Transforming Gray Space into Green Space:

Integrating Green Infrastructure Into Our Built Environment

September 26, 2016

Kevin Robert Perry, ASLA

Urban Rain | Design

Photo: www.graham.umich.edu

Why Green Infrastructure?

Retrofit Projects

Multiple Shades of Green

Micro-greening

Start Small, Think Big

Why Green Infrastructure?

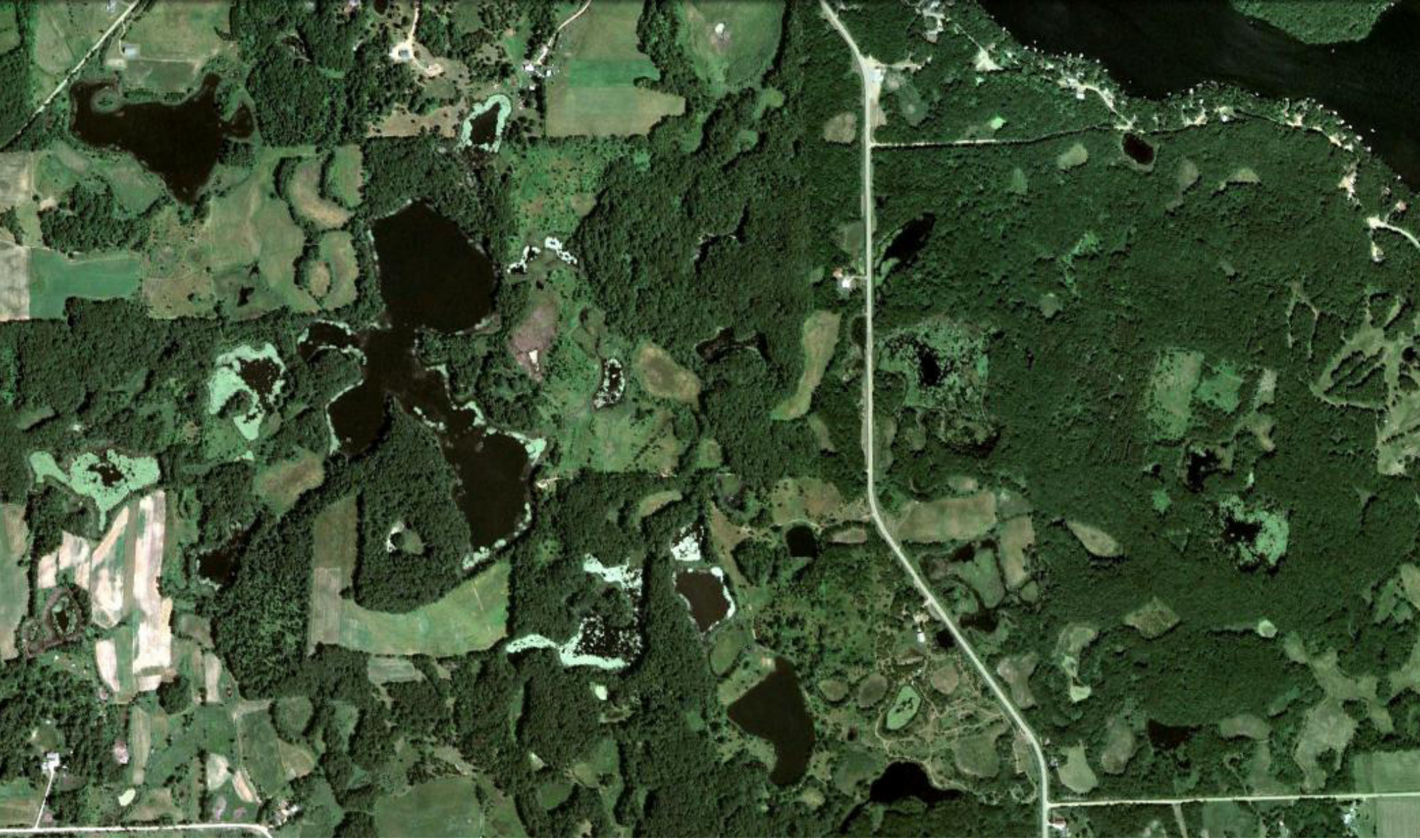

Photo: Google Earth

Natural Landscape

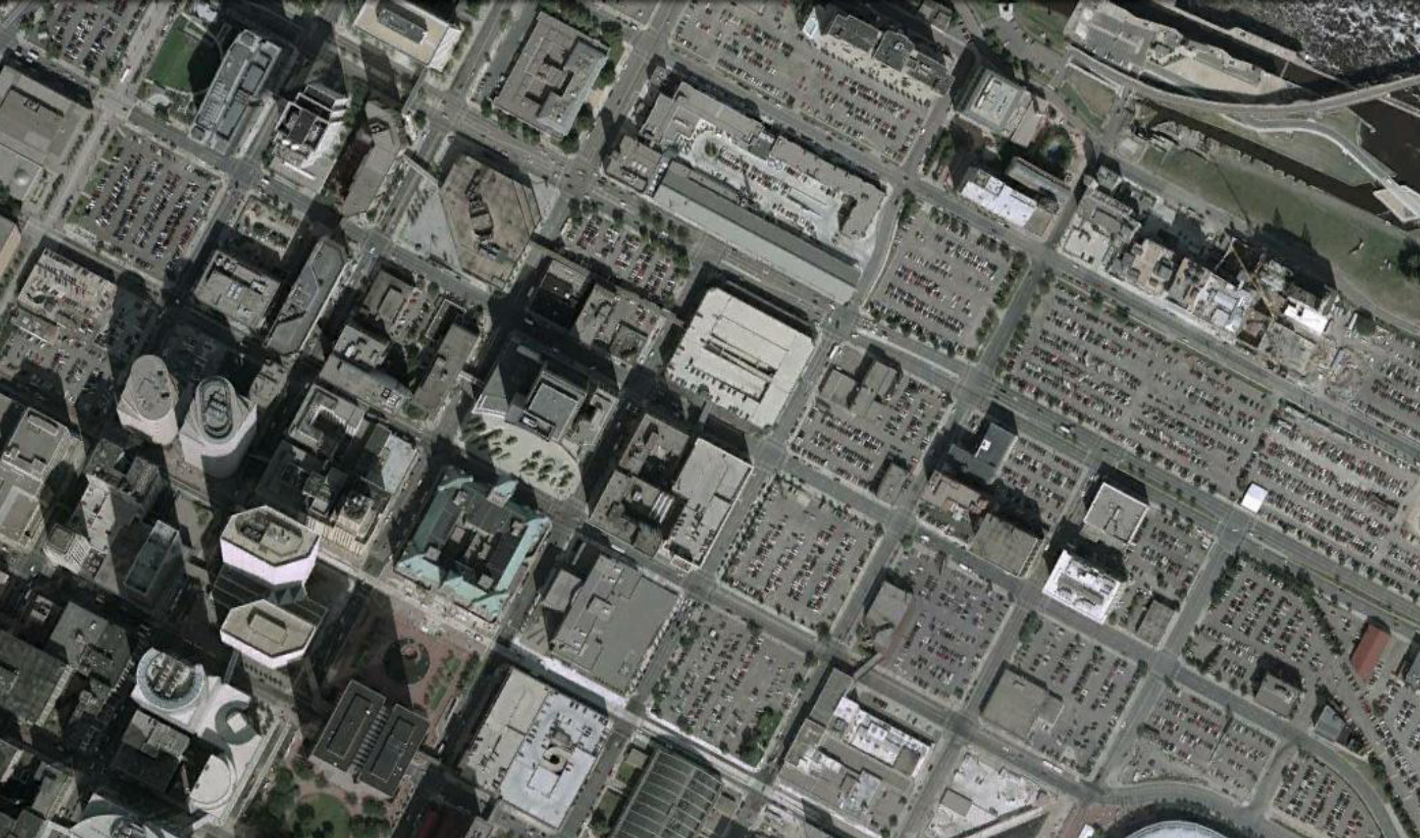

Photo: Google Earth

Urbanization

Minneapolis, Minnesota

Photo: Google Earth

Natural Landscape

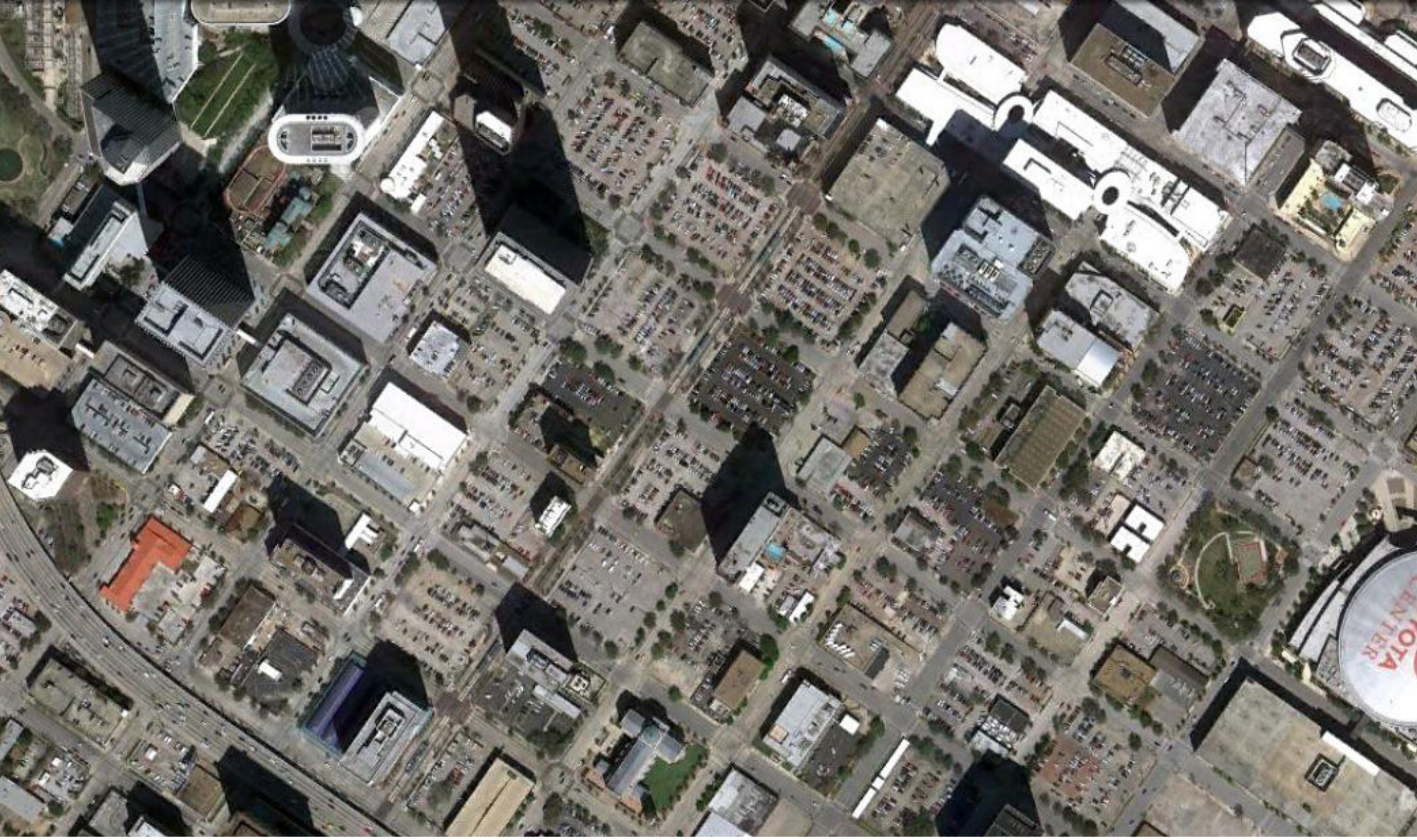

Photo: Google Earth

Urbanization

Houston, Texas

Photo: Google Earth

Natural Landscape

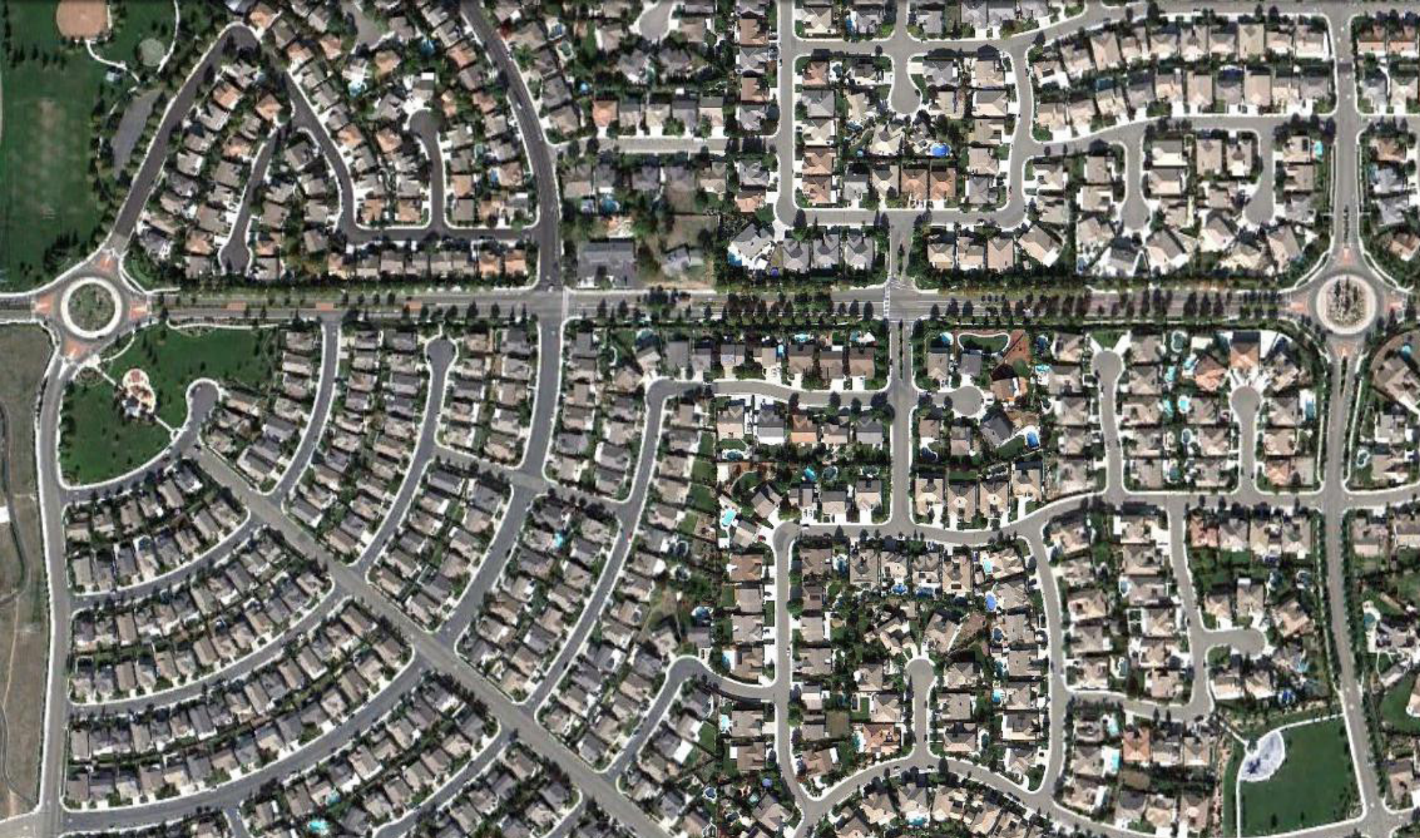

Photo: Google Earth

Sub-Urbanization

California Central Valley

