Scenic City Stormwater Design

for the

Resource Rain Chattanooga
Low Impact Development Design Challenge

June 20, 2014

Scenic City
STORMWATER

INTRODUCTION

The City of Chattanooga has embarked on an ambitious effort to rethink how the community and the region address their watersheds. This effort requires looking at new strategies that have been explored nationally but rarely implemented to the level Chattanooga desires. Its "Resource Rain" program establishes a tool for the residents, developers, and local government officials to put stormwater principles into action.

The challenge is great. Development and growth lead us further and further away from the natural conditions that our waterways, rivers, streams, and land have historically functioned. Water from rain events has fewer alternatives for routes of travel beyond the traditional stormwater conveyances that have been implemented for years.

- Chattanooga's average annual rainfall mimics an environment close to a tropical rain forest
- Climate change has resulted in more extreme weather patterns creating periods of heavy rainfall and periods of drought
- Water seeks the path of least resistance

We have reached the tipping point:

Downtown Chattanooga's combined sewer systems are simply overwhelmed. In periods of heavy rain, the system quickly reaches capacity and local flooding occurs. During dry times, low flow through the conveyance pipe results in the discharge of odors. This is caused by the sanitary within the combined system reducing in velocity due to lack of storm water causing the sanitary to turn septic. Together these issues pose financial challenges to the economy and cultural challenges to the City.

Resource Rain challenges us to collect the first inch of a rain event, for this particular project, thereby reducing the stress on our current infrastructure. As you will see in the following design, Chattanooga now has a blueprint for implementing a progressive AND realistic vision for capturing water and more importantly reconnecting the urban, Broad Street environment with pre-development conditions.

The title of the design is **Scenic City Stormwater (SCS)**. The name incorporates the community's connection to water, mountains, culture, and tourism and its passion for creating a sustainable future that emphasizes renewed watersheds.

Scenic City STORMWATER

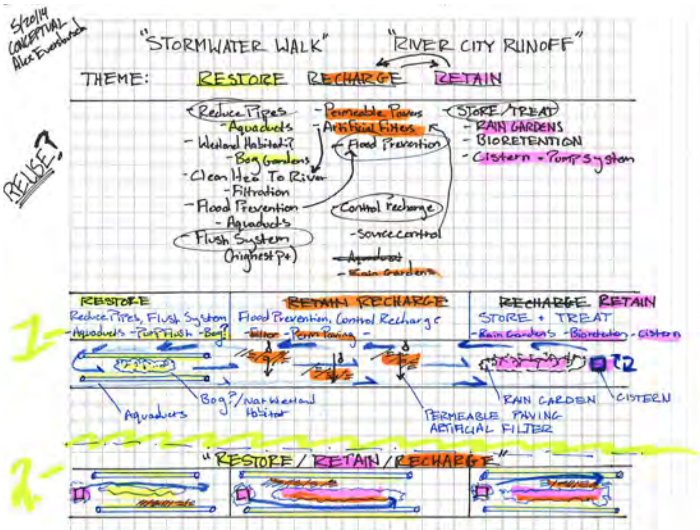
PROCESS

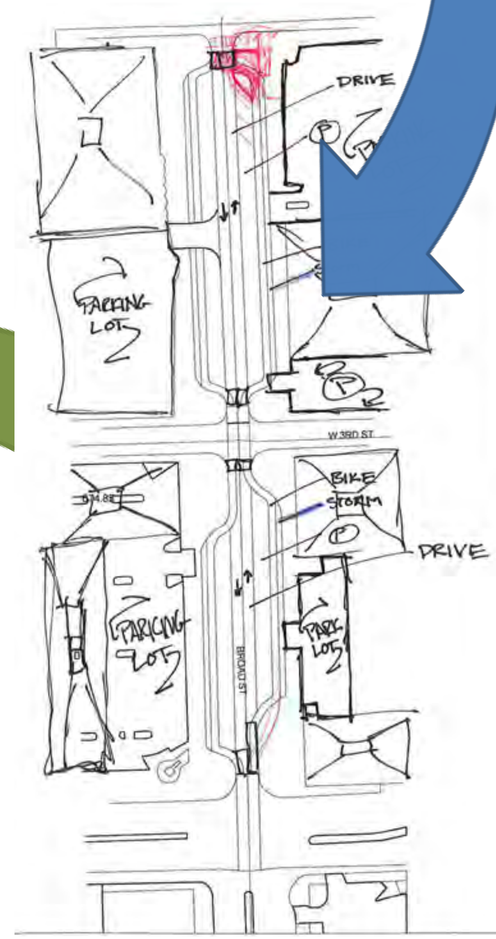
Addressing stormwater in urban streetscape conditions provides an exciting opportunity to strengthen the economic outlook of a business district, expand opportunities for all users (including bicyclists and pedestrians), rethink how our community uses infrastructure, and provide an aesthetically pleasing experience. Broad Street is a major north-south spine through the heart of downtown Chattanooga. The project area expands the downtown business district culminating at the north end with the entrance to the Tennessee Aquarium. The following criteria were used to establish the SCS design:

- **Consider existing infrastructure.** Can existing elements of the streetscape be reused to be efficient and provide an acceptable retrofit which is more manageable from a cost and constructability perspective?
- **Incorporate historic features.** Celebrate the existing historic fabric that makes downtown Chattanooga special.
- **Maintain functionality of the road**. The design should maintain Broad Street's functionality as an important downtown arterial.
- **Provide access to more users.** A Complete Streets approach would provide a more dynamic environment and offer greater opportunities for all users.
- **Better connect the River with the City and its infrastructure.** With its location near the Tennessee River, what better place to physically and emotionally reconnect the street to the river.
- **Educate the public.** Similar to the efforts of the City's Water Quality Program, this design is a demonstration project attractive equally to the experienced stormwater engineer and the weekend tourist. Why couldn't Chattanooga become the Portland of the East Coast?
- **One size doesn't fit all!** Acknowledge local conditions. Each block or collections of blocks has different conditions and different concerns. A multi-faceted approach allows the design to meet the "micro" needs of each block while repeating features across the entire corridor provides a unity in design.
- **Connecting Humans and Culture.** If people can make intimate, visceral connections with their surrounding resources, studies show they will welcome their new stewardship role. The SCS design can create these lasting relationships.

3rd St. looking north

CONCEPT TO VISION





DESIGN STRATEGY

Step 1: Evaluating Stormwater On-Site

The first step in the design process was to understand the project site as it related to stormwater. The highest point of the project area is located at Broad St. and Martin Luther King Jr. Blvd. This represented a logical point to incorporate retention strategies to alleviate pressures at lower elevations.

The central part of the corridor provided a logical point to highlight stormwater quality and groundwater recharge.

Broad Street's northern end offered an opportunity to strengthen the relationship of the community with the Tennessee River. Restoring the site to a condition that more closely mimicked the natural environment is a great "entrance" to the Aquarium.

Dividing the project into three sections creates three smaller project areas that are more manageable and can be studied more closely upon implementation. It further creates a series of experiences within a linear "watershed" that would be both technically and visually attractive.

Between Aquarium Way and 3rd St. looking south

Step 2: Establish a connective theme

The SCS design evolved into exploring key themes that defined Chattanooga and related to the project area. Ultimately, it was decided on three R's that are represented throughout SCS: Retain, Recharge, Restore. These themes align themselves with the three key elements of Resource Rain:

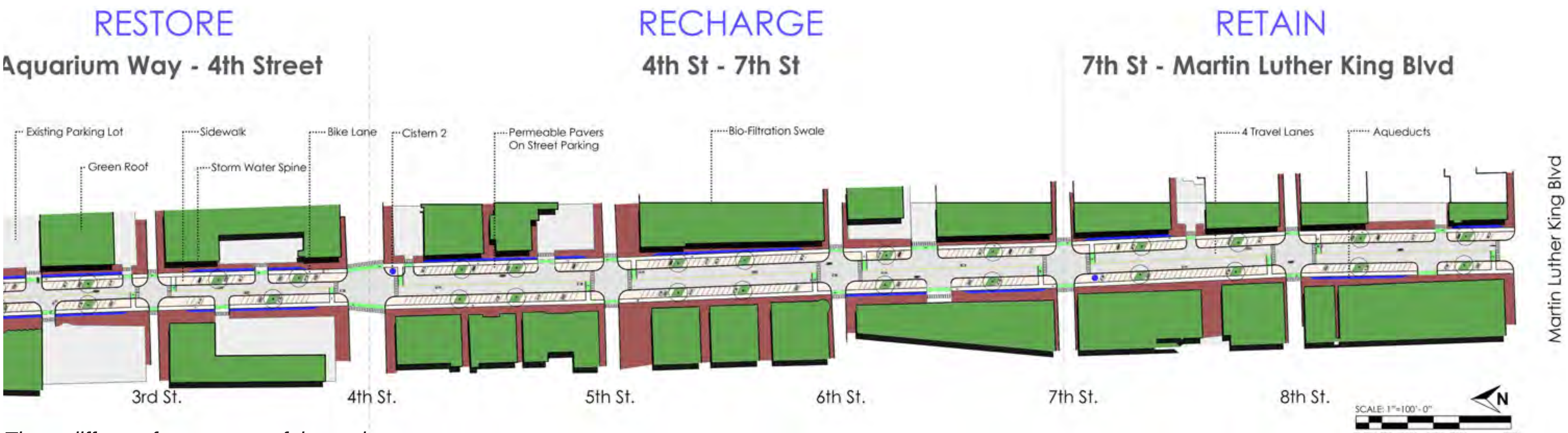
- Retain = Volume Management (Stay on Volume). Retaining the first inch is a practice in managing the volume of water in the project area.
- Recharge = Water Quality Treatment. Treating the water so that it can be returned to the ground in an improved state.
- Restore = Peak Rate Control. Using features to restore the water quality and create a pre-development condition addresses the peak rate of flow.

