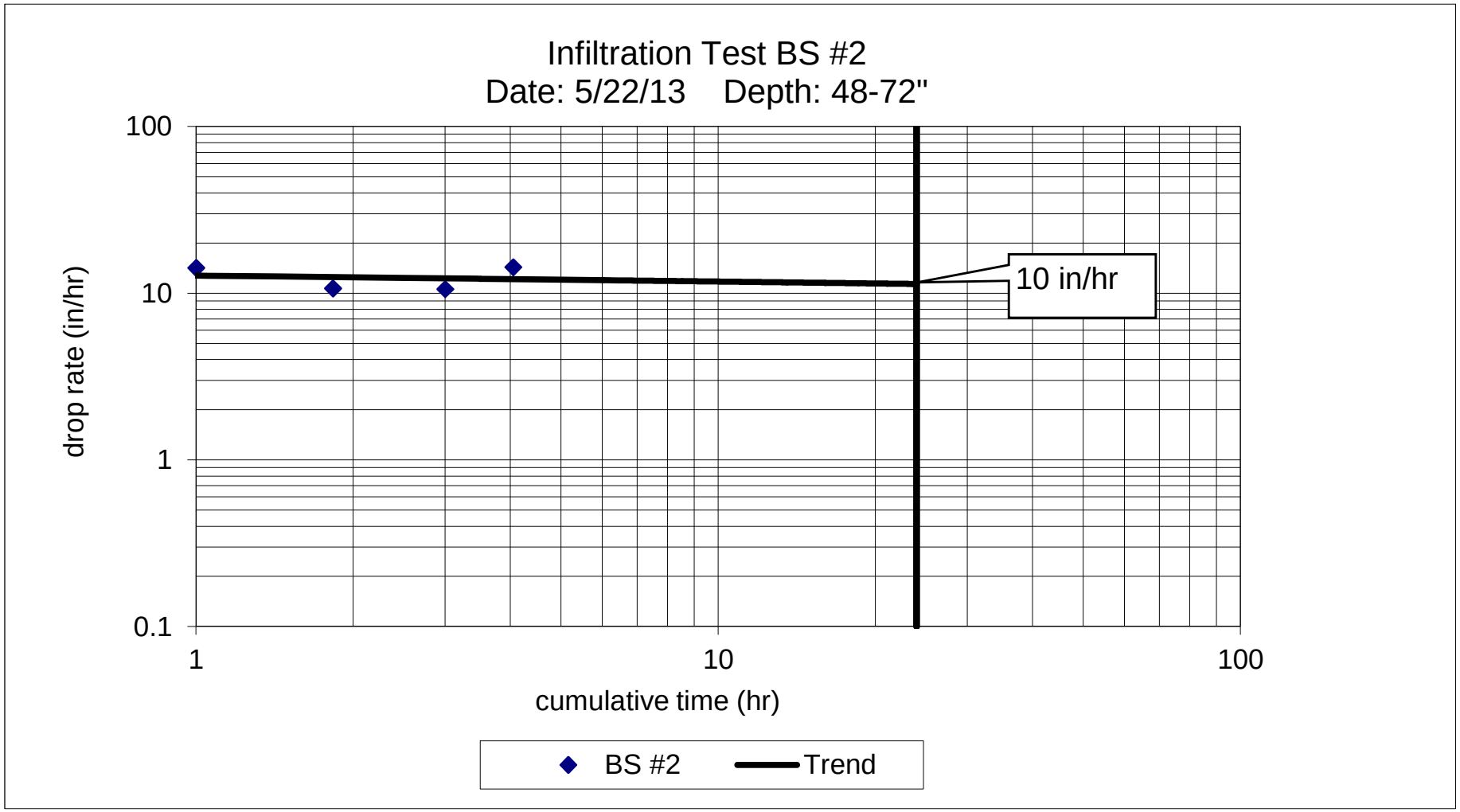
Soil Boring Logs

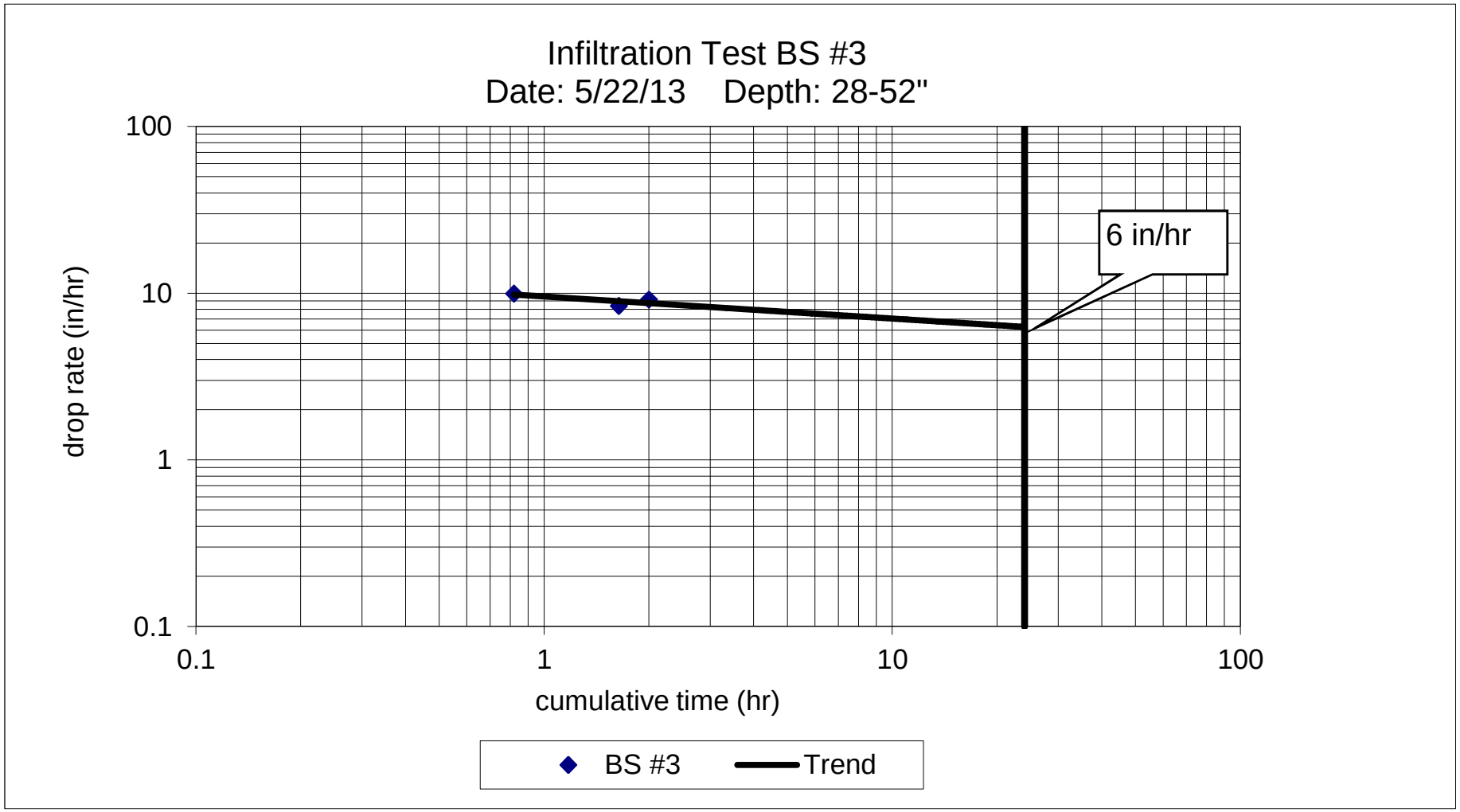
Boring Number:	**BS #5**
Site Name:	**College Street Stormwater Study** **South of Key Bank at Edge of College Street**