Photo: Google Earth

Natural Landscape

Photo: Google Earth

Urbanization

Calgary, Canada

Desert

Redwoods

Riparian

Oaks

Moving Towards An Unhealthy Watershed

Photo: Kevin Robert Perry

The Urban Street Stormwater System

Impervious, Little or No Landscape

Photo: Kevin Robert Perry

The Natural Stream Stormwater System

Pervious, Considerable Landscape System

Photo: Kevin Robert Perry

The “Green Infrastructure” Stormwater System

Pervious, Integrated Landscape System

The Green Infrastructure “Toolbox”

Retrofit Projects

Photo: Kevin Robert Perry, City of Portland

NE Siskiyou Green Street

Portland, Oregon

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SW 12th Avenue Green Street

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SW 12th Avenue Green Street

Portland, Oregon

Nevue Ngan Associates recently assisted URS Engineers with the development of streetscape design plans for Sandy Boulevard between NE 14th and NE 48th Avenue. NNA was responsible for assessing existing street trees, developing and illustrating streetscape design alternatives related to landscape, and assisting with the development of construction documents.

NNA worked closely with the Portland Bureau of Environmental Services, Portland Office of Transportation, and Urban Forestry to create an innovative plan that incorporates several landscaped stormwater treatment areas into the right-of-way. Both infiltration basins and landscaped curb extensions are being utilized to achieve the dual purpose of reducing CSOs and to bring a stronger visual identity to specific intersections.