To highlight the three Rs, associated each with a sub-area of the site:

- Retain - Martin Luther King Jr. Boulevard to 7th Street
- Recharge - 7th Street to 4th Street
- Restore – 4th Street to Aquarium Way

By dividing the project area based on a best management practices (BMP) themed approach, it offers educational opportunities through a linear learning experience so that visitors and residents alike better understand stormwater management at a site (micro) level. This breakdown also offers a functional purpose. By dividing the corridor into three different focus areas (page 6), it provides a laboratory for the City to study which design features perform better and which design features are more economical. The result is an open-source approach which allows the City to modify specific stormwater techniques within the project area without affecting the larger network.

THE CONNECTIVE THEME



Three different focus areas of the project area

Step 3: Responding to Project Constraints

The competition defined a number of requirements including retaining the number of travel lanes, protected bicycle facilities, and maintaining parking spaces. Although the corridor is wide (average of 90 to 95 feet between curb lines) incorporating all elements would require making difficult decisions. Several design features were incorporated throughout the corridor to address these constraints:

- Eliminate the median. Although the median was attractive, team members felt it was important to narrow the road for pedestrians while simultaneously creating stormwater and vegetation opportunities in the adjacent sidewalk spaces.
- Narrow travel lanes. Narrowing the travel lanes to 10.5 feet provided another traffic calming measure and provided additional room for stormwater features on the edge of the road.
- Raise the road. Curbs and gutter generate increased stormwater velocity. Raising the roadway provides a better sheet flow pattern for stormwater and removes potential severe roadway crowns. In addition, raising the road provides additional storage depth below the roadway and helps equalize vehicular, pedestrian, and bicycle traffic. Broad Street essentially becomes a "woonerf", a shared road experience that is safer and functions better.
- Install reverse-angled parking. This is already present in the two-lane section of Broad Street. By eliminating medians, parallel parking meant a loss of parking spaces. Reverse-angled parking helps to offset the loss of median parking. The parking is defined by permeable pavers thereby doubling potential storage vs. a traditional parallel parking space. The permeable pavers allow for an attractive pavement treatment that helps to visually distinguish from the roadway. Reverse-angled parking is already in affect north of 4th Street. It is a configuration that has proven to be a safer parking configuration.
- Create protected bicycle facilities. Several approaches for protected bicycle facilities were investigated. The final design includes bicycle lanes which are situated behind proposed reverse-angled parking and adjacent to vegetated and stormwater facilities. The bicycle lanes are separated from parking with a three-foot flush concrete curb which is equipped with delineated bollards. This creates a visual distinction between spaces. Bike boxes, traffic signals specifically designed for bicycle traffic, are located at each intersection for bicyclists wishing to turn left or right. This is accompanied with new phasing for traffic signals that allow for dedicated turning for bicycle facilities. For bicyclists continuing straight, the lanes run continuously north-south with a push-button crosswalk activation system to facilitate through movement.
- Amend soils. The disturbed, urban soils of Broad Street do not make for a great plant material or stormwater conveyance. All of the soils used in the project would need to be amended to improve their function and porosity.

What the SCS Design Does

Eliminates the median

Narrows travel lanes

Raises the road

Installs reverse-angled parking

Creates protected bicycle facilities

Amends soils

Step 4: System-Wide Stormwater Features

Three specific elements were incorporated throughout the entire corridor which impact stormwater runoff and assist with overflow and maintenance of the combined sewer-system.

- Green roofs. Roof runoff equates to a large percentage of the total stormwater runoff within the project area. The best solution is for the existing buildings to be retrofitted to include green roofs. These systems can be simple or complex, but regardless of the approach, they will drastically eliminate runoff into the existing combined-sewer system resulting in a cost savings to the Owner and offer long-term cost savings for tenants. This also provides an opportunity to connect green infrastructure with historic preservation, a growing trend nationwide.

The ASLA Headquarters Green Roof is an excellent precedent for green roof construction.

  Because this particular project's focus is Broad Street, the process of installing green roofs on the buildings adjacent to the street, was not included in any of the results. As the Low Impact Development mindset is absorbed throughout the community, it is assumed that green roofs would be installed resulting in a reduction to the stormwater load to the system. Any reduction to the loading would result in an increase in storage volume and ultimately improve the functionality of the system.

- Cisterns. Cisterns assist in helping capture stormwater overflow to be reused on site. The SCS plan includes three above ground cisterns at high visibility locations along Broad Street. These cisterns retain stormwater overflow once other measures are exceeded and prior to entering the combined-sewer system during rain events that exceed 1 inch. The cisterns are used to help irrigate plant material on site. They also serve another, more important purpose. During drier periods, water from the cisterns could be used to "flush" the combined sewer system. This could help to increase the velocity of the sanitary system and dislodge stagnant material from the walls of the conveyance pipe. The cisterns are also intended to serve as public art pieces which provide a new vertical landmark along the corridor. These blank slates could be used to advertise for upcoming celebrations including holidays, festivals, and races/fundraising walks as murals or alternating exhibits.

A cistern used as a public art piece in St. Paul, Minnesota.

- Permeable Pavers. A third element is a permeable paver system that is located in the parking zone along the corridor. With an increase in reverse-angled parking spaces, the amount of stormwater volume captured increases tremendously. Water from the roadway is meant to be captured by the pavers and returned to the groundwater. However, a piping system is in place should the stored capacity become too great. The permeable pavers also function as a wayfinding tool to distinguish travel lanes and parking lanes.

Permeable paver lot at Stone Mountain Park, Georgia

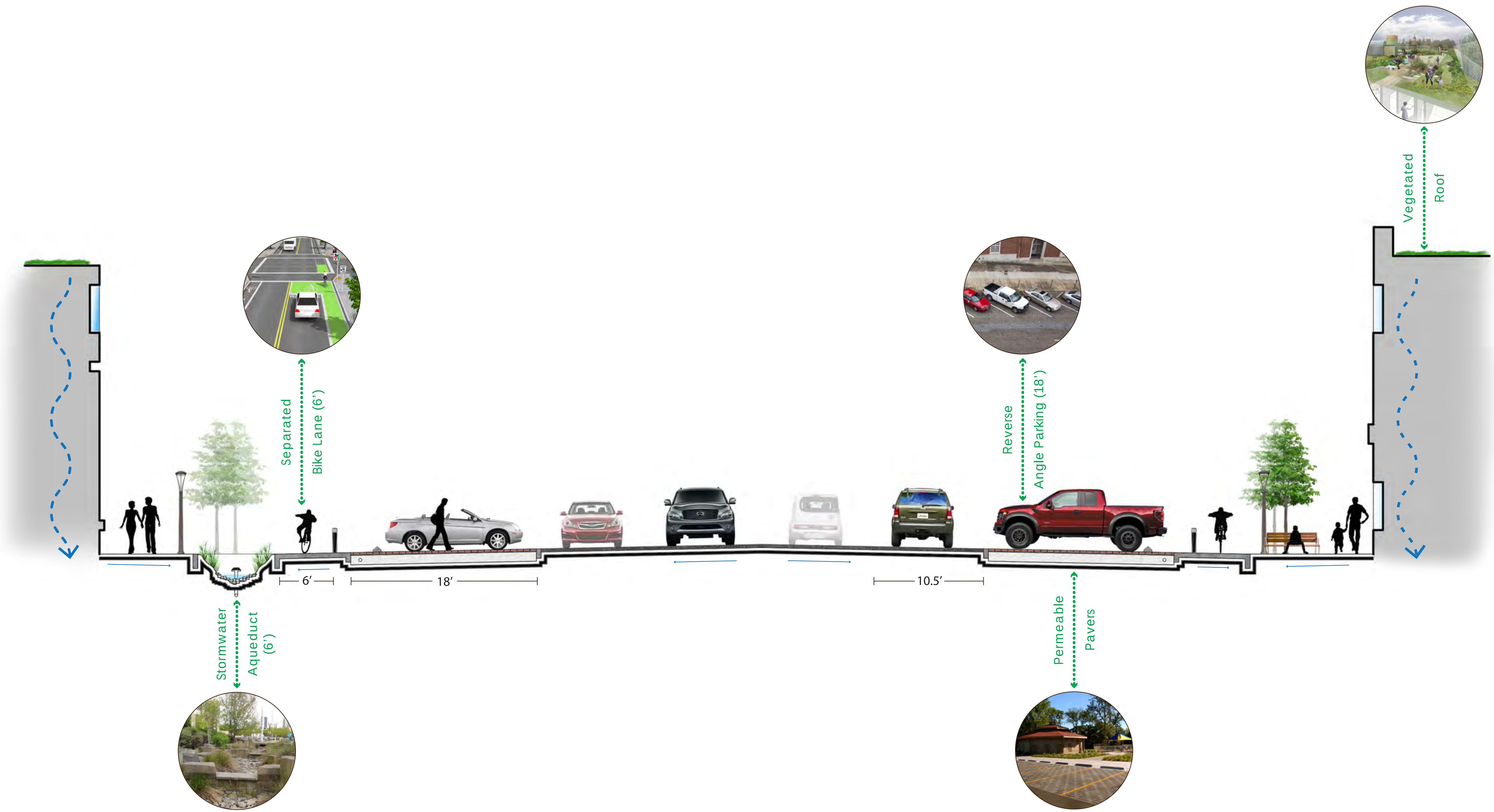
Step 5: Themed Stormwater Elements

Each of the three stormwater sections has a distinctive approach to capturing stormwater. Because of physical constraints and variable distances to building faces, the design also incorporated these elements along the corridor that would also allow for sufficient pedestrian movement. The design highlights these alternating elements.