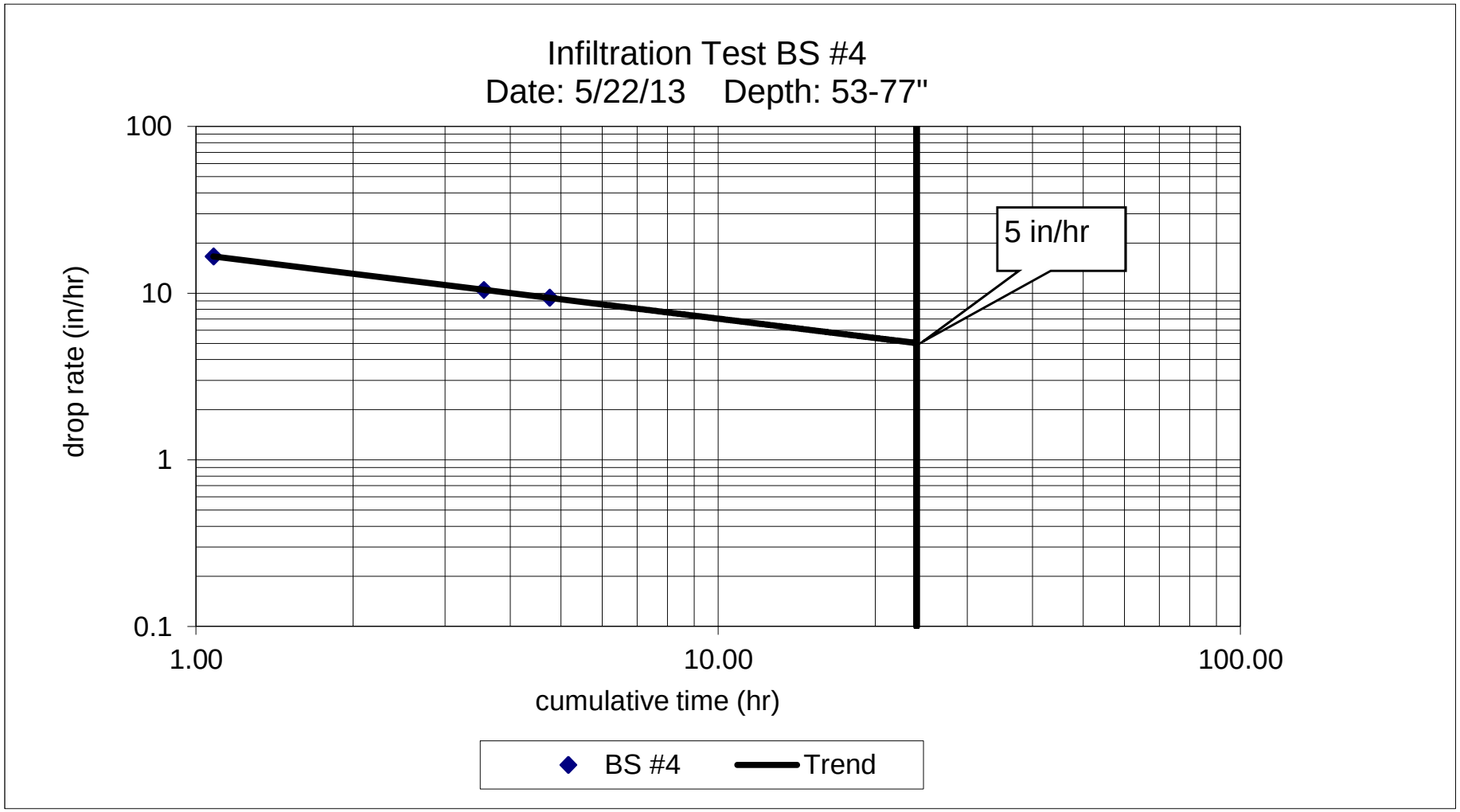
WEM Project #	2013-10	Date Installed:	5/23/2013
Installed by:	Waite-Heindel Environmental Management	Drilling Method:	hand auger
Logged by:	MW, Wk	Sampling Method:	na
		Development Method:	na

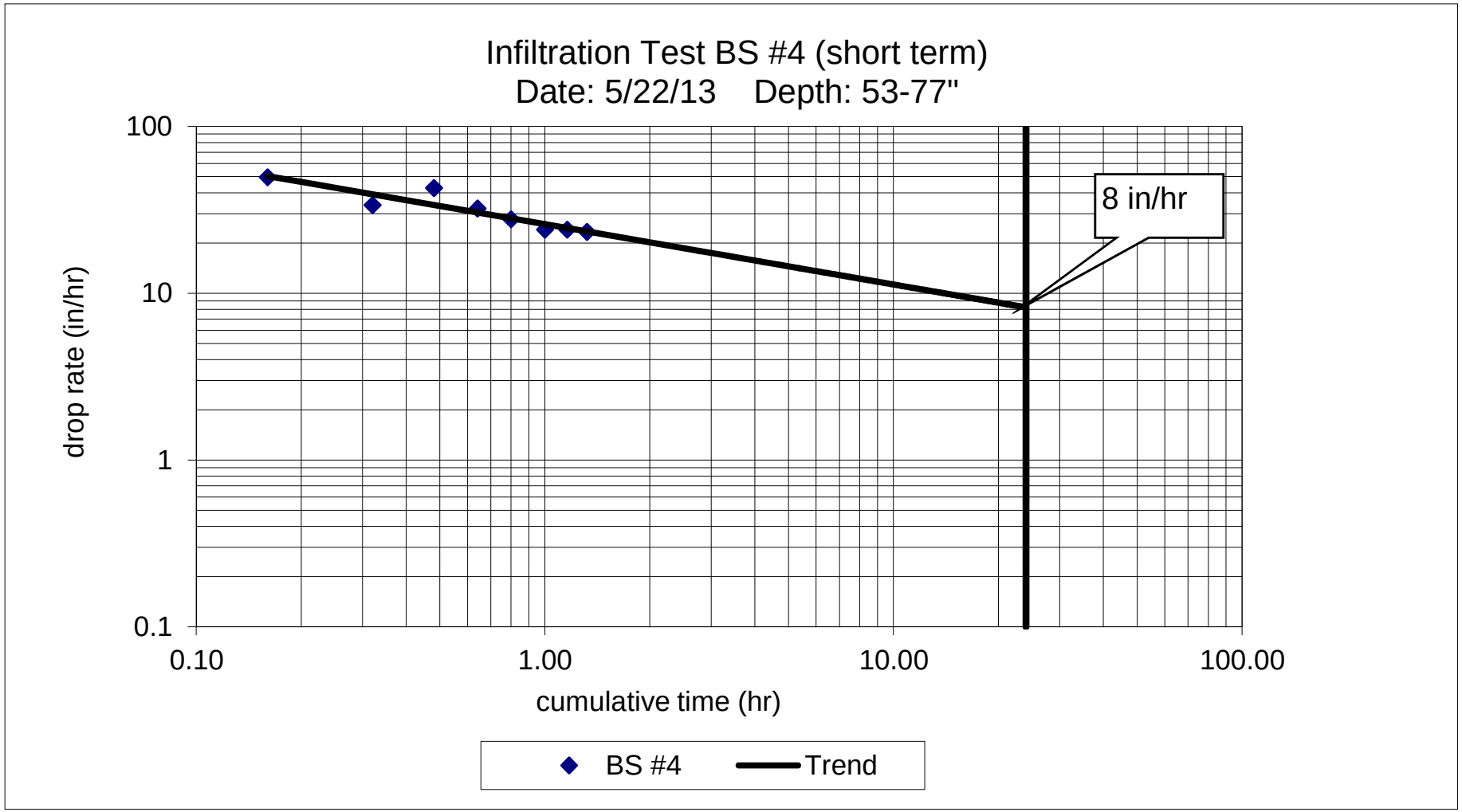
Soil Boring	Depth Below Ground Surface	Color	Texture and Description
BS #5	0-5"	Very Dark Brown (7.5 YR 2.5/2)	Loam (top soil)
	5-7"	Very Dark Brown (7.5 YR 2.5/2)	Fine gravel (fill)
	7-15"	Very Dark Grayish Brown (10 YR 3/2)	Fine gravel (fill)
	15-40"	Very Dark Grayish Brown (10 YR 3/2)	Fine Sand with Fine Gravel, well graded, loose
	40-42"	Olive Brown (2.5 Y 4/3)	Very Fine Silty Sand, well graded, loose
	42-46"	Very Dark Grayish Brown (10 YR 3/2)	Sand with Fine Gravel, friable
	46-56"	Olive Brown (2.5 Y 4/3)	Fine-Medium Sand, poorly graded, firming
	56-72"	Light Olive Brown (2.5 Y 5/3)	Fine Sand, poorly graded, iron staining below 68"
	End of boring		
	49-73"	*Infiltration Test Zone*	


Infiltration Test BS #1
Date: 5/22/13 Depth: 72-96"
100
10
1
0.1
drop rate (in/hr)
1
10
100
cumulative time (hr)
2 in/hr
BS #1
Trend


Infiltration Test BS #2
Date: 5/22/13 Depth: 48-72"
100
10
1
0.1
drop rate (in/hr)
1
10
100
cumulative time (hr)
10 in/hr
BS #2
Trend


Infiltration Test BS #3
Date: 5/22/13 Depth: 28-52"
100
10
1
0.1
drop rate (in/hr)
0.1
1
10
100
cumulative time (hr)
6 in/hr
BS #3
Trend


Infiltration Test BS #4
Date: 5/22/13 Depth: 53-77"
100
10
1
0.1
drop rate (in/hr)
1.00
10.00
100.00
cumulative time (hr)
5 in/hr
BS #4
Trend


Infiltration Test BS #4 (short term)
Date: 5/22/13 Depth: 53-77"
100
10
1
0.1
drop rate (in/hr)
0.10
1.00
10.00
100.00
cumulative time (hr)
8 in/hr
BS #4
Trend