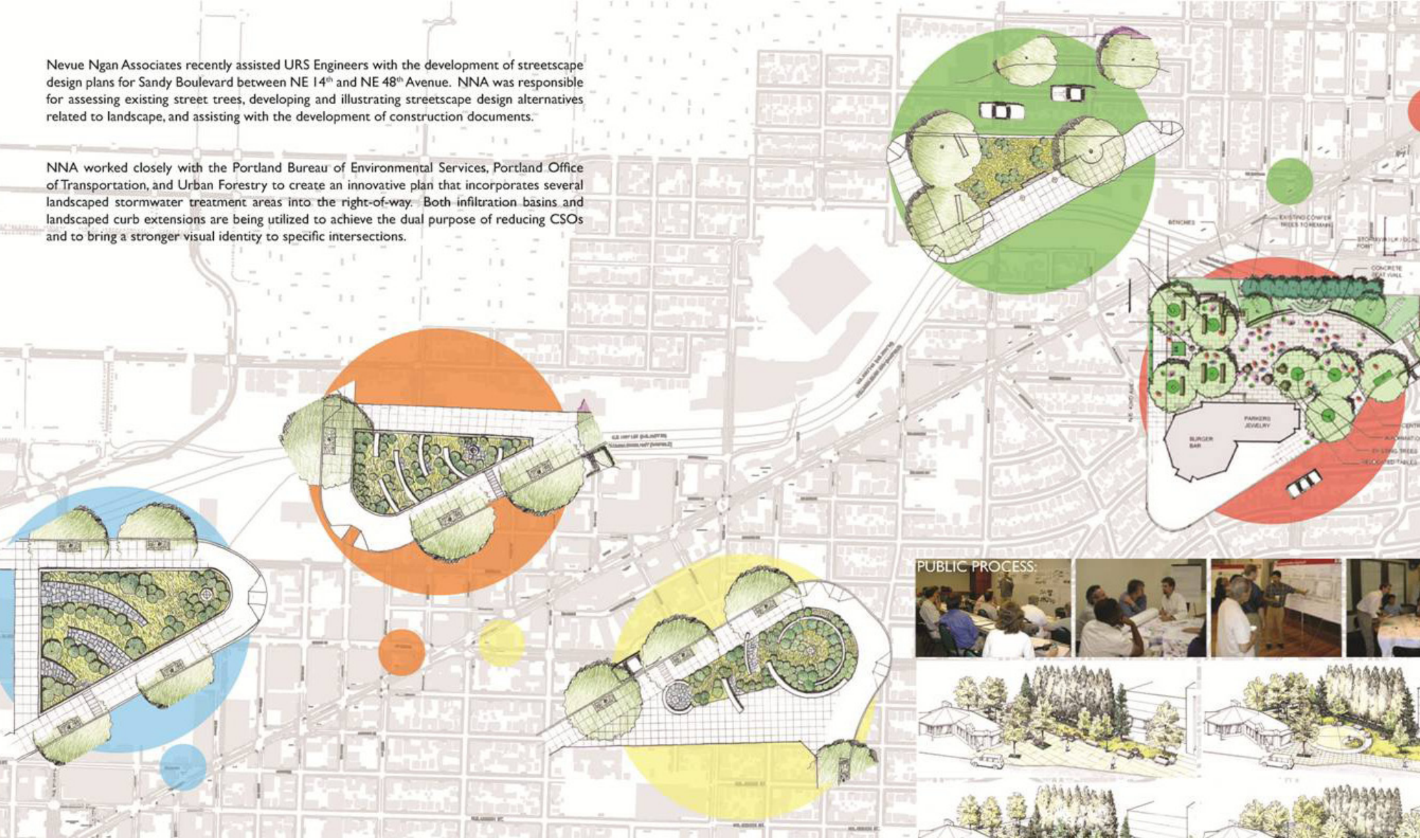

Illustration: Nevue Ngan Associates

NE Sandy Boulevard Rain Gardens

Portland, Oregon

Photo: Kevin Robert Perry, Nevue Ngan Associates

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Portland, Oregon

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NE Sandy Boulevard Rain Gardens

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Photo: Kevin Robert Perry, City of Portland

Mount Tabor Middle School Rain Garden

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Mount Tabor Middle School Parking Lot Retrofit

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Mount Tabor Middle School Building Planters

Portland, Oregon

Photo: Kevin Robert Perry, City of Portland

Mount Tabor Middle School Building Planters

Portland, Oregon

Photo: Google Earth

Brisbane City Hall Rain Garden

Brisbane, California

Photo: Kevin Robert Perry, Nevue Ngan Associates

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Logus Road Green Street

Milwaukie, Oregon

Photo: Kevin Robert Perry, Nevue Ngan Associates

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Milwaukie, Oregon

Photo: Kevin Robert Perry, Nevue Ngan Associates

Logus Road Green Street

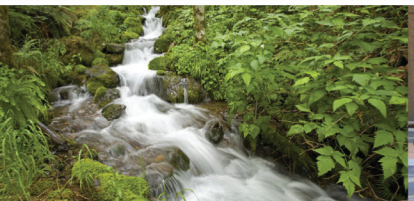
Milwaukie, Oregon

Site Plan

SW Montgomery Green Street

Connecting the West Hills to the Willamette River

The SW Montgomery Green Street is regarded as Portland's most innovative green street effort. The project demonstrates how, in even the most ultra-urban conditions, downtown streets can be planned and retrofitted not only to fully manage stormwater runoff but to also create, integrate, and preserve vibrant pedestrian spaces. This 9-block concept plan incorporates a variety of green infrastructure and alternative transportation strategies throughout this emerging neighborhood in downtown Portland.



The "Stormwater Spine"

SW Montgomery Green Street

Connecting the West Hills to the Willamette River

1 Stormwater Bridges

Multiple pedestrian bridges across the stormwater spine are needed to provide adequate pedestrian flow throughout the corridor. These bridges should be wide enough and spaced frequently to accommodate specific users such as bikes, people, and even autos.

2 "Curbless" Street Profile

Providing a flush drainage condition along the stormwater spine allows stormwater runoff to sheet flow into the landscape area. This provides both a barrier free condition for pedestrians and a shallower and more aesthetic stormwater facility.

3 High-Density Planting

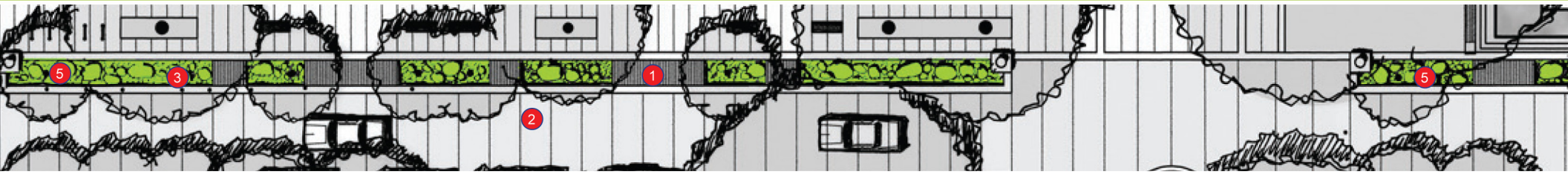
The stormwater spine is a functional landscape area used to clean and absorb stormwater runoff. Providing a high-density spacing of trees, shrubs, and groundcovers maximizes the ability for plant roots to clean pollutants and absorb runoff.

4 Simple and Shallow

There is a maximum grade change of 6-inches from the walking surface to the finish grade of the stormwater spine. This simple design approach eliminates the typical need for a perimeter curb around the landscape and still allows for adequate pedestrian safety.

5 A Continuous Theme

The stormwater spine functionally and visually links individual blocks within the street corridor. Planting types and the width of the spine does vary from block-to-block in response to unique conditions. However, the overall "green thread" remains consistent throughout.