- Dry Riverbed System (Retain). In the first project area from Martin Luther King, Jr. Boulevard to 7th Street, a dry creekbed system has been designed between the bike lane and the sidewalk (page 11). These linear open spaces include planters on either side of a rock material to generate flow (from south to north). The total depth is three feet from curb height to top of rock which provides a large capture zone. The plant material on either side is used to "soften" the edges and provide a visual barrier to the base. The configuration of the design prevents adequate room for the stormwater structures on both sides of the road. They alternate but are connected via piping. An overflow pipe is located at the end of the system for transport water into the combined-sewer system. A drop inlet at the northern end of the riverbed captures water into a piping system that travels directly to the cistern.

Example of a Dry Creekbed Stream

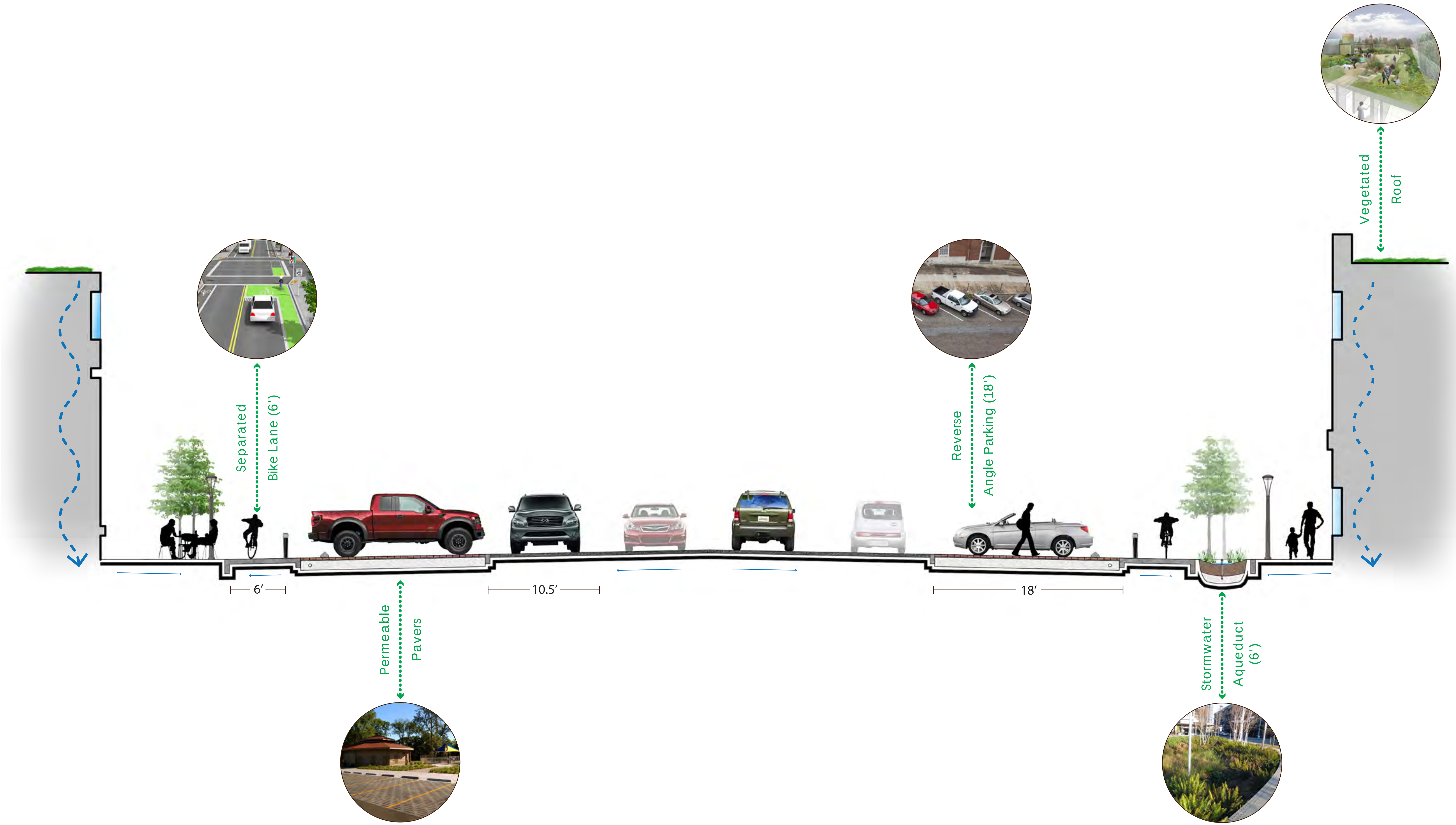
DRY RIVERBED SYSTEM (RETAIN)



- Raingardens (Recharge). In the three block, central portion of the project (7th Street to 4th Street), a raingarden approach is proposed between the sidewalk and the bike lane (page 13). These gardens function to provide infiltration at a controlled rate into the water table. These are vegetated structures (including street trees) and have a two foot watertable. Similar to the Dry Riverbed System, they flow from south to north with an overflow structure and piping in the northernmost cell. The configuration of the design prevents adequate room for the stormwater structures on both sides of the road. They alternate but are connected via piping. The piping connects to the second of three cisterns.

A heavily planted raingarden

RAINGARDENS (RECHARGE)

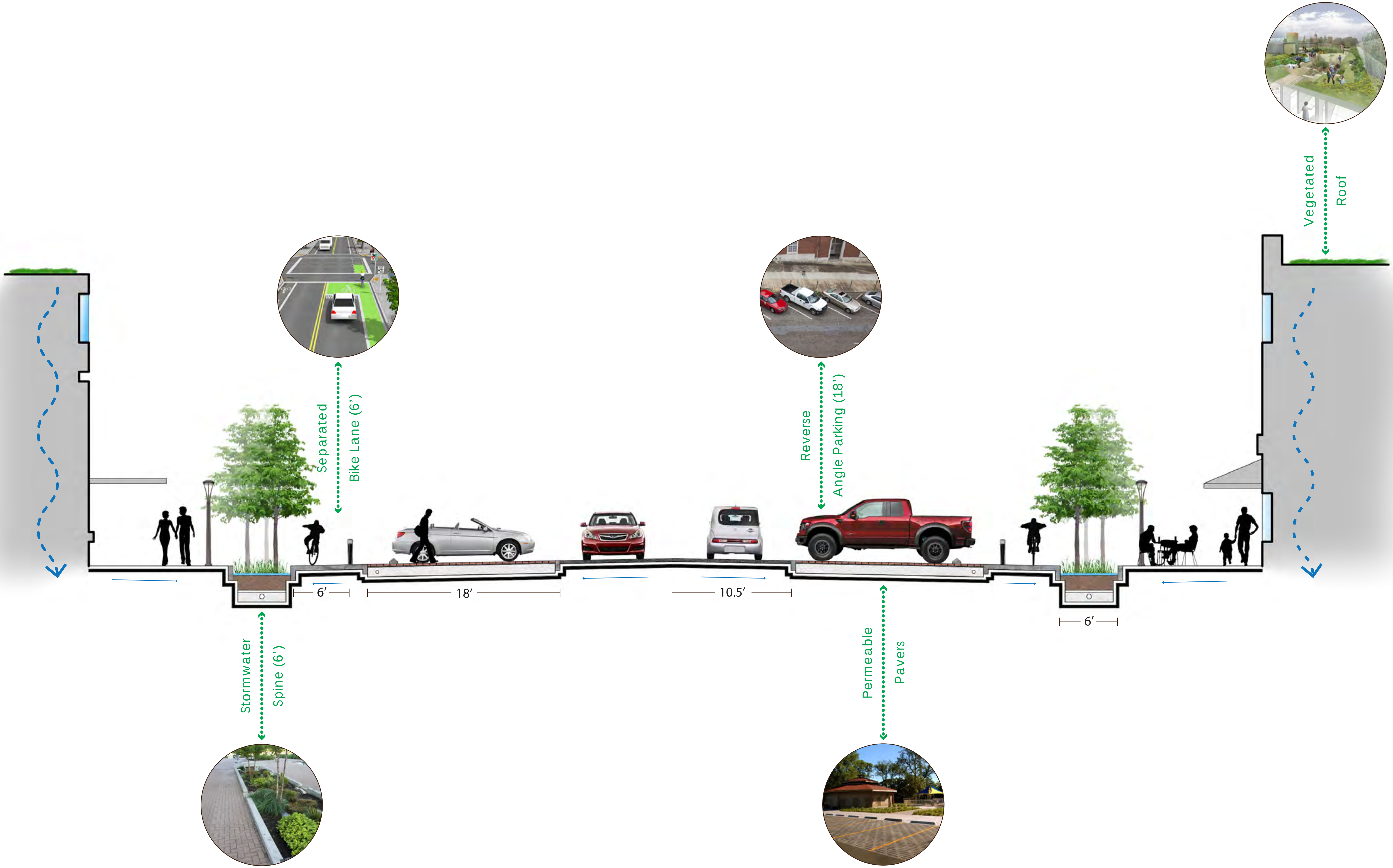


- Stormwater Spine (Restore). The northernmost portion of the corridor (4th Street Aquarium Way) has a larger footprint to work with because there are only two travel lanes. Here a stormwater "spine" was designed that would be present on both sides of the street adjacent to the sidewalks (page 15). This spine functions in a similar fashion to a raingarden, however, rather than a naturalized swale, vegetation only exists at the bottom of the spine. As opposed to infiltration, the spine moves the water (like a stream) north towards the aquarium. Designed without weirs or cells, this spine is meant to represent a streambed. This design is part infiltration, part retention and the remaining overflow water is captured in a third cistern at the northern end of the project site.