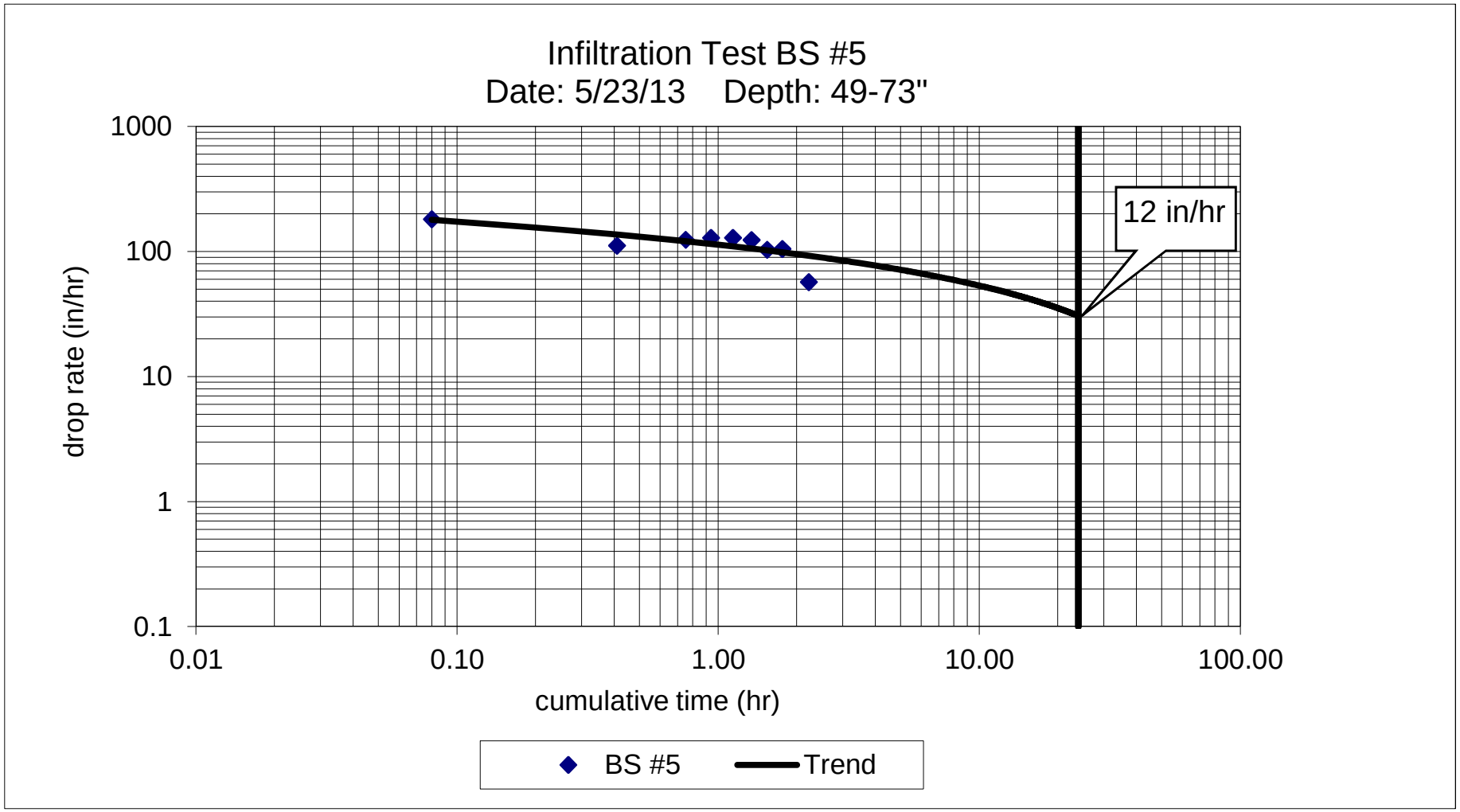

Infiltration Test BS #5
Date: 5/23/13 Depth: 49-73"
1000
100
10
1
0.1
drop rate (in/hr)
0.01
0.10
1.00
10.00
100.00
cumulative time (hr)
12 in/hr
BS #5
Trend

TABLE 1
Summary Infiltration Test Data
College Street Stormwater Study
Burlington, Vermont

Boring	Infiltration Test Zone (in)	Measurement Interval	Open Borehole or PVC Pipe	Soil in Test Zone	Infiltration Rate in/hr	Infiltration Rate min/in
BS #1	72-96"	Long (1 hr)	Open Borehole	Medium Sand, firm	2	30
BS #2	48-72"	Long (1 hr)	PVC Pipe	Fine Sand, loose	10	6
BS #3	28-52"	Long (1 hr)	Open Borehole	Fine-Medium Sand, firming	7	9
BS #4	53-77"	Long (1 hr)	Open Borehole	Fine Sand, firming	5	12
BS #4	53-77"	Short (10 min)	Open Borehole	Fine Sand, firming	8	8
BS #5	49-73"	Short (10 min)	Open Borehole	Fine Sand with Fine Gravel Layer	12	5

APPENDIX 3

Green Infrastructure Retrofit Inventory Sheet

Location:		**BMP Description:**	
Today's date:	**Time (Military):**	**Investigators:**	**Form completed by:**
GPS Unit:		**Camera:**	**Photo #s:**
Ownership: ☐ Private ☐ Public		**Type:** ☐ Infiltration ☐ Filtration	

Feasibility Ranking Criteria: (Engineering Feasibility)

☐ Utility Conflicts:

☐ Transportation Constraints (traffic, safety, etc.):

☐ Collateral benefits (scenic, air, pedestrian, visibility):

☐ Ease of Operation and Maintenance:

☐ Location within Watershed ("Upstream vs "Downstream") :

Assessment Criteria:

☐ Cost per greened acre:

☐ Water Quality treatment capabilities (e.g. P, TSS removal):

Discussion:

Sketch:

College Street Stormwater Basin

Stormwater Opportunities Toolkit

Burlington, Vermont

June 2013

WATERSHED CONSULTING ASSOCIATES, LLC

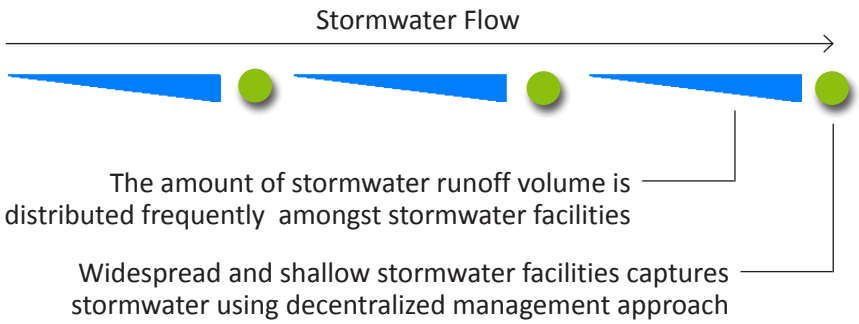
Urban Rain | Design

The Office of Kevin Robert Perry, ASLA

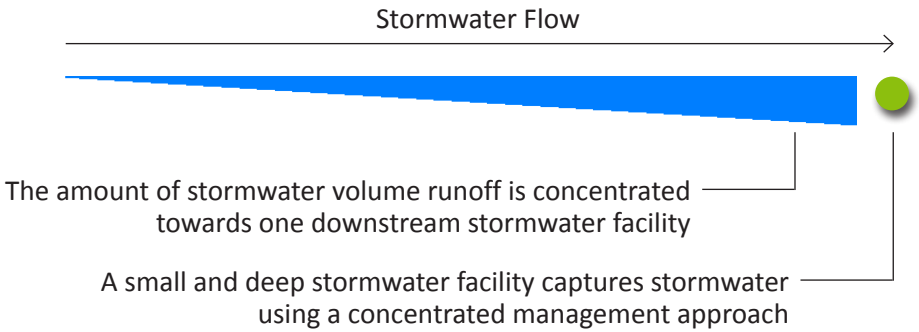
Stormwater Approach

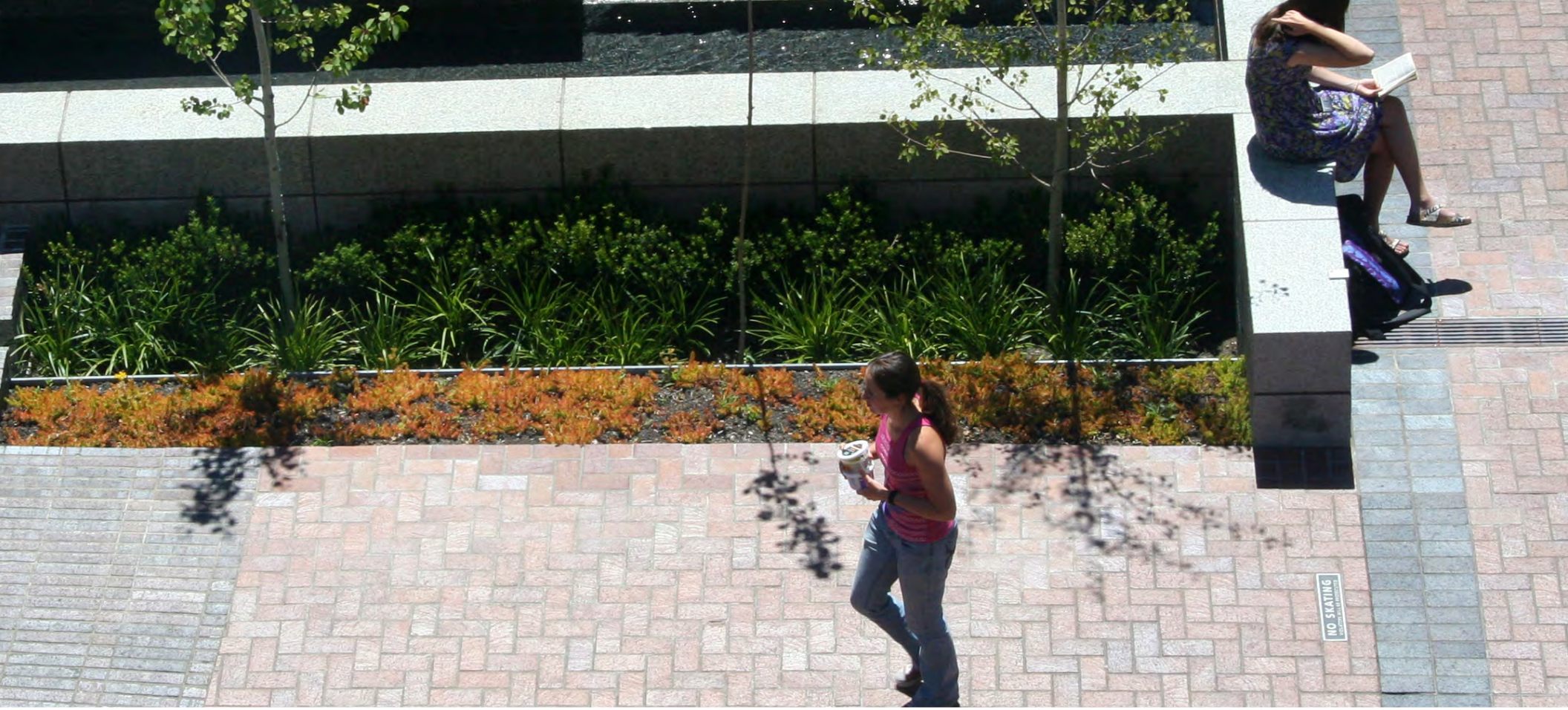
The overall approach to manage stormwater runoff within the College Street Drainage Basin is a rather simple one of creating a decentralized, shallow, and widespread stormwater system used to capture, slow, cleanse, and infiltrate runoff. In the past, stormwater runoff in ultra-urban conditions has been managed in a opposite way by concentrating a lot of runoff, flow, and pollutant loads to small and deep stormwater facilities (most likely in the form of planters or curb extensions sited near existing inlets). Though this approach does work in some situations, it limits the choice of plant material, creates awkward pedestrian conflicts, and can often be aesthetically unattractive. The decentralized approach for downtown Burlington suggests spreading shallow stormwater facilities along the entire streetscape frontage as much as possible thereby capturing runoff before it becomes too concentrated and heavy in volume. In addition, the approach would allow for much greater plant diversity and integration with other streetscape amenities. For example, the High Line Park project in New York City (shown to the left of the opposite page) uses a shallow, widespread, and decentralized approach to stormwater management. In contrast, the example shown in Portland illustrates a concentrated and deep stormwater curb extension located at the bottom of the street's catchment that is not well integrated with the pedestrian zone.

Decentralized Natural Capture Approach



Concentrated Capture Approach





The Stormwater Management Opportunities Toolkit

Based on Burlington's College Street Drainage Basin existing conditions, site constraints, and the latest streetscape design thought, we have identified 16 different design opportunities that could potentially be employed throughout the project area. The 16 opportunities listed on the following pages are separated into three specific sub-groups based on their stormwater management style and location: Impervious Area Reduction/Site Improvements, At-grade Stormwater Facilities, and Above-Ground Runoff Capture and Management. It is envisioned that many of these opportunities will be used as a combined effort to develop an overall stormwater management goal and/or design theme. Many of the opportunities have been successfully designed and built and can be modified to fit the vernacular of downtown Burlington. Some opportunities are new ideas that have yet to be built, but would have very good applicability to the overall downtown area.

Impervious Area Reduction/Site Improvements

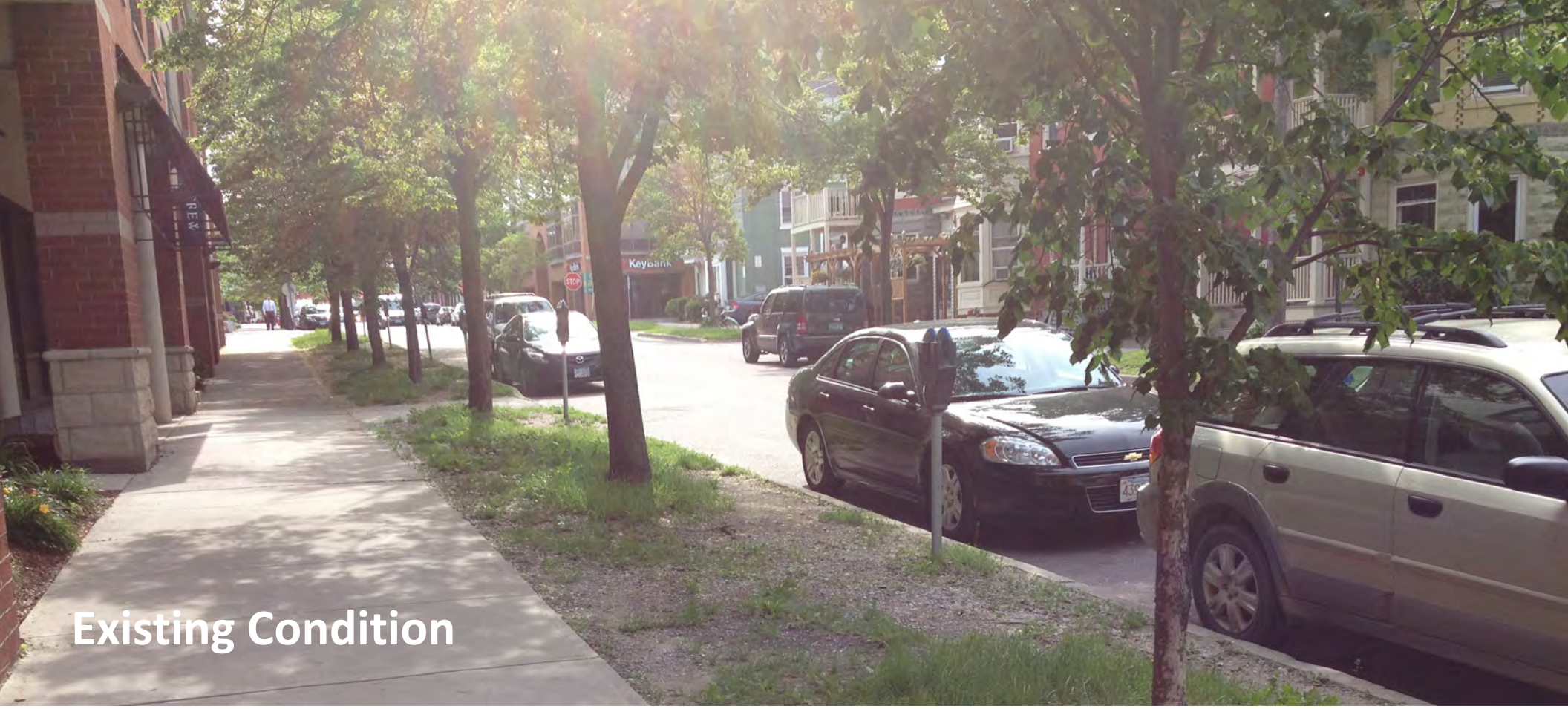
1. Conventional Landscaping with Pedestrian Paths at Sidewalk Zones

At-Grade Capture Stormwater Facilities

2. Stormwater Curb Extensions (Parallel Parking)
3. Stormwater Curb Extensions (Diagonal Parking)
4. Rain Garden (Urban Context)
5. Rain Garden (Landscape Context)
6. Stormwater Planter (Without On-Street Parking)
7. Stormwater Planter (With On-Street Parking)
8. Stormwater Planters (Parking Lot Condition)
9. Stormwater Swale (Parking Lot Condition)
10. Stormwater Planters (Along Pathways)
11. Stormwater Planters (Terraced)
12. Green Gutter (Along Street)
13. Green Gutter (Along Pathways)
14. Green Infiltration Joints/Pervious Paving

Above-Ground Capture and Management

15. Stormwater Planter (On Top of Parking Structure)
16. Rooftop Stormwater Canopies Directing Water to Landscape



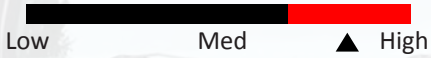
1
STRATEGY

Conventional Landscaping with Pedestrian Paths at Sidewalk Zones

Enhancing conventional landscaping and pedestrian circulation along the street frontage has a lot of benefits and is a commonly undervalued approach to stormwater management. Many downtown streets are often paved from the building zone to the curb zone with little or no ground plane landscaping. From a stormwater perspective, every square foot of new conventional landscape space is essentially removing the same amount of impervious area off the stormwater collection system. Many cities, such as Chicago, New York, and Washington D.C. have made a conscious effort to introduce more landscaping to the streetscape in order to redefine the character of downtown streets and enhances the pedestrian experience. The photo to the right shows a downtown street in Nashville not only functioning as a vibrant streetscape, but also reduces the impervious area of the sidewalk zone significantly.