The continuous Stormwater Spine along the SW Montgomery Green Street is planned as a highly functional landscape system used to capture and manage stormwater runoff from over 75,000 square feet of impervious area. The spine is the project site's "workhorse" for stormwater management. Each block along the corridor has the stormwater spine traversing through it, however, the form and size of the landscape system does vary in response to the unique conditions of each block. Sections of the stormwater spine have already been built along the SW Montgomery Green Street and are so well integrated into the urban fabric that many can not even distinguish them as being functional stormwater landscapes.

Multi-Modal Street Planning

SW Montgomery Green Street

Connecting the West Hills to the Willamette River

Light Rail/Streetcar

Lines of Rail Transportation **4**

Active Pedestrians

Average Sidewalk Width in Feet **17**

Bike Transit

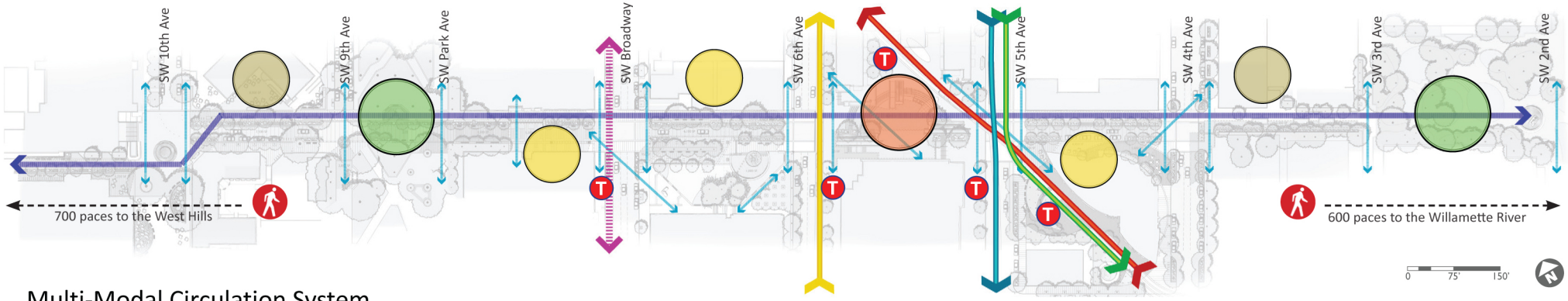
Additional Bike Spaces Provided **82**

Passive Pedestrians

Additional Benches for Seating **63**

Electric/Hybrid Autos

Parking Spaces for plug-in parking **12**



Multi-Modal Circulation System

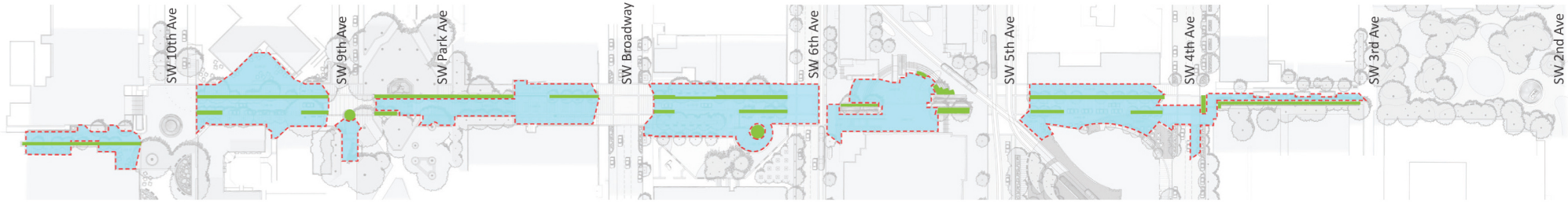
North Bound Street Car
South Bound Street Car
SW Broadway Cycle Track
South Bound Light Rail
North Bound Light Rail
Primary Pedestrian Corridor
Secondary Pedestrian
Transit Stop
Significant Green Space
Significant Urban Space
Academic Hub
Student Housing

The highest caliber green street looks beyond only managing stormwater runoff. It also promotes a transportation mode switch from primarily auto-centric design to a street that emphasizes alternative transportation. The SW Montgomery Green Street exemplifies complete street planning by providing a balanced set of transportation choices, but also provides a clear emphasis on enhanced pedestrian and bicycle infrastructure. The street's "curbless" cross section and wide sidewalks allows for maximum flexibility in overall street programming. Autos are allowed within the corridor, however, the concept plan allows the street to be phased into a pedestrian-only promenade in the future.

Stormwater Performance

SW Montgomery Green Street

Connecting the West Hills to the Willamette River



Surface Stormwater System

11th to 10th	10th to 9th	Park Blocks	Park to Broadway	Broadway to 6th	Urban Center Plaza	5th to 4th	4th to 3rd	Pettygrove Park
4,000 SF Catchment Area 830 SF Landscape Area 21% Landscape to Impervious	17,200 SF Catchment Area 830 SF Landscape Area 8% Landscape to Impervious	4,880 SF Catchment Area 780 SF Landscape Area 16% Landscape to Impervious	10,630 SF Catchment Area 780 SF Landscape Area 9% Landscape to Impervious	13,500 SF Catchment Area 1,650 SF Landscape Area 12% Landscape to Impervious	12,320 SF Catchment Area 1,010 SF Landscape Area 8% Landscape to Impervious	9,315 SF Catchment Area 1,450 SF Landscape Area 16% Landscape to Impervious	5,350 SF Catchment Area 950 SF Landscape Area 18% Landscape to Impervious	No on-site stormwater management due to the historical character of Pettygrove Park
92 THOUSAND GALLONS	397 THOUSAND GALLONS	113 THOUSAND GALLONS	245 THOUSAND GALLONS	311 THOUSAND GALLONS	284 THOUSAND GALLONS	215 THOUSAND GALLONS	123 THOUSAND GALLONS	

Estimated Annual Stormwater Performance

11th to 10th	10th to 9th	Park Blocks	Park to Broadway	Broadway to 6th	Urban Center Plaza	5th to 4th	4th to 3rd	Pettygrove Park
Significant Landscape Area High Street Tree Cover Manages Stormwater Emphasizes Alt. Transportation Building, Site, and Street	Significant Landscape Area High Street Tree Cover Manages Stormwater Emphasizes Alt. Transportation	Significant Landscape Area High Street Tree Cover Manages Stormwater	Significant Landscape Area High Street Tree Cover Manages Stormwater Emphasizes Alt. Transportation Building, Site, and Street	Significant Landscape Area High Street Tree Cover Manages Stormwater Emphasizes Alt. Transportation Building, Site, and Street	Significant Landscape Area High Street Tree Cover Manages Stormwater Emphasizes Alt. Transportation	Significant Landscape Area High Street Tree Cover Manages Stormwater Emphasizes Alt. Transportation Building, Site, and Street	Significant Landscape Area High Street Tree Cover Manages Stormwater	Significant Landscape Area High Street Tree Cover
LEVEL 5	LEVEL 4	LEVEL 3	LEVEL 5	LEVEL 5	LEVEL 4	LEVEL 5	LEVEL 3	LEVEL 2