Example of a Stormwater Spine

Potential Conclusion of the Stormwater Spine in front of the Aquarium

STORMWATER SPINE (RESTORE)



Step 6: A "Complete" Approach to the Street

Complete Streets policies have become incredibly popular in the United States in recent years (example on page 17). Chattanooga is an environment that provides a wonderful testing ground for implementing complete streets policies. Streets are for everyone: bicyclists, pedestrians, automobiles, plant material, and even stormwater. When you expand the concept of "Complete Streets" to include a healthy tension between humans and nature, a community can reap even more benefits. This plan incorporates numerous key elements that make Broad Street more Complete. Several of these elements are listed below:

- Equalizing the roadway by raising the road and creating a woonerf helps to equalize different transportation options.
- Traffic Calming:
    - Bulbouts
    - Reverse-angled parking,
    - Narrower lanes
- Dedicated, protected bike paths
- Making parking more consistent
- Making parking safer (no more parking in the median and crossing the road)
- Eliminating infrastructure and simplifying the profile
- Improved accessibility for all users

Raise the Road - A Complete Street Concept

Signage directing bicyclists to use a queue box at a signalized intersection

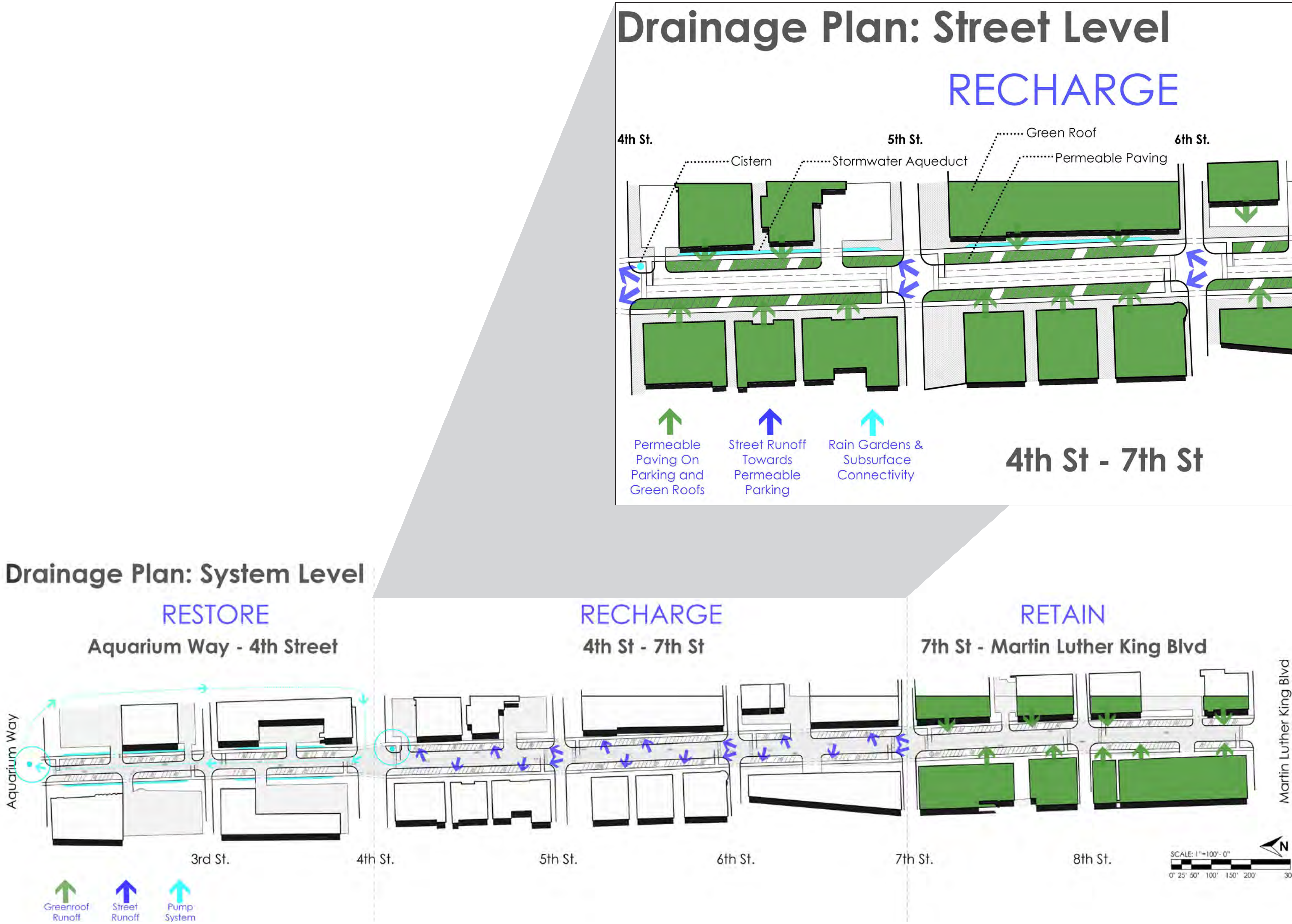
Bicycle Queue Box at Signalized Intersection

COMPLETE STREETS DESIGN EXAMPLE (IRVINE, CALIFORNIA)

Drainage Patterns

The following plan (page 19) highlights the tiered approach to on-site stormwater management. The tiers are as follows:

- Tier 1: Capture the surface flow. Techniques such as the rain gardens and permeable pavers offer a first step in retaining runoff.
- Tier 2: Retain, Recharge, Restore. These techniques capture overflow from tier one and surface water from the sidewalk.
- Tier 3: Cisterns. The cisterns provide a third level of capture and water reuse on site.
- Tier 4. Existing infrastructure. Overflow pipes for the cisterns transfer water back into combined-sewer system as a last step in stormwater management. By this point, the first inch has been captured and retained on site, water has been recharged, and water has been returned to the water table.



Scenic City STORMWATER

Evaluating the Design: SOV and Storage Capacity

By the use of the LID calculation Tool, provided by the Rainwater Management Guide, the Stay on Volume (SOV) for downtown Broad Street was calculated for the Traditional and LID design, as shown in the table below. The tool implements the Small Storm Hydrology Method (SSHM), which was developed to estimate the runoff volume from urban and suburban land uses during small storm events. The SOV calculation is based on the rainfall depth, 1-inch in our case (redevelopment projects), the SSHM runoff coefficient (Rv), located in Table 7-1 of the Rainwater Management Guide, and the area of land use. To assure the capture volume is greater than the SOV, the drainage area (DA) was taken as 27 acres; consisting of half the city block east and west of Broad Street, and from MLK Blvd to Aquarium Way. The areas of flat roofs, parking lots, sidewalks, and roadways were all considered separately to assure the proper Rv coefficients were used.

The idea of the LID design is to manage the stormwater volume through BMP practices close to the source of runoff. As such, the total DA was divided into three R sections: Restore, Recharge, and Retain. Each section consist of multiple BMPs all sized to manage the required SOV of that section. The results are shown below. **The resulting impact of the Scenic City Stormwater design is a surplus of storage volume that can handle greater than the 1 inch requirement.**

Comparison of SOVs for Traditional Design versus LID

Section #	Section	From	To	Traditional Required SOV Ft^3	LID Required SOV Ft^3	Total Storage Volume Available in LID BMPs
1	Restore	Aquarium Way	W 4th St.	23515	21007	28559
2	Recharge	W 4th St.	W 7th St.	37194	34494	45000
3	Retain	W 7th St.	W MLK BLVD	24343	21900	29283
				85052	**77401**	**102842**

Small Storm Hydrology Coefficients (Rv) for Urban Land Uses

	Rv for 0.5"	Rv for1.0"	Rv for 1.6"	Rv for 2.1"
Flat Roof	0.79	0.85	0.88	0.90
Pitched Roof	0.95	0.97	0.99	0.99
Large Impervious Areas	0.97	0.98	0.99	0.99
Small Impervious Areas	0.64	0.70	0.79	0.85
Sandy Soils	0.02	0.03	0.05	0.08
Typical Urban Soils	0.10	0.12	0.15	0.18
Clayey Soils	0.19	0.21	0.24	0.27

Source: Pitt, 2003

Note:
- Soils mapped as "Urban" must use Rv values for urban soils.
- Soils mapped as Hydrologic Group A may use Rv values for sandy soils if soil group is described as sand. Otherwise, urban Rv values apply.
- Soils mapped as Hydrologic Group B must use Rv values for typical urban soils.
- Soils mapped as Hydrologic Group C or D must use Rv values for clayey soils.