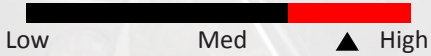
Range of Cost: $10 to $20/Square Foot

Ability to Avoid Underground Utilities:



Use with Poor Soil Conditions:

Ability to Green the Overall Streetscape:



Opportunities:

- Helps provide landscape areas as well as defined zones for pedestrian circulation
- Offers a low-tech, landscape approach to impervious surface removal
- Can be placed over most utilities
- Reduces or eliminates soil erosion

Constraints:

- Little or no stormwater retention depth
- May not be considered, from a policy, funding, and maintenance perspective, a viable stormwater management solution

Existing Condition

2

STRATEGY

Stormwater Curb Extensions (Parallel Parking)

There are many instances along streets within the College Street Drainage Basin where the parking zones could be reconfigured to allow for stormwater curb extensions. These types of stormwater facilities replace either existing parking spaces or areas within the parking zone striped as “no parking” with a landscape system that captures stormwater runoff. The example above shows the existing street condition with parallel parking along College Street and the sketch to the right depicts a parking zone with a stormwater curb extension inserted.

Range of Cost: $25 to $30/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

Low Med ▲ High

Opportunities:

- Can significantly "green" a street with minimal investment.
- Can be inexpensive to build
- Can act as a "backstop" to capture stormwater flow on steep streets
- Can narrow portions of a street and provide traffic calming benefits
- Allows for ease of pedestrian access to parking meters

Constraints:

- Generally requires the removal of on-street parking
- Can sometimes conflict with bike travel if adequate space is not allowed between edge of curb extension and a street's travel lane

3

STRATEGY

Stormwater Curb Extensions (Angled Parking)

Pine Street offers a unique opportunity to convert the existing parallel parking spaces on one side of the street into 45 degree angled parking. This can be done because Pine Street has a rather wide curb-to-curb distance. Within the newly created angled parking zone, intermittent stormwater curb extensions can be inserted. The photo to the right shows a downtown street with angled stormwater curb extensions.

Example

Range of Cost: $25 to $60/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

Low Med ▲ High

Opportunities:

- Can significantly "green" a street with minimal investment.
- Can act as a "backstop" to capture stormwater flow on steep streets
- Can narrow portions of a street and provide traffic calming benefits
- Maximizes available space in dense urban streescape for stormwater management
- Range of treatment capabilities depending on site conditions

Constraints:

- Generally requires the removal of on-street parking
- Can sometimes conflict with bike travel if adequate space is not allowed between edge of curb extension and a street's travel lane
- Can become complicated depending on if there are substantial existing utilities in the green belt

4
STRATEGY

Rain Garden (Urban Context)

The existing grassy area shown above is an excellent opportunity to create a large public plaza space and urban rain garden at the intersection of College and Battery Street. Located at the low point of the overall study area, a terraced rain garden at this location could potentially redirect stormwater from the existing storm drainage system into the landscape area. The rain garden and associated plaza could be a well-designed showcase of environmental sustainability at a prominent public location. In addition, since there is significant grade change at this location, this provides the opportunity for people to “watch the water” move from terrace to terrace in an artful way. The photo to the right illustrates an example of a rain garden and adjacent public plaza space.

Range of Cost: $25 to $60/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

Low Med ▲ High

Opportunities:

- Opportunity to create an urban plaza with a strong landscape component
- Can accept stormwater overflow from upstream storm pipe infrastructure
- Can provide the greatest stormwater flow and volume
- Offers versatility in shape

Constraints:

- Often more maintenance required because of the rain garden's large size
- Can be more expensive to build depending on their context and materials used

5
STRATEGY

Rain Garden (Landscaped Context)

The existing grass depression at the front of the People's Bank along Pine Street offers a unique opportunity to create a tranquil rain garden space that could potentially accept stormwater runoff from the building rooftop and upper portion of the watershed if it could be routed to this spot. Not only could this rain garden space provide stormwater management benefits, but it could also be an area for passive seating for building employees as demonstrated by the photo to the right.

Range of Cost: $25 to $50/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

Low ▲ Med High

Opportunities:

- Can manage stormwater runoff from building rooftops and stormwater canopies as well as general site area
- Can provide significant stormwater flow and volume benefit
- Offers versatility in shape

Constraints:

- Often more maintenance required because of the rain garden's large size
- Can be more expensive to build depending on the scale and materials used

6
STRATEGY

Stormwater Planters (Without On-Street Parking)

There are several sites within the watershed where space is limited to manage stormwater within the street, which offers an opportunity to retrofit the existing greenbelt with stormwater planters and/or vegetated swales. These opportunities are especially prevalent along Battery Street. Intermittent stormwater planters can be inserted into the existing landscape areas to accept street runoff without compromising existing trees.

Range of Cost: $25 to $50/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

Low Med ▲ High

Opportunities:

- Can fit between other streetscape/ parking lot elements (trees, utilities, signage, etc.) and are highly versatile in shape and size
- Can provide both volume and flow stormwater benefits

Constraints:

- Are generally more expensive due to increased hardscape infrastructure
- Need to provide for adequate pedestrian circulation
- Will need to accommodate street trees and utilities

7
STRATEGY

Stormwater Planters (With On-Street Parking)

Where space exists between the street curb and the building face, stormwater planters can be inserted and accommodate on-street parking. There would need to be adequate space for a decent sidewalk zone, stormwater planting, and a pedestrian egress zone along the street edge for people to be able to access their vehicles and the sidewalk. A built example of this stormwater strategy is shown to the right.

Range of Cost: $25 to $50/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

Low Med High

Opportunities:

- Can fit between other streetscape/ parking lot elements (trees, utilities, signage, etc.) and are highly versatile in shape and size
- Can provide both volume and flow stormwater benefits
- On-street parking is retained

Constraints:

- Are generally more expensive due to increased hardscape infrastructure
- Need to provide for adequate pedestrian circulation

8
STRATEGY

Stormwater Planters (Parking Lot Condition)

In areas of oversized parking spaces and inefficient use of landscape areas, stormwater planters can be inserted to capture runoff. The example above shows an existing condition on the back side of ??? church with both oversized parking spaces and under-performing landscape area. This zone can easily be converted into a stormwater planter as illustrated by example to the right.

Range of Cost: $25 to $50/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

Low Med ▲ High

Opportunities:

- Can fit between other streetscape/ parking lot elements (trees, utilities, signage, etc.) and are highly versatile in shape and size
- Can provide both volume and flow stormwater benefits

Constraints:

- Are generally more expensive due to increased hardscape infrastructure
- Need to provide for adequate pedestrian circulation

9
STRATEGY

Stormwater Swale (Parking Lot Condition)

Oversized parking stalls, as illustrated in the existing condition above, can be redesigned to convert the excess space into a stormwater swale place at the front of the parking stalls. Alternatively, the existing landscape space shown above could also be regraded and planted to accommodate runoff. Given the two alternatives, placing the stormwater swale within the existing excess space offers the best scenario because it helps reduce overall impervious area and it provides more space for stormwater management and space separation against the existing retaining wall.

Range of Cost: $20 to $30/Square Foot

$0/SF — $100/SF

Ability to Avoid Underground Utilities:

Low — Med — High

Use with Poor Soil Conditions:

Low — Med — High

Ability to Green the Overall Streetscape:

Low — Med — ▲ High

Opportunities:

- Swales are a widely-accepted stormwater strategy
- Swales often require less infrastructure to build and as a result are simple to construct and relatively low cost to implement