Green Street Rating Block-by-Block

Gallons of Runoff Managed/Year: **1.8** Million

Combined Green Street Rating: Level **4**

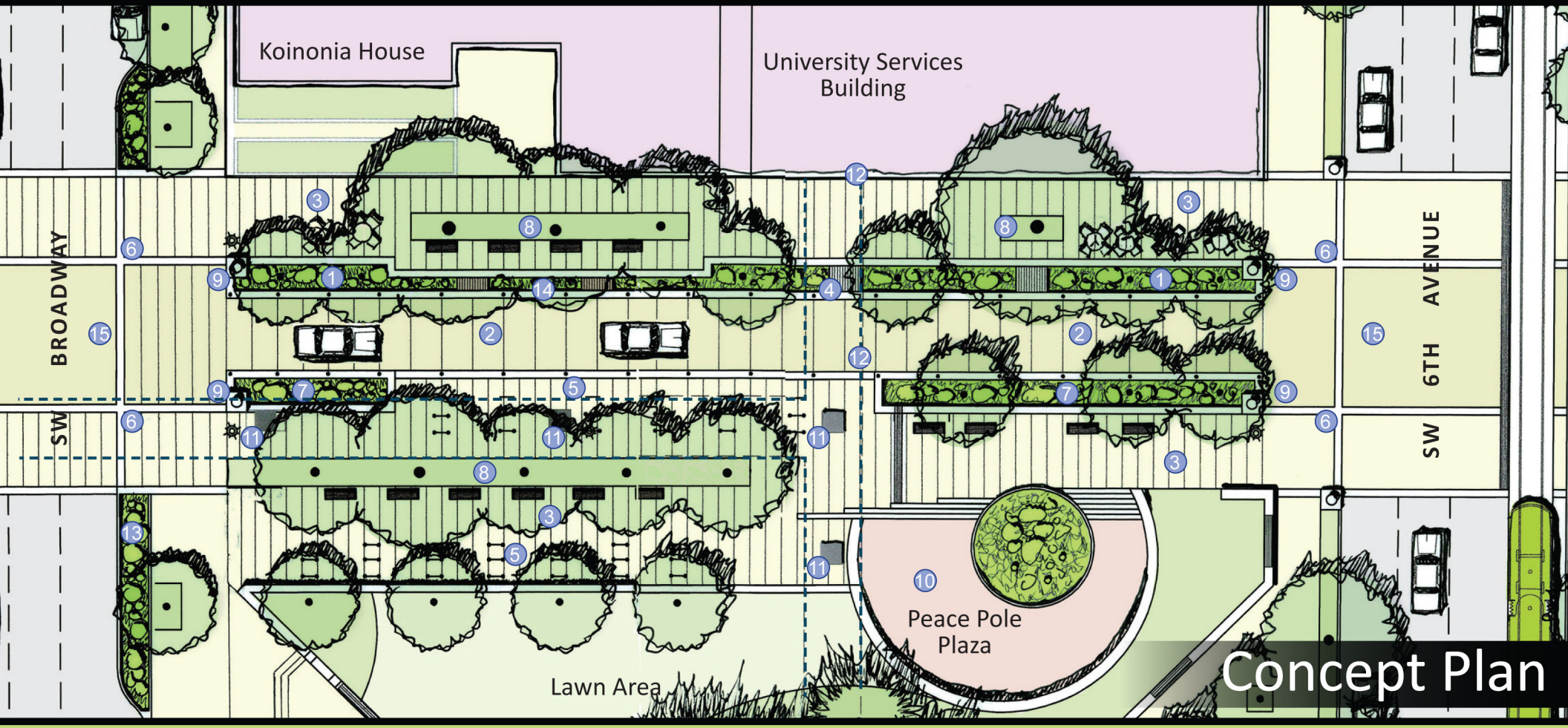
Once fully implemented, the SW Montgomery Green Street has the potential to manage millions of gallons of runoff each year. However, there is a lot of variability in how "green" a street really is and all green streets are not created equal. Within some streets, and as in the case of SW Montgomery, individual blocks can vary on how aggressive the green street approach is. The graphic to the right shows "Multiple Shades of Green" when defining a green street. Level 1 is considered a beginning approach, while Level 5 represents the boldest design effort.

Level 1	Maximize landscaped areas along the street and minimize overall impervious area. Some runoff from adjacent sidewalks may be managed in landscaped areas.
Level 2	Significant tree canopy is added to the urban streetscape.
Level 3	Stormwater runoff is fully managed from the street, sidewalk, and driveway areas within a landscaped system. Design solutions are cost effective, provide direct environmental benefits, and are aesthetically pleasing.
Level 4	Green street provides a direct focus on alternative modes of transportation including mass transit, biking, and walking.
Level 5	The building, site, and street "envelope" becomes one integrated space for private and public stormwater management.