Evaluating the Design: Cost

Low Impact Development and Green Infrastructure are vehicles to improve water quality/habitat, improve flood control, and increase the overall quality of life. As the City of Chattanooga implements newly developed stormwater runoff reduction standards for the development and redevelopment of property within the city limits, it is imperative to consider cost as one of the driving parameters. In order to qualify the cost effectiveness of Low Impact Development/Green Infrastructure alternatives, it is necessary to create a level playing field of the considered alternatives. This particular design utilizes three different approaches, separated by the city blocks, to address stormwater along Broad Street. The expected installed cost of each of these approaches will be compared to the theoretical cost to build the roadway as it currently exists.

In order to appropriately compare the LID alternatives with the traditional alternatives, numerous assumptions must be made. For instance, since the same sidewalk is needed for both, the traditional and the LID alternatives, the installed cost of the sidewalk is not included in the estimates. The area of Broad Street between the sidewalks would be assumed to be graded flat to the subgrade, ready for construction of each of the alternatives. As such, each alternative would be built to match the existing sidewalk and intersecting roadway elevations. It is also assumed that only differing construction fees will be taken into account. Design fees, mobilization costs, utility relocation, etc. will all be ignored, as they will be the same for both, LID and traditional approaches. This will allow the true installed cost differences to be determined and compared. Because the same unit prices will apply to each of the scenarios, the resulting total costs for each line item will be relative to each other and will demonstrate the cost differences between the LID and Non-LID infrastructure by the number of units required for the design.

It should also be noted that it is assumed that the entire length of the study area is currently served by combined sewers. As such, the existing properties located on Broad Street discharge stormwater into the combined sewer. The stay on volumes that were calculated as part of this study, took into account that half of the city blocks to the east and west would discharge to the combined sewer on Broad Street. In the event that the City elects to continue to allow this runoff to enter the combined sewer, any associated fees that might be paid to the City and are not assumed to affect any of these scenarios. This approach allows the existing stormwater discharge conditions to remain in place. In the future when stormwater is addressed differently by each individual property owner, the installed SOV of the street would become more conservative with time, improving flood control in the area and increasing the amount of storage associated with rainfalls that exceed 1”. This would also reduce the amount of storm water that is discharged to the combined sewer, which would also result in an annual savings to the City because it will not have to be conveyed or treated at the Moccasin Bend Wastewater Treatment Plant.

Each subsection of Broad Street will be compared to its corresponding counterparts in the following tables. Table 1 (page 22) compares costs for the “Restore” Section of the project from Aquarium Way to 4th St. Table 2 (page 23) compares costs for the West 4th St. to West 7th St. Table 3 (page 24) compares costs for the West 7th St. to West MLK Blvd.

Table 1

Restore Section: Aquarium Way to 4th St.						
			Traditional Design		LID Restore Base Design	
Typical Road Construction Capital Costs:	*Unit*	*Installed Cost*	*No. of Units*	*Total Cost*	*No. of Units*	*Total Cost*
Grading (6" rock, at 2% SE from center, Sub grade beneath)	CY	$8.00	8728	$69,821.63	4082	$32,654.22
Compacted Aggregate Base	CY	$32.00	1827	$58,471.29	597	$19,114.67
Bituminous Base	CY	$75.00	1218	$91,361.39	398	$29,866.67
Asphalt Surface	CY	$105.00	609	$63,952.97	199	$20,906.67
Curb and Gutter	LF	$24.00	2607	$62,563.67	0	$0.00
Catch Basins	Each	$1,900.00	24	$45,600.00	0	$0.00
Crosswalks	SF	$6.00	5904	$35,424.00	1728	$10,368.00
Parking:						
Number of Spaces	Each	N/A	62	---	64	---
Pervious Pavers	SF	$6.50	0	$0.00	25467	$165,535.50
Sand Setting Bed (1" Depth)	CY	$20.00	0	$0.00	79	$1,572.04
Aggregate Base Layer (12" Depth)	CY	$20.00	0	$0.00	967	$19,348.15
Perforated HDPE (4" Dia.)	LF	$50.00	0	$0.00	896	$44,800.00
Bollard	Each	$500.00	0	$0.00	366	$182,875.00
Parking Back Stops	Each	$200.00	0	$0.00	64	$12,800.00
Concrete Curb	CY	$200.00	0	$0.00	24	$4,837.04
Vegetation Planters:						
Aqueducts						
Concrete	CY	$200.00	0	$0.00	139	$27,740.74
Aggregate Base	CY	$20.00	0	$0.00	198	$3,962.96
No. 4 Open Graded Aggregate	CY	$25.00	0	$0.00	50	$1,238.43
Biorention Soil Mix (18")	CY	$14.00	0	$0.00	317	$4,438.52
Vegetation (10' Canopy Tree)	Each	$75.00	0	$0.00	153	$11,464.29
Perforated HDPE (6" Dia.)	LF	$50.00	0	$0.00	896	$44,800.00
Parking Area Planter						
Concrete	CY	$200.00	0	$0.00	10	$2,074.07
Aggregate Base	CY	$20.00	0	$0.00	104	$2,074.07
No. 4 Open Graded Aggregate	CY	$40.00	0	$0.00	26	$1,037.04
Biorention Soil Mix (18")	CY	$14.00	150	$2,100.00	156	$2,177.78
Vegetation (30' Canopy Tree)	Each	$75.00	75	$5,625.00	7	$525.00
Additional Cost:						
Cistern	Each	$100,000.00	0	$0.00	1	$100,000.00
Vehicle Traffic Lights	Each	$25,000.00	3	$75,000.00	3	$75,000.00
Bicycle Traffic Lights	Each	$25,000.00	0	$0.00	3	$75,000.00
Total:				**$509,919.95**		**$896,210.84**

Assumptions: All costs exclude design, construction administration, EPSC, roadway paint.

1. Roadway between existing sidewalks is being constructed as new, including roads entering section.
2. The entire area is part of the combined sewer system.
3. Existing area is graded flat (w/o super elevation)
4. Two storm sewer pipes per building will be constructed from the edge of the sidewalk to the centerline to tie into the trunk sewer.
5. Assume 12 catch basins per city block each equipped with 12" of concrete.
6. Parking Area Planters are 20 ft. by 20 ft.
7. All existing Light Poles will remain.
8. Bollards are placed every 4-ft. on both sides of bike lanes.
9. Trees planted in Aquaducts will be spaced at approximately 7-ft. on center.
10. Asphalt Material:
    - Asphaltic Surface will be 2" in depth.
    - Bituminous Base will be 4" in depth.
    - Aggregate Base will be 6" in depth.
    - Sub-Base will be 6" in depth.

Table 2

Recharge Section: 4th St. to 7th St.						
			Traditional Design		LID Recharge Base Design	
Typical Road Construction Capital Costs:	*Unit*	*Installed Cost*	*No. of Units*	*Total Cost*	*No. of Units*	*Total Cost*
Grading (6" rock, at 2% SE from center, Sub grade beneath)	CY	$8.00	13997	$111,979.56	6546	$52,370.67
Compacted Aggregate Base	CY	$32.00	2883	$92,243.52	1437	$45,984.00
Bituminous Base	CY	$75.00	1922	$144,130.50	958	$71,850.00
Asphalt Surface	CY	$105.00	961	$100,891.35	479	$50,295.00
Curb and Gutter	LF	$24.00	4130	$99,118.80	0	$0.00
Catch Basins	Each	$1,900.00	36	$68,400.00	0	$0.00
Crosswalks	SF	$6.00	7216	$43,296.00	3696	$22,176.00
Parking:						
Number of Spaces	Each	N/A	106	---	144	---
Pervious Pavers	SF	$6.50	0	$0.00	43622	$283,539.75
Sand Setting Bed (1" Depth)	CY	$20.00	0	$0.00	135	$2,692.69
Aggregate Base Layer (12" Dept	CY	$20.00	0	$0.00	1657	$33,140.74
Perforated HDPE (4" Dia.)	LF	$50.00	0	$0.00	1437	$71,850.00
Bollard	Each	$500.00	0	$0.00	513	$256,375.00
Parking Back Stops	Each	$200.00	0	$0.00	144	$28,800.00
Concrete Curb	CY	$200.00	0	$0.00	41	$8,285.19
Vegetation Planters:						
Flow Through Rain Garden						
Concrete	CY	$200.00	0	$0.00	124	$24,707.41
Aggregate Base	CY	$20.00	0	$0.00	176	$3,529.63
No. 4 Open Graded Aggr	CY	$25.00	0	$0.00	44	$1,103.01
Biorention Soil Mix (18")	CY	$15.00	0	$0.00	282	$4,235.56
Vegetation (10' Mature (	Each	$75.00	0	$0.00	136	$10,210.71
Pervious HDPE (6" Dia.)	LF	$50.00	0	$0.00	1437	$71,850.00
Parking Area Planter						
Concrete	CY	$200.00	0	$0.00	18	$3,555.56
Aggregate Base	CY	$20.00	0	$0.00	178	$3,555.56
No. 4 Open Graded Aggr	CY	$40.00	0	$0.00	44	$1,777.78
Biorention Soil Mix (18")	CY	$14.00	160	$2,240.00	267	$3,733.33
Vegetation (30' Canopy 1	Each	$75.00	80	$6,000.00	12	$900.00
Additional Cost:						
Cistern	Each	$100,000.00	0	$0.00	1	$100,000.00
Vehicle Traffic Lights	Each	$25,000.00	3	$75,000.00	3	$75,000.00
Bicycle Traffic Lights	Each	$25,000.00	0	$0.00	3	$75,000.00
Total:				$743,299.72		$1,306,517.57

Assumptions: All costs exclude design, construction administration, EPSC, roadway paint.