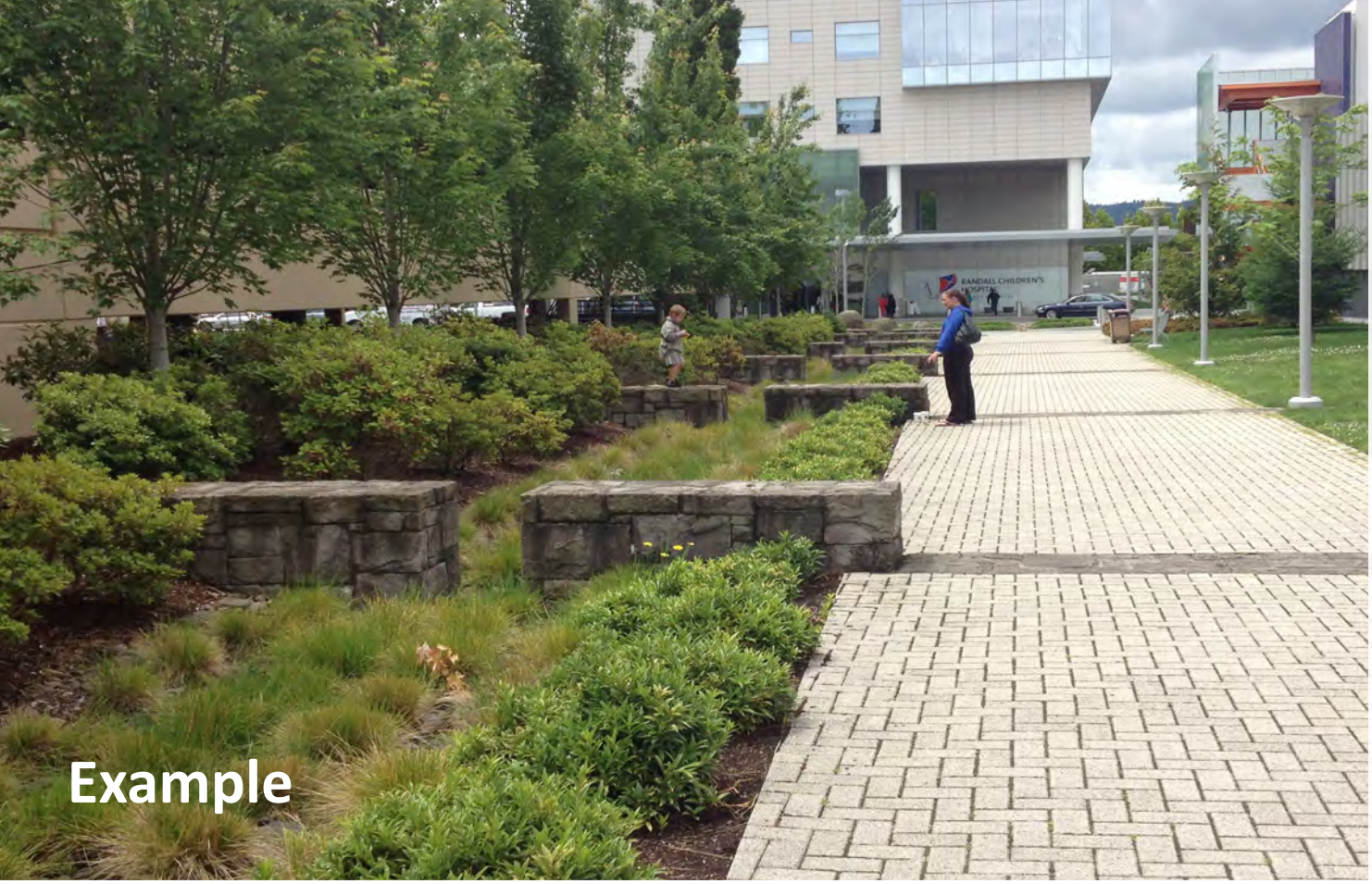
Constraints:

- Swales need long, continuous spaces which can be difficult to find in retrofit conditions
- Swales are often designed to be “too deep” and, as a result, are not aesthetically pleasing
- Need to provide for adequate pedestrian circulation

10
STRATEGY

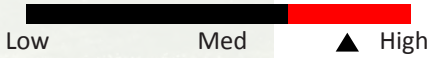
Stormwater Planters (Along Pathways)

If there is a desire to manage both pathway runoff and adjacent parking structure/building runoff within the existing landscape areas shown above, a series of stormwater planters might be the best choice because they can be built to retain more stormwater than a swale or green gutter system might offer. Stormwater planters could be placed on both sides of the pathway or simply on one side and water directed to it. The photo to the right actually shows an example of a stormwater planter next to a parking garage and pedestrian pathway.



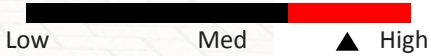
Range of Cost: $25 to $50/Square Foot

Ability to Avoid Underground Utilities:



Use with Poor Soil Conditions:

Ability to Green the Overall Streetscape:



Opportunities:

- Can capture runoff from both parking structures and building rooftops
- Can be placed over most types of utilities if they are designed to be shallow
- Can retain water volumes in a small area of space

Constraints:

- More expensive to build because the terracing requires more hardscape material

11
STRATEGY

Stormwater Planters (Terraced)

In areas of steep grade, stormwater planters can be placed and terraced to capture stormwater, slow down flow, and minimize erosion. These planters can be made of a variety of material, however metal is a top choice because it offers a very thin profile for saving space. Terraced planters, depending on how extensively used in the existing condition above, can accept stormwater from the new pathway, but also from the downspouts of the parking garages. The photo example to the right shows a terraced stormwater planter system accepting water from an adjacent roof downspout in Portland, Oregon.

Range of Cost: $40 to $60/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med ▲ High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

Low Med ▲ High

Opportunities:

- Can capture runoff from parking structures and building rooftops
- Can be placed over most types of utilities
- Can be made of a variety of materials such as metal as concrete
- Can retain water volumes in a small area of space

Constraints:

- More expensive to build because the terracing requires more hardscape material

12
STRATEGY

Green Gutter (Along Street)

Along many streets that only have parking on one side of the street, there is often an opportunity to integrate a narrow landscape strip, called a green gutter along the vehicular travel lane. The existing photo shown above along Bank Street shows the potential to consolidate space between the existing landscape strip and vehicular travel lane where there is no parking allow on that side of the street. A 2-3 foot wide green gutter system to capture half of the street's runoff and would be placed intermittently between existing driveway access areas. The photo to the right illustrates a narrow green gutter next to an existing landscaped space. One can also detect the check dams placed within the landscape area to slow water as it moves down the steep grade of the street.

Range of Cost: $25 to $50/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med ▲ High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

Low Med ▲ High

Opportunities:

- Can be placed over most types of utilities if they are designed to be shallow
- Helps further separate pedestrians and vehicles

Constraints:

- Because green gutters are shallow, they do not retain the same volume of water as other stormwater strategies. However, they are excellent for achieve flow reduction and water quality benefits

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STRATEGY

Green Gutter (Along Pathways)

Shallow green gutter system along existing pathways would be used to only capture stormwater generated from the pathway itself. This could help remedy the issue of soil erosion due to stormwater runoff and also provide a new aesthetic to the pathways. The photo example to the right is a pedestrian and bike path system supported by a sedum-filled green gutter in Stockholm, Sweden.

Range of Cost: $20 to $30/Square Foot

$0/SF — $100/SF

Ability to Avoid Underground Utilities:

Low — Med — ▲ High

Use with Poor Soil Conditions:

Low — Med — High

Ability to Green the Overall Streetscape:

Low — Med — ▲ High

Opportunities:

- Can capture runoff from both parking structures and building rooftops
- Can be placed over most types of utilities if they are designed to be shallow
- Can be built fairly expensively to regrading and replanting existing landscape space

Constraints:

- Because green gutters are shallow, they do not retain the same volume of water as other stormwater strategies. However, they are excellent for achieve flow reduction and water quality benefits

Existing Condition

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STRATEGY

Green Infiltration Joints/Pervious Paving

Green infiltration cracks within parking lots is an alternative to pervious paving in that it provides more structural support for vehicular travel, but allows stormwater to sheet flow into vegetated infiltration joints. Vegetation would grow within the infiltration joints, however, water would be able to infiltrate within the aggregate subgrade beneath the concrete slabs. This is a very new technology that has not been built before.

Range of Cost: $5 to $25/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med ▲ High

Use with Poor Soil Conditions:

Low Med ▲ High

Ability to Green the Overall Streetscape:

Low Med High

Opportunities:

- Helps reduces the parking lot's overall impervious surface
- Offers a low-tech, landscape approach to impervious surface removal
- Can be placed over many types of utilities
- Can help provide any artful means of stormwater management

Constraints:

- Technology needs to take into account ADA requirements
- May not be considered, from a policy, funding, and maintenance perspective, a viable stormwater management solution
- Infiltration cracks within the sidewalk zone is a new and unproven technology

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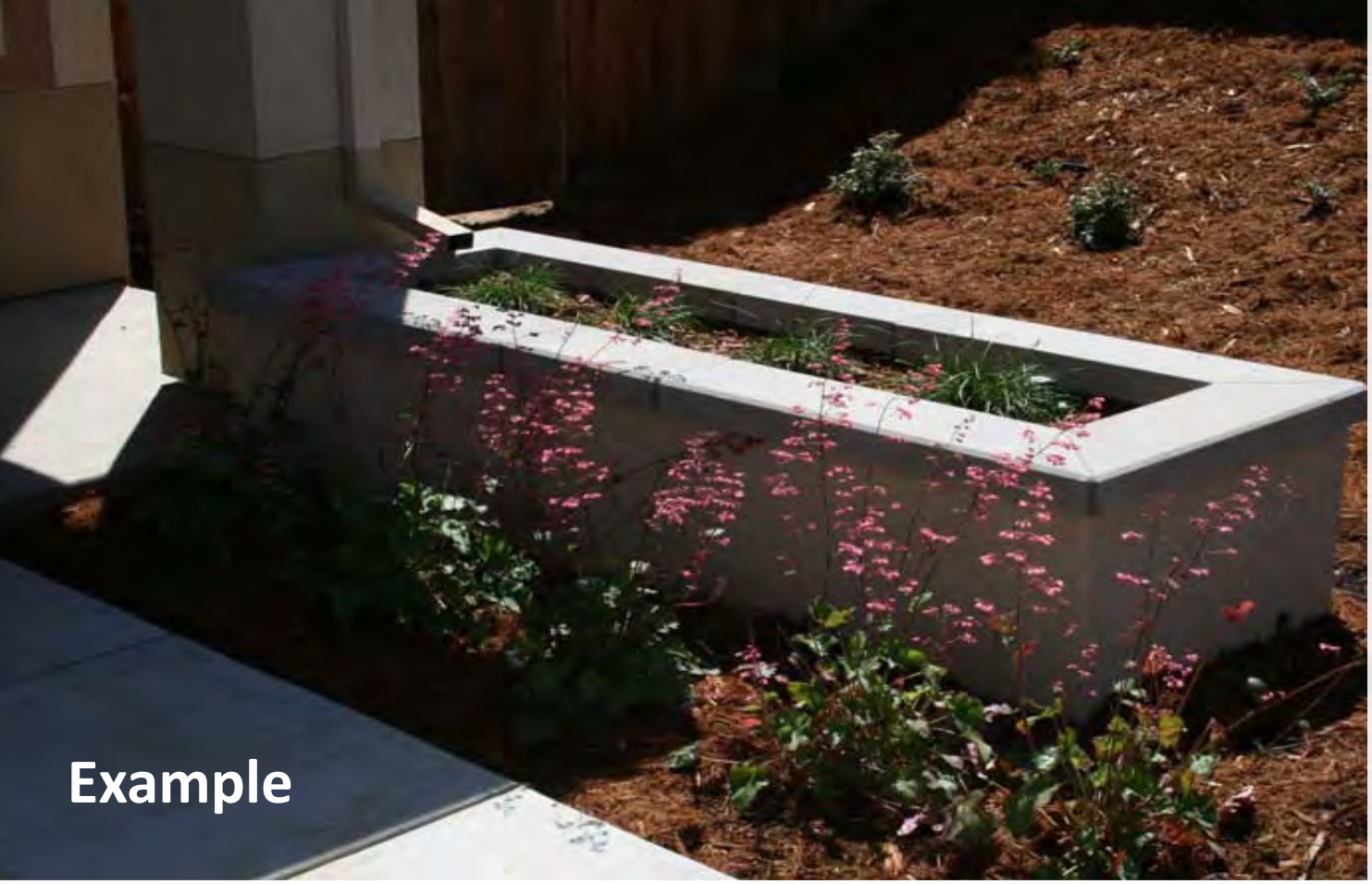
STRATEGY