University Services Block

SW Montgomery Green Street

Connecting the West Hills to the Willamette River



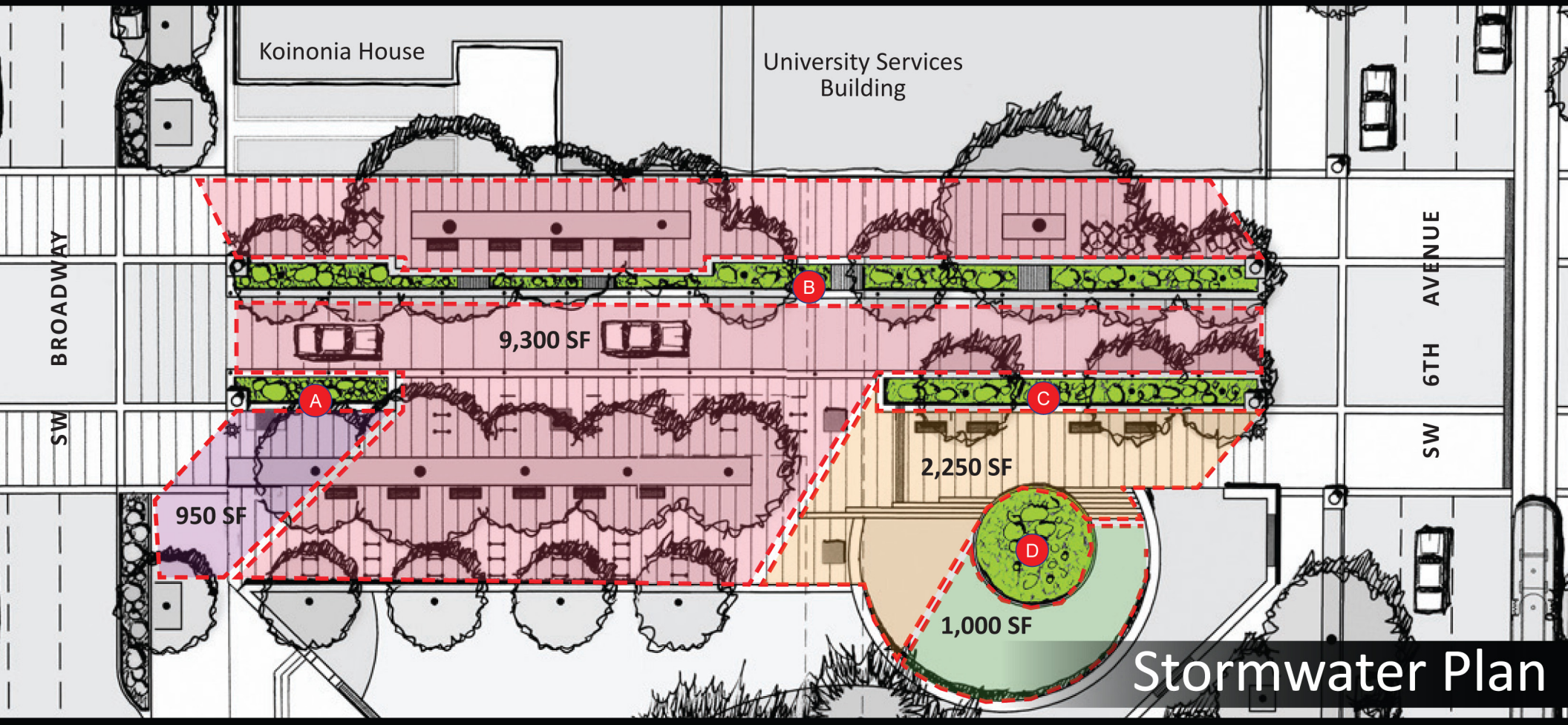
Key Streetscape Improvements

1. SW Montgomery stormwater spine. This 5-foot wide stormwater planter, with significant landscaping and street trees, retains stormwater to a design depth of 6 inches.
2. SW Montgomery allows for one-way eastbound vehicular traffic. The street is "curbless" to allow all modes of traffic to be integrated on one horizontal plane.
3. Sidewalk zones are widened to allow for a generous pedestrian through zone, cafe and park seating, moveable planters, street lighting, and bike parking.
4. Stormwater bridges/boardwalks allow pedestrians to cross the stormwater spine.
5. Flexible space that can be used for large capacity bike parking and/or food carts.
6. Tactile warning strips alert pedestrians to oncoming traffic from vehicles and mass transit.
7. Secondary stormwater planters accept stormwater from additional sidewalk space and skybridge system.
8. Existing trees to be preserved.
9. Ornamental art/landscape features at intersection demarcate the block's entry points.
10. Elevated brick plaza space allows stormwater to flow into a circular stormwater planter. The existing Peace Pole installation is relocated to this space to form the "Peace Pole Plaza."
11. Existing skybridge structural columns.
12. Potential location for vegetated green wall.
13. Stormwater curb extensions capture runoff from SW Broadway.
14. The stormwater spine is narrowed to 3-feet wide to preserve existing large-canopy trees.
15. Street intersection extends the sidewalk paving treatment into the street reinforcing the strong east-west pedestrian connectivity of SW Montgomery Street.

University Services Block

SW Montgomery Green Street

Connecting the West Hills to the Willamette River



Catchment Area	Contributing Impervious Area (IA)	Stormwater Planter Area	Percentage Landscape to IA*	Additional Capacity**
Catchment Area A	950 SF	140 SF	16%	650 SF
Catchment Area B	9,300 SF	760 SF	8%	0 SF
Catchment Area C	2,250 SF	350 SF	16%	1,800 SF
Catchment Area D	**1,000 SF**	400 SF	40%	3,650 SF

* This percentage uses the Bureau of Environmental Services (BES) Simplified Approach of a ratio between impervious area catchment and stormwater facility size.

** Additional capacity looks at how much additional impervious area can be potentially managed in a 10-year storm event based on using the BES Presumptive Approach Calculator.

Photo: Kevin Robert Perry, Nevue Ngan Associates

Smith Memorial Student Union Plaza

Portland, Oregon

Photo: Kevin Robert Perry, Nevue Ngan Associates

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Urban Center Plaza Stormwater Retrofit