1. Roadway between existing sidewalks is being constructed as new, including roads entering section.
2. The entire area is part of the combined sewer system.
3. Existing area is graded flat (w/o super elevation)
4. Two storm sewer pipes per building will be constructed from the edge of the sidewalk to the centerline to tie into the trunk sewer.
5. Assume 12 catch basins per city block each equipped with 12" of concrete.
6. Parking Area Planters are 20 ft. by 20 ft.
7. All existing Light Poles will remain.
8. Bollards are placed every 4-ft. on both sides of bike lanes.
9. Trees planted in the Flow through Rain Garden will be spaced at approximately 7-ft. on center.
10. Asphalt Material:
    Asphaltic Surface will be 2" in depth.
    Bituminous Base will be 4" in depth.
    Aggregate Base will be 6" in depth.
    Sub-Base will be 6" in depth.

Table 3

Retain Section: 7th St. to MLK Blvd						
			Traditional Design		LID Retain Base Design	
Typical Road Construction Capital Costs:	*Unit*	*Installed Cost*	*No. of Units*	*Total Cost*	*No. of Units*	*Total Cost*
Grading (6" rock, at 2% SE from center, Sub grade beneath)	CY	$8.00	9195	$73,562.07	4300	$34,403.56
Compacted Aggregate Base	CY	$32.00	1850	$59,200.98	944	$30,208.00
Bituminous Base	CY	$75.00	1233	$92,501.53	629	$47,200.00
Asphalt Surface	CY	$105.00	617	$64,751.07	315	$33,040.00
Curb and Gutter	LF	$24.00	2746	$65,909.64	0	$0.00
Catch Basins	Each	$1,900.00	24	$45,600.00	0	$0.00
Crosswalks	SF	$6.00	5904	$35,424.00	3024	$18,144.00
Parking:						
Number of Spaces	Each	N/A	64	---	89	---
Pervious Pavers	SF	$6.50	0	$0.00	28880	$187,716.75
Sand Setting Bed (1" Depth)	CY	$20.00	0	$0.00	89	$1,782.69
Aggregate Base Layer (12" Depth	CY	$20.00	0	$0.00	1097	$21,940.74
Perforated HDPE (4" Dia.)	LF	$50.00	0	$0.00	944	$47,200.00
Bollards	Each	$500.00	0	$0.00	407	$203,625.00
Parking Back Stops	Each	$200.00	0	$0.00	89	$17,800.00
Concrete Curb	CY	$200.00	0	$0.00	27	$5,485.19
Vegetation Planters:						
Bio-Filtration Swale						
Concrete	CY	$200.00	0	$0.00	64	$12,781.48
Aggregate Base	CY	$20.00	0	$0.00	91	$1,825.93
No. 4 Open Graded Aggr	CY	$25.00	0	$0.00	23	$570.60
Biorention Soil Mix (18")	CY	$14.00	0	$0.00	146	$2,045.04
Vegetation (10' Canopy	Each	$75.00	0	$0.00	70	$5,282.14
Pervious HDPE (6" Dia.)	LF	$50.00	0	$0.00	944	$47,200.00
Parking Area Planter						
Concrete	CY	$200.00	0	$0.00	12	$2,370.37
Aggregate Base	CY	$20.00	0	$0.00	119	$2,370.37
No. 4 Open Graded Aggre	CY	$40.00	0	$0.00	30	$1,185.19
Biorention Soil Mix (18")	CY	$14.00	80	$1,120.00	178	$2,488.89
Vegetation (30' Canopy Tr	Each	$75.00	40	$3,000.00	8	$600.00
Additional Cost:						
Cistern	Each	$100,000.00	0	$0.00	1	$100,000.00
Vehicle Traffic Lights	Each	$25,000.00	2	$50,000.00	2	$50,000.00
Bicycle Traffic Lights	Each	$25,000.00	0	$0.00	2	$50,000.00
Total:				**$491,069.30**		**$927,265.92**

Assumptions: All costs exclude design, construction administration, EPSC, roadway paint.

1. Roadway between existing sidewalks is being constructed as new, including roads entering section.
2. The entire area is part of the combined sewer system.
3. Existing area is graded flat (w/o super elevation)
4. Two storm sewer pipes per building will be constructed from the edge of sidewalk to the centerline to tie into the trunk sewer.
5. Assume 12 catch basins per city block each equipped with 12” of concrete.
6. Parking Area Planters are 20 ft. by 20 ft.
7. All existing Light Poles will remain.
8. Bollards are placed every 4-ft. on both sides of bike lanes.
9. Trees planted in the Bio-Filtration swale will be spaced at approximately 7-ft. on center.
10. Asphalt Material:
    - Asphaltic Surface will be 2" in depth.
    - Bituminous Base will be 4" in depth.
    - Aggregate Base will be 6" in depth.
    - Sub-Base will be 6" in depth.

The difference in capital costs will be offset by increased revenues recognized by additional parking that is available as a result of the new designs. Table 4 summarizes annual revenue that would be recognized as a result of additional parking achieved as part of the LID approach. This additional revenue will be used to calculate a simple payback period to cover the higher capital costs associated with the LID approach.

Table 5 summarizes the total costs difference with each section.

Lastly it should be noted that the LID approach requires less asphalt which would require resurfacing through the years. Again this cost savings is not considered in these calculations contributing to the overall conservative financial approach which further supports the LID alternatives.

Table 4

Reoccurring Revenue			
Additional Parking Spaces	Daily Revenue per Space	Business Days per Year	Annual Total
65	$12.00	260	$202,800.00

These projections assume that 1) only additional parkingthat is a result of the LID approach is considered; 2) revenue from parkingfines was not considered; 3) capital cost and operating fees of metering devices were not considered.

Table 5

Return on Investment			
Section	**LID Section Name**	**Traditional Design**	**LID Design**
W Aquarium Way to W. 4th St. (2 City Blocks) - From Table 1	Restore	$509,919.95	$896,210.84
W 4th St. to W 7th St. (3 City Blocks) - From Table 2	Recharge	$743,299.72	$1,306,517.57
W 7th St. to W MLK Blvd. (2 City Blocks) - From Table 3	Retain	$491,069.30	$927,265.92
	Total Design Cost	$1,744,288.97	$3,129,994.33
		Design Cost Difference	$1,385,705.36
		Potential Annual Revenue from Additional Parking	$202,800.00
		Payback Period in Years*	**6.8**

**Payback period was calculated by dividing the difference in design costs by the potential annual revenue from additional parking created with the LID Design option.*

SUMMARY

Scenic City Stormwater represents an achievable vision for the future. The initial capital costs are more expensive than traditional streetscape design. The vision set forth in this plan is one that carries social, economic, and environmental implications which far outweigh development considerations. We believe these benefits establish Scenic City Stormwater as the preferred alternative for Chattanooga's future.

Environmental Benefits

- The tiered system of retention, recharge, and restoration offer three different approaches to improving stormwater quality.
- No one approach is favored over the other, creating a flexible system that can be built over time and modified to meet the needs of environmental change.
- The entire system promotes improved water quality and groundwater recharge.
- The proposed design decreases stress on the existing combined sewer system.
- Street trees and vegetation take a prominent role in maintaining urban habits with a focus on improved soils and biodiversity.
- The presence of cisterns helps to prevent toxic smells during drought periods.
- The proposed design has the storage capacity to capture greater than the first one inch requirement. This, coupled with the proposed future use of green roofs, can further expand the storage capacity of the public right-of-way. The end result is a street that represents a one solution to severe flooding.

Social Benefits

- The proposed design offers an opportunity to engage the community.
- Cisterns as public art create a civic pride and a sense of place along Broad Street.
- Public stormwater improvements that positively impact private land owners strengthens partnerships between the public and private sector.
- The proposed design creates metaphorical design solutions that better connect the community to the Tennessee River and the surrounding watershed, instilling a greater sense of place.
- The proposed design offers an educational component for all ages.
- The complete street approach provides greater connectivity for all users, and provides safer options for travel.