Stormwater Planters (On Top of Parking Structure)

The parking structure adjacent to People's Bank offers a unique opportunity to divert stormwater that currently flows into the storm infrastructure into two landscaped planters placed in lieu of two parking spaces. These stormwater planters would sit directly on the parking structure deck with a predefined depth, soil, and planting media. The existing downspouts with be retrofitted to convey runoff into the planter systems, but flow would be allowed to overflow back into the existing storm drainage system. This is a relatively new stormwater strategy with not many built examples, however, the example photo to the right illustrates a raised stormwater planter condition.



Range of Cost: $25 to $50/Square Foot

$0/SF ▲ $100/SF

Ability to Avoid Underground Utilities:

Low Med ▲ High

Use with Poor Soil Conditions:

Low Med High

Ability to Green the Overall Streetscape:

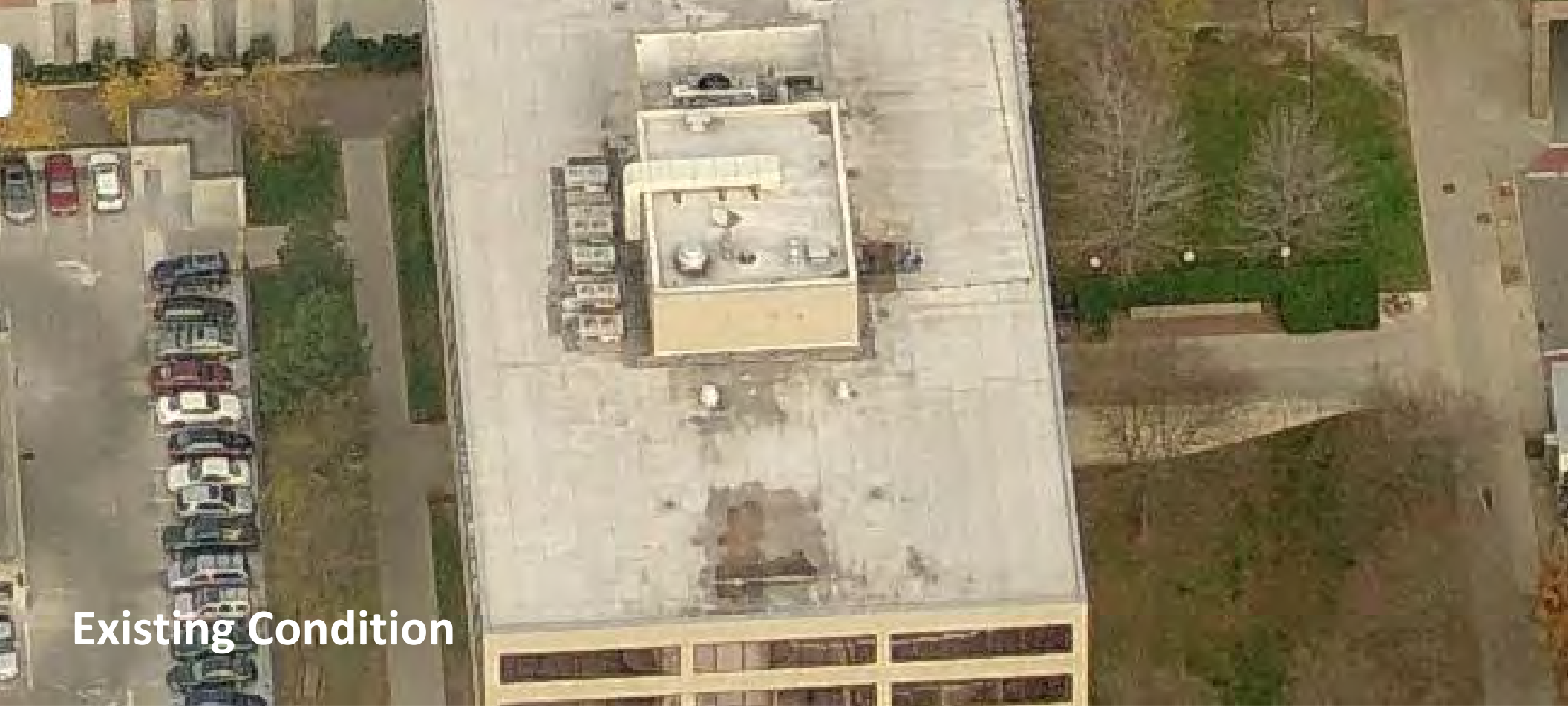
Low Med High

Opportunities:

- Can manage stormwater without impeding surface infrastructure
- Can be placed over most types of utilities
- Can be made of a variety of materials such as metal or concrete
- Overflow from planters can easily be directed back into existing storm line

Constraints:

- Will need to lose a parking space at the location of each planter
- Will need to develop a means to irrigate the parking deck planters during summer months
- Stormwater facility offers no infiltration ability, but can slow water and provide evapotranspiration



16
STRATEGY

Rooftop Stormwater Canopies Directing Water to Landscape

Many building rooftops have drainage systems that are internally plumbed rather than directed to exterior downspouts making it difficult to capture this rainfall. There are however some exciting opportunities to manage rainfall before it even hits these types of building rooftops. Using stormwater canopies that collect and direct stormwater runoff into perimeter landscape areas could help manage stormwater at these difficult locations. Furthermore, these stormwater canopies can double as photo voltaic panels for energy creation.

Range of Cost: $80 to $100/Square Foot

$0/SF ▲$100/SF

Ability to Avoid Underground Utilities:

Low Med ▲ High

Use with Poor Soil Conditions:

Low Med ▲ High

Ability to Green the Overall Streetscape:

Low Med High

Opportunities:

- Allows for capture of rainfall before it hits the ground without impeding with pedestrian zones and underground utilities
- Stormwater can be directed in an artful way to cisterns or landscape

Constraints:

- Infrastructure is expensive to build depending on the size of the canopy
- Stormwater Canopies are a new and unproven technology
- Canopies need to be designed to not conflict with overhead utilities/ infrastructure

Map Key:

1. Conventional Landscaping with Pedestrian Paths at Sidewalk Zones
2. Stormwater Curb Extensions (Parallel Parking)
3. Stormwater Curb Extensions (Diagonal Parking)
4. Rain Garden (Urban Context)
5. Rain Garden (Landscape Context)
6. Stormwater Planter (Without On-Street Parking)
7. Stormwater Planter (With On-Street Parking)
8. Stormwater Planters (Parking Lot Condition)
9. Stormwater Swale (Parking Lot Condition)
10. Stormwater Planters (Along Pathways)
11. Stormwater Planters (Terraced)
12. Green Gutter (Along Street)
13. Green Gutter (Along Pathways)
14. Green Infiltration Joints/ Pervious Paving
15. Stormwater Planter (On Top of Parking Structure)
16. Rooftop Stormwater Canopies Directing Water to Landscape

GI Retrofit Opportunities

College St. Stormwater Project
Burlington, Vermont
July, 2013

Urban Rain | Design
The Office of Kevin Robert Perry, ASLA

In Partnership with:

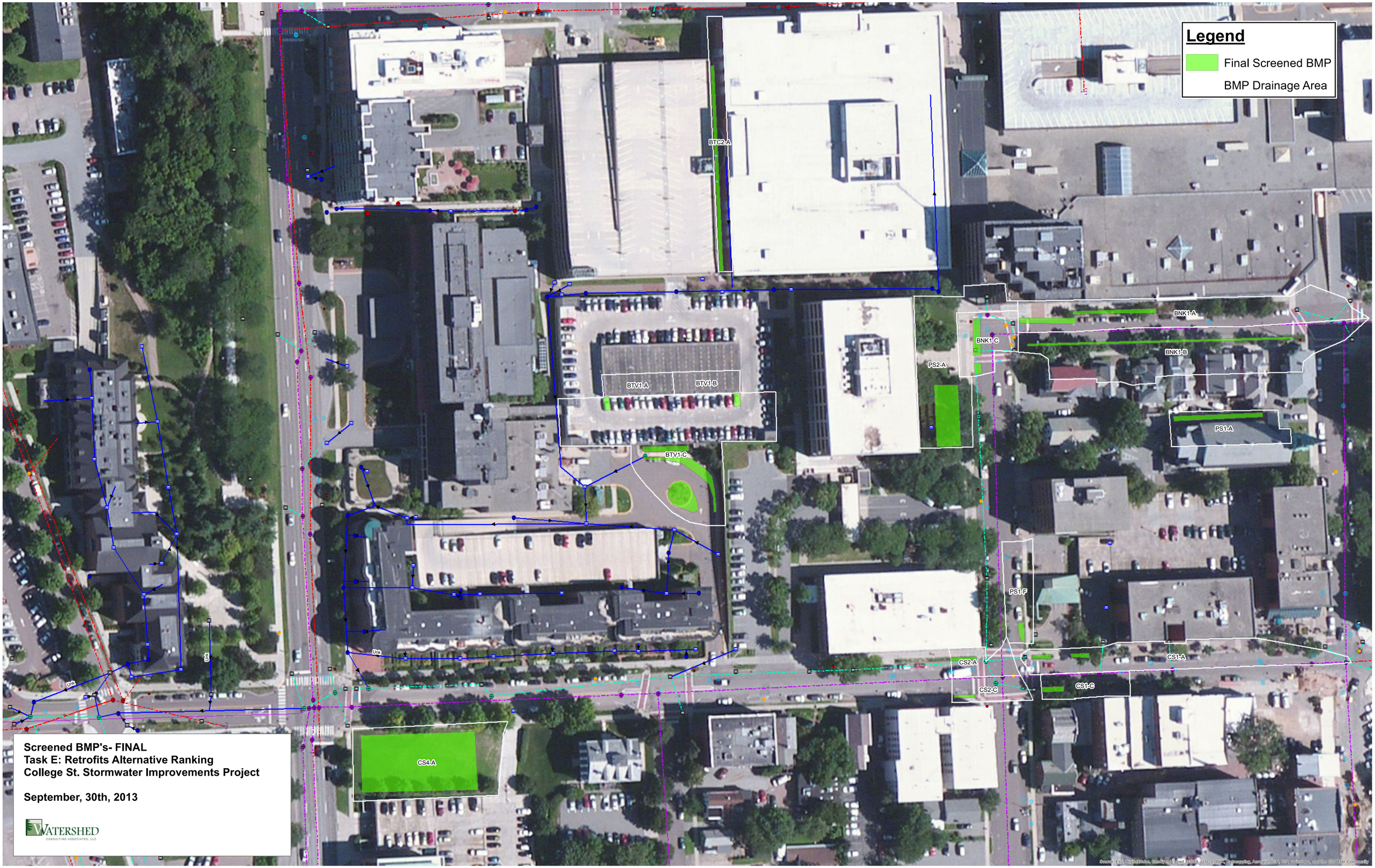
WATERSHED
CONSULTING ASSOCIATES, LLC

*Aerial Imagery from ESRI 2004

APPENDIX 4

Table 1: College St. Stormwater Retorfit Opportunities- Screen 1 Ranking Martix

Zone	Subwatershed	GI ToolBox ID	BMP Description	Ranking Criteria									
				Land Ownership Pu-2, Pr-1	Infiltrative Capacity (1-5)	Location in WS "Uppper-3"	Cost/ Greened Acre	WQ Benefit (ie. P and TSS Removal)	Collatoral Benefits	Transportation Conflicts	Utility Conflicts	Ease of O/M	**Rank**
Pine	PS2	5	Infiltration Unit with Landscaping	1	3	3	3	8	3	3	1	1	**25**
Bank	BNK1	1,2,7,12	Green Gutters, SW Planters	2	3	3	2	3	3	2	2	3	**24**
College	CS2	2	Curb Extensions w/ Parallel Parking	2	4	3	3	3	3	1	2	3	**24**
Battery	BS2	10	Infiltrative SW Planters	2	5	2	2	3	2	3	1	3	**23**
Battery	BS1	6	Bioretention Curb Bump Ins	2	5	2	1	2	2	3	2	3	**23**
College	CS4	4	Infiltration Unit with Landscaping	1	3	2	2	8	3	3	1	1	**23**
Parking Garage	BTV1	8,11,15	SW Planters	2	4	3	2	3	2	3	1	3	**23**
Parking Garage	BTV3	10,13	Green Gutters	2	4	3	2	1	2	3	3	3	**23**
College	CS3	1,2	Conventional Landscaping Strips	2	3	2	3	1	3	3	3	3	**23**
College	CS1	2	Curb Extensions w/ Parallel Parking	1	5	3	3	2	3	1	1	3	**22**
Main St. Landing	MSL1	7	SW Planters with On-street Parking	2	5	1	3	2	3	1	2	3	**21**
Pine	PS1	8	Parking Lot Filter Strip, Bioretention	1	3	3	2	3	1	3	2	2	**20**
Fletcher Allen	FA1	11	SW Planters	1	4	3	2	2	1	3	2	2	**20**
Peoples	PB2	8	Parking Lot Filter Strip	1	4	3	2	2	1	3	2	2	**20**
Peoples	PB3	12	Green Gutter	1	4	3	2	1	1	3	3	2	**20**
Parking Garage	BTV2	8	Rooftop Disconnection Planter	2	0	3	1	2	1	2	3	3	**18**
College	CS5	6	SW Planters in ROW	2	0	1	2	1	3	3	2	3	**17**
Water Front	WF2	9	Parking Lot Filter Strip	2	2	1	2	1	1	2	2	3	**16**
Mall	BTC1	16	Rooftop SW Cathment	1	0	3	2	2	1	3	3	2	**16**
Peoples	PB1	16	Rooftop Disconnection Planter	1	0	3	2	2	1	3	3	2	**16**
Water Front	WF3	2	Flow Through SW Planter	2	0	1	1	0	1	3	2	3	**15**
Mall	BTC2	11	Terraced SW Planters	1	1	3	2	1	1	3	1	2	**15**
Water Front	WF1	9	Curb Extension w/ Bioretention	1	0	1	2	0	1	2	2	2	**11**
College	CS6	8	Parking Lot Filter Strip, Bioretention	1	0	1	3	1	1	2	1	2	**11**



Source:
Aerial Imagery: ESRI 2013
Infrastructure: BTV 2013, Revisions by WCA 2013
College St. Watershed Delineation: WCA 2013
Subwatershed Delineation: WCA 2013

College and Pine Street Stormwater Improvements - Burlington, VT

Scale: 1”=10’
September 2013

Urban Rain | Design
The Office of Kevin Robert Perry, ASLA

1. A series of stormwater curb extension captures stormwater from College Street. Depending on if there are mature street present, the stormwater landscape expands into the sidewalk furnishing zone.
2. Pine Street parking zone on the east side is converted from parallel parking to diagonal parking
3. A stormwater curb extension captures stormwater runoff from Pine Street. Access to existing bank is closed to allow for improvements.
4. A stormwater curb extension captures stormwater overflow wrapping around College Street during high-intensity rainfall events.
5. A pair of stormwater curb extensions captures runoff from the College Street/Pine Street intersection
6. Specialty paving at pedestrian crossings.
7. College Street maintains two 10’ travel lanes
8. Pine Street maintains two 10’ travel lanes.
8. Existing access to bank is retained.

Stormwater curb extensions with diagonal parking

Stormwater curb extensions with parallel parking

Bank and Pine Street Stormwater Improvements - Burlington, VT

Scale: 1”=10’
September 2013

Urban Rain | Design
The Office of Kevin Robert Perry, ASLA

1. Where there are no mature street trees, three stormwater planters are inserted within the existing landscape strip to capture low-flow runoff from Bank Street. On-street parking is retained.
2. A 3’-wide pedestrian egress zone allows people to exit and enter their vehicles within conflict with stormwater planters.
3. 5’-wide carriage pathways allow for pedestrian access from the sidewalk to parking zone. These pathways can be in boardwalk form to allow stormwater to flow continuously from planter to planter.
4. A stormwater curb extension captures stormwater during high-intensity rainfall events.
5. A 2-wide green gutter captures stormwater from the southern half of bank street. The green gutter system would traverse the entire length of bank street except at driveway entrances.
6. Existing landscape area is to remain.
7. New landscape areas, but not designed for stormwater capture.
8. A stormwater curb extension captures runoff at the low-point of the Bank Street/Pine Street intersection.
9. Bank Street still maintains two 10’ wide travel lanes.

Stormwater planters with on-street parking

Boardwalk bridge

Green gutter system