Portland, Oregon

Photo: Kevin Robert Perry, Nevue Ngan Associates

Urban Center Plaza Stormwater Retrofit

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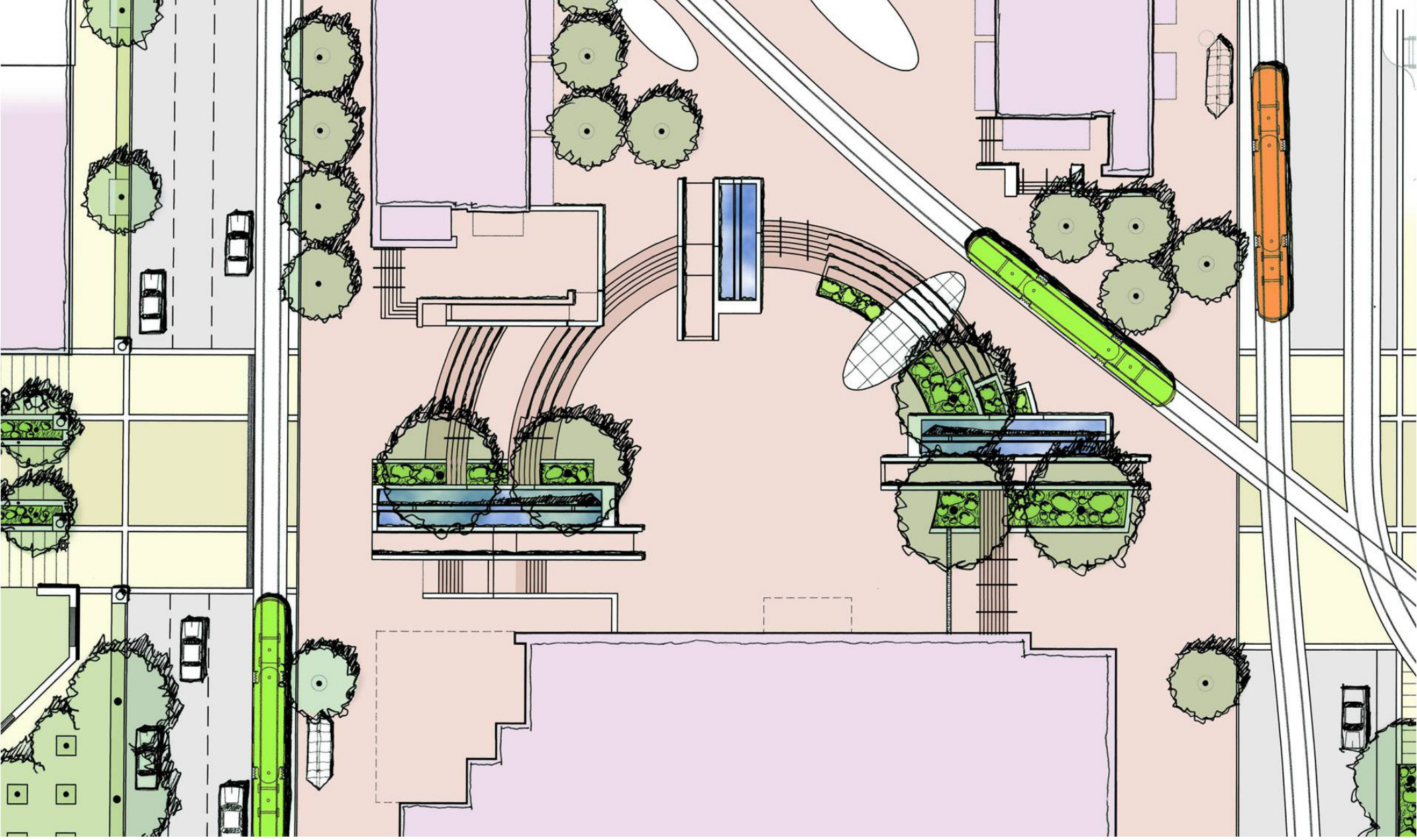

Photo: Kevin Robert Perry, Nevue Ngan Associates

Urban Center Plaza Stormwater Retrofit

Portland, Oregon

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Photo: Kevin Robert Perry

Laurel Elementary School

San Mateo, California

Photo: Kevin Robert Perry

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Laurel Elementary School

San Mateo, California

3. Drop-off/pick-up parking zone.
4. One-way travel aisle for parent/student drop-off/pick-up/pull-through.
5. New rain gardens accept stormwater runoff from drop-off/pick-up zones as well as a portion of the MPR rooftop.
6. One-way travel aisle for staff parking lot area. The travel aisle would be controlled to only allow staff to enter during drop-off and pick-up times.
7. New ADA accessible pathway from Hacienda Street to drop-off/pick-up zone.
8. Existing landscape area/new conventional landscape area.
9. New stormwater planter accepts stormwater runoff parking lot area.
10. Reinforced concrete pad for trash and recycling truck access
11. New entry driveway to parking lot and drop-off/pick-up zone from Hacienda Street.
12. New pedestrian entrance from Hacienda Street.
13. Bollards for protecting pedestrian zone are placed continuously along sidewalk zone. Some bollards will be more closely spaced than others.
14. Existing trees (with open white circle tree trunk) to be protected and retained)(Typical).
15. New trees (with closed black circle tree trunk)(Typical).
16. Relocate exit driveway from parking lot and drop-off/pick-up zone to 36th Avenue.
17. A 2'-wide trench drain allows for a portion of adjacent rooftop runoff to be conveyed to a rain garden.
18. Expanded concrete paving zone allows for more pedestrian area for drop-off and pick-up.
19. New rain garden and circular seatwall provides an attractive entry point into the school.
20. Stormwater curb extension accepts stormwater runoff from the north side of 36th Avenue.
21. New concrete curb extension with ADA accessible ramps helps shorten pedestrian crossing distances. Corner of sidewalk zone is pulled back to allow for easier pedestrian flow and better site distance.
22. Overflow from stormwater landscape is allowed to overflow on the surface and down the driveway.
23. 8' high perimeter fence.
24. Gated access into the school grounds.

Photo: Kevin Robert Perry

Laurel Elementary School

San Mateo, California

Photo: Kevin Robert Perry

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Laurel Elementary School

San Mateo, California

Multiple Shades of Green

Multiple Shades of Green

Level 1

Maximize landscaped areas along the street and minimize overall impervious area.

Level 2

Significant tree canopy is added to the urban streetscape.

Level 3

Stormwater runoff is fully managed from the street, sidewalk, and driveway areas within a landscaped system. Design solutions are park-like, provide direct environmental benefits, and are aesthetically pleasing.

Level 4

Green street provides a direct focus on alternative modes of transportation including mass transit, biking, and walking.

Level 5

The building, site, and street frontage become one integrated space for stormwater management. The entire green street "envelope" manages both public and private runoff.

Photo: Kevin Robert Perry

Level 1- Maximize Landscape Space

Multiple Shades of Green

Photo: Kevin Robert Perry

Level 1- Maximize Landscape Space

Multiple Shades of Green

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Level 1- Maximize Landscape Space

Multiple Shades of Green

Photo: Kevin Robert Perry

Level 1- Maximize Landscape Space

Multiple Shades of Green

Photo: Kevin Robert Perry

Level 1- Maximize Landscape Space

Multiple Shades of Green

Photo & Design: Hood Design Studio, LLC

Level 1- Maximize Landscape Space

Multiple Shades of Green

Photo: www.actfortransit.org

Level 1- Maximize Landscape Space

Multiple Shades of Green

Photo: Ben Ngan

Level 2- Add Significant Street Tree Canopy

Multiple Shades of Green

Photo: Kevin Robert