Economic Benefits

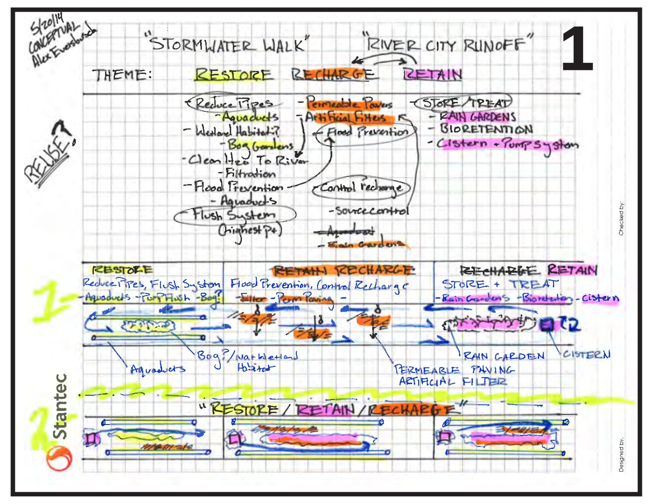
- The initial capital investment will generate revenue for the engineering and construction industry which often directly impacts local businesses.
- Reduced reliance on asphalt reduces long-term paving and maintenance costs. Permeable pavers require little maintenance versus traditional paving materials.
- Creating a safer roadway for bicyclists and pedestrians reduces the risk of injury and death to bicyclists and pedestrians which represents a definable cost.
- Expanding the number of parking spaces increases opportunities for local businesses. This also increases the amount of parking fees that can be collected.
- The presence of bicycle facilities provides opportunities for additional users who may visit Broad Street and spend additional time shopping, dining, and being entertained.
- A revitalized streetscape complete with an innovative green infrastructure can attract new business, redevelopment, and more tourists generating additional revenue for the City.
- Healthier environments for trees and plant material equate to less future replacement.
- The proposed design represents a public effort to address SOVs that directly impact local business owners. The City can use this as incentive to attract developers to Broad Street and other corridors where this type of streetscape is implemented. If the City can assist in reducing redevelopment costs, developers have an additional motive to want to conduct business along Broad Street and other corridors.
- The proposed use of green roofs and the resulting expanded storage capacity of the street equates to a corridor that can better address flooding. The negative impact of heavy rains and flooding is lessened because the street can more quickly return to a pre-flood condition.

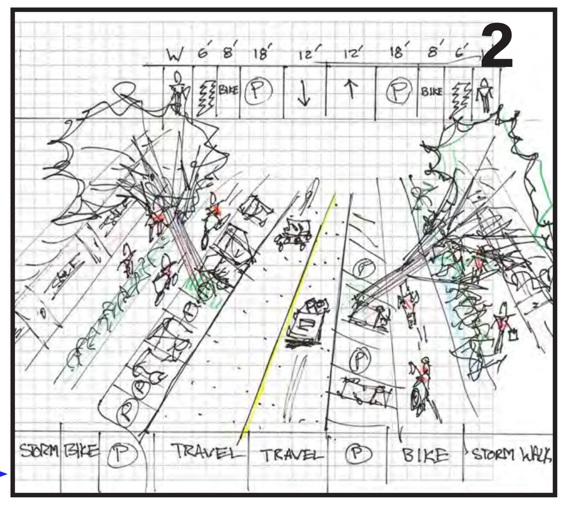
APPENDIX

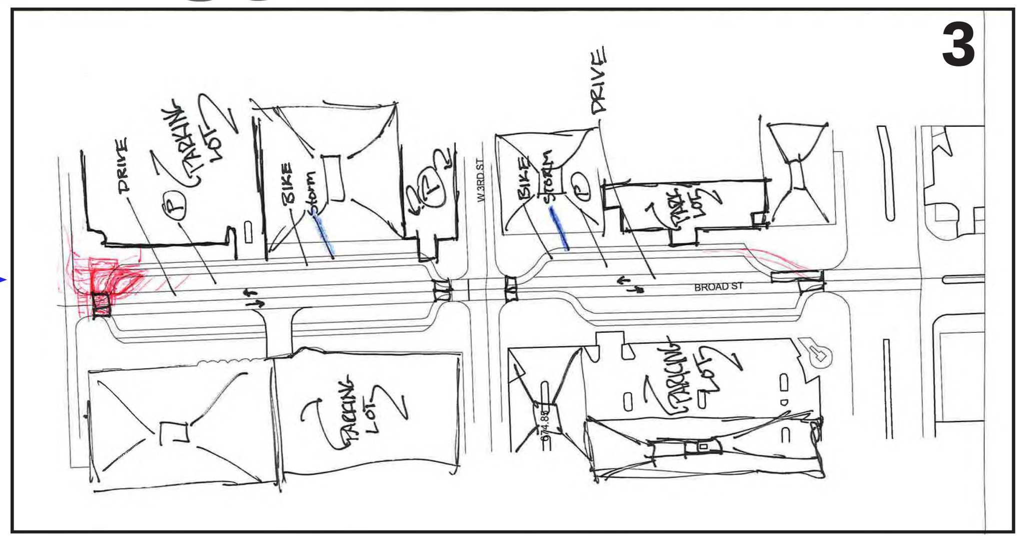
Scenic City STORMWATER

Master Plan

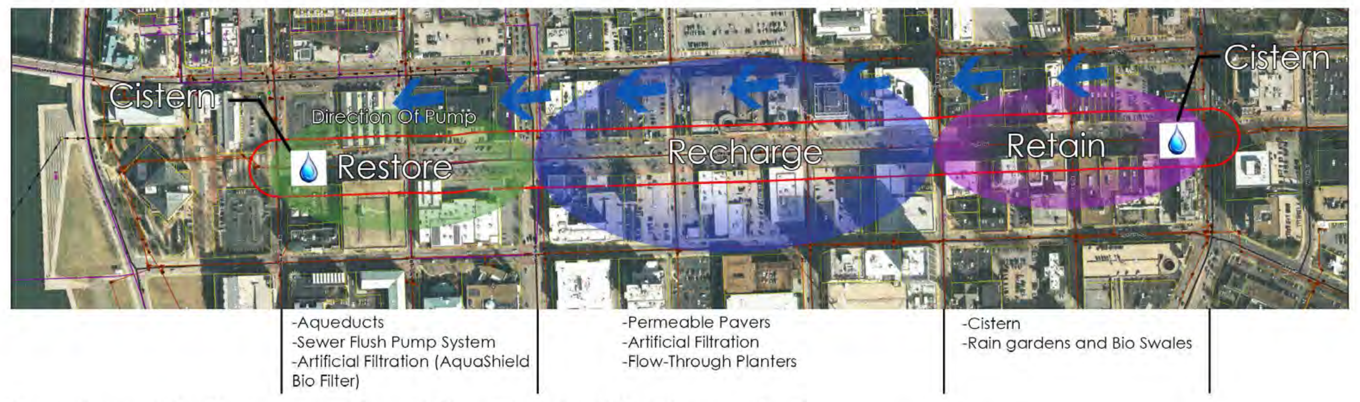
The Process







The Vision



Downtown Chattanooga – Broad St. "Scenic City Stormwater"

Theme: "Restore" "Recharge" "Retain"

Restore: The restoration of the watershed, its natural drainage, and its capacity to withstand excess rainwater in the event of flooding will set the stage for successful stormwater management.
-Minimize Pipes on Site – promote natural drainage
-Flush Sewer System – reduce standing waste in watershed
-Return Clean H20 to River – benefit/restore surrounding ecosystem
Key Elements: Aqueducts, Pump System, Artificial Filtration

Recharge: The return of pollution-free stormwater to the ground at a controlled rate using both mechanical and bio-filtration methods. This will also mitigate flooding, and benefit the water table and ecosystems on and around the site.
-Replace impermeable surface with permeable surfaces
-Source Control – prevent hazardous materials from infiltrating the ground
Key Elements: Permeable Pavers, Artificial Filtration, Flow-Through Planters

Restore	Recharge	Retain
Aqueducts	Permeable Pavers	Cistern
Pump System	Artificial Filtration	Rain Gardens/ Bio Swales
Artificial Filtration (AquaShield Bio-Filter)	Flow-Through Planters	

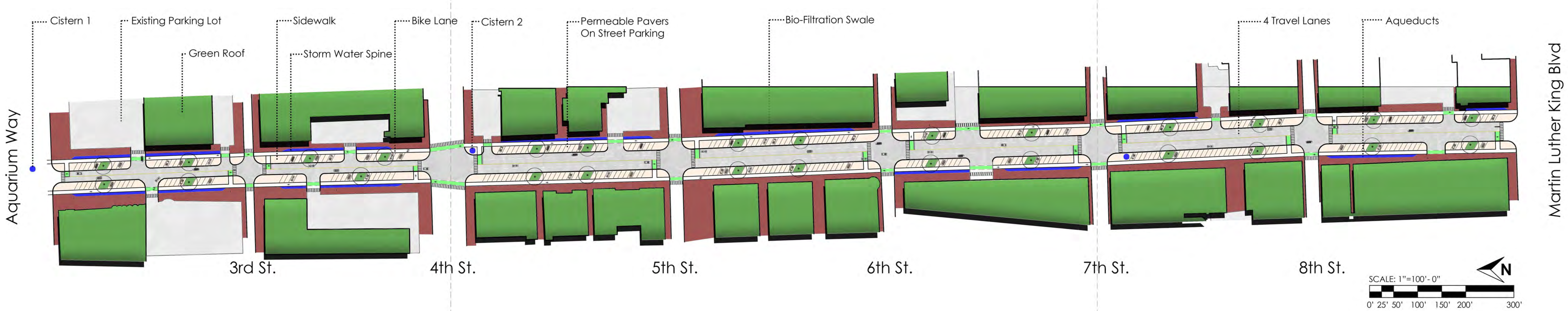
Retain: Storing and treating stormwater for reuse using bio retention and mechanical retention methods. This will benefit the site's ecosystem and the people living and working in it.
-Treat stormwater before returning it to the sanitary sewer system
-Use stormwater to nourish vegetation in the area, and contribute to the visual appeal of the site
-Store water onsite, allowing for a backup pump system to flush the sewers or irrigate vegetation in dry season
Key Elements: Cistern, Rain Gardens / Bio Swales

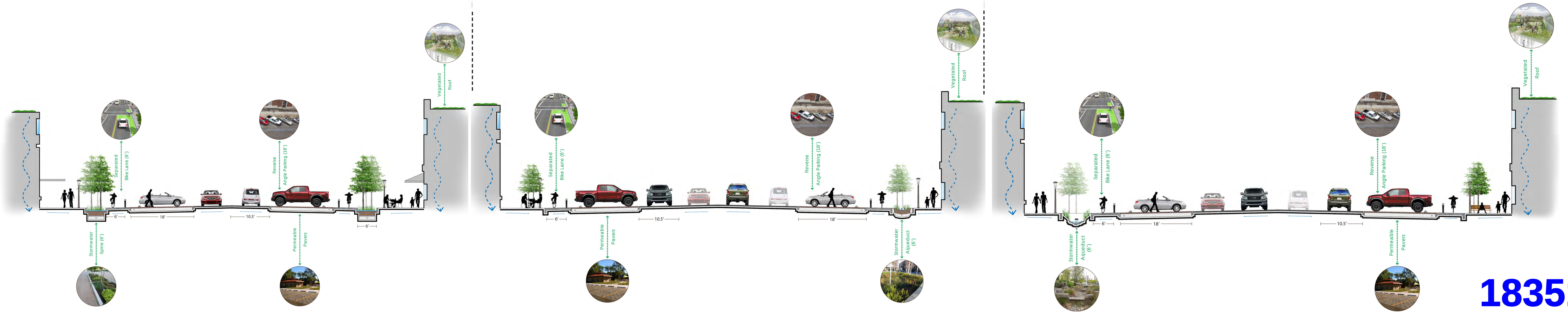
Chattanooga, TN   Broad Street   Stormwater Management Study   May 2014   Sht 1

RESTORE
Aquarium Way - 4th Street

RECHARGE
4th St - 7th St

RETAIN
7th St - Martin Luther King Blvd





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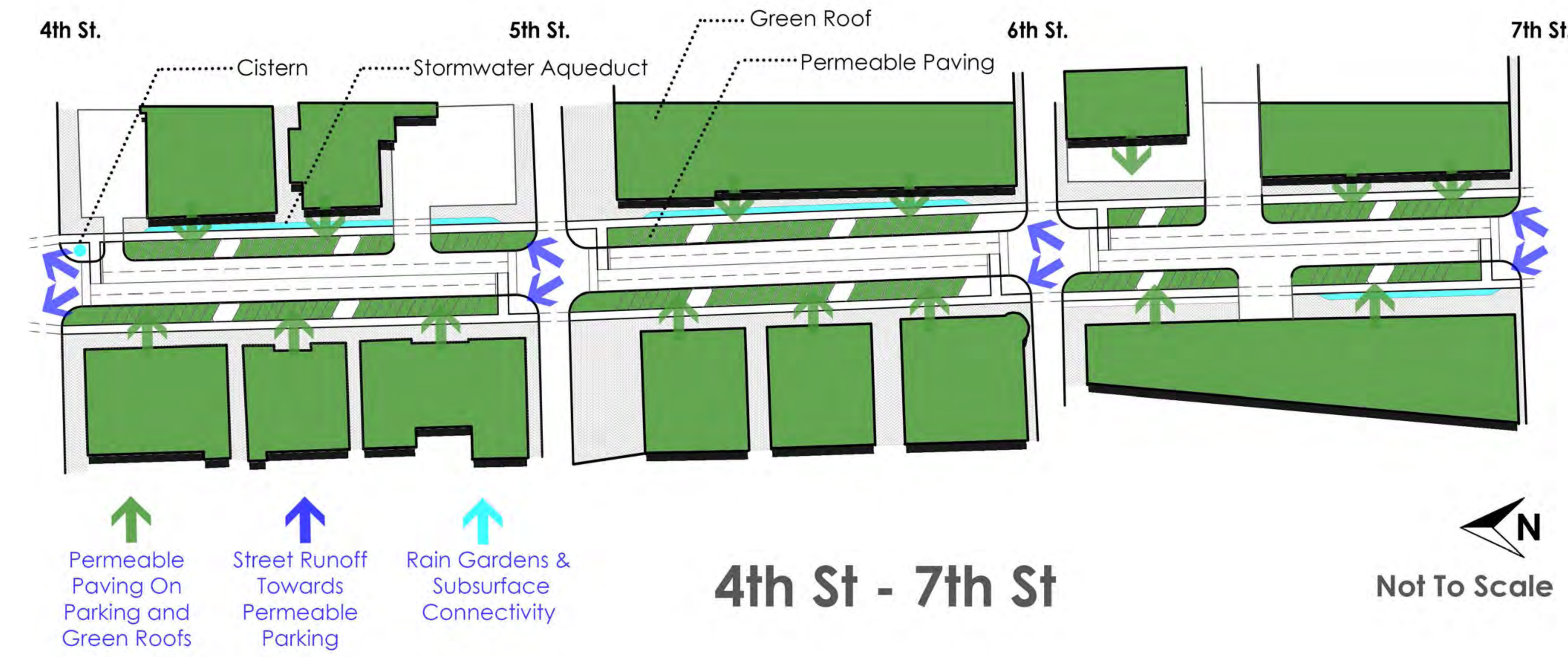
Scenic City STORM WATER

Drainage Plan And Project Numbers

Drainage Plan: Street Level

RECHARGE



Drainage Plan: System Level

RESTORE

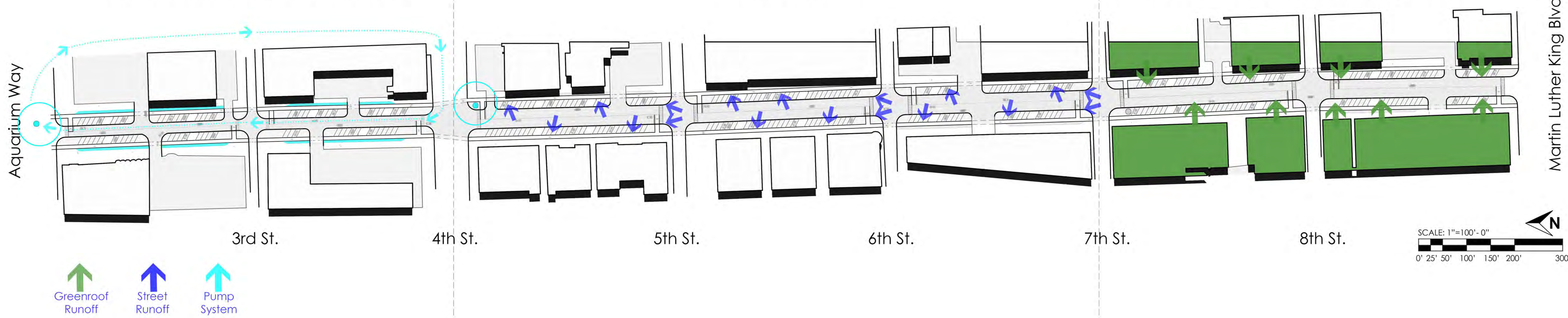
Aquarium Way - 4th Street

RECHARGE

4th St - 7th St

RETAIN

7th St - Martin Luther King Blvd



Existing Conditions

Chattanooga Annual Averages	
Precipitation	52.48 Inches
Snowfall	3.9 Inches
SOV Design Rainfall	1 Inch
Target Loading Ratio	10
Initial Target BMP Area, Ft³	**15,233 Ft2**

Factoid

Chattanooga's Average Rainfall Per Year is 79% of The Average Rain Fall in Costa Rica's Rainforsets

Total Surface Area Per Section

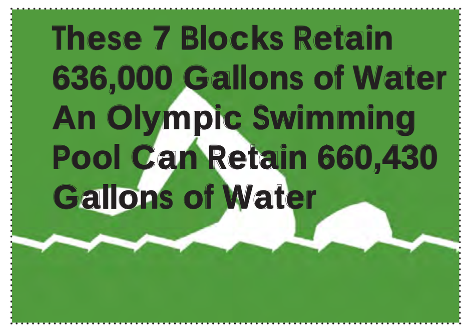
Section #	Section Name	From	To	Distance, Ft²	Area, Ft²	Area, Acres
1	Restore	Aquarium Way	W 4th St.	945	312,740	7.2
2	Recharge	W 4th St.	W 7th St.	1,110	490,092	11.5
3	Retain	W 7th St.	W MLK BLVD	945	326,750	7.5

Factoid

Stay On Volume Per Section

Section #	Section Name	From	To	Traditional Required SOV Ft³	LID Required SOV Ft³	Total Storage Volume Available in LID BMPs
1	Restore	Aquarium Way	W 4th St.	23,515	21,007	28,559
2	Recharge	W 4th St.	W 7th St.	37,194	34,494	45,000
3	Retain	W 7th St. v	W MLK BLVD	24,343	21,900	29,283
				85,052	**77,401**	**102,842**

Factoid



The Investment

Section	LID Section Name	Non-LID Design	LID Design
W Aquarium Way to W. 4th St.	Restore	$509,919.95	$896,210.84
W 4th St. to W 7th St.	Recharge	$743,299.72	$1,306,517.57
W 7th St. to W MLK Blvd.	Retain	$491,069.30	$927,265.92
	Total:	**$1,744,288.97**	**$3,129,994.33**

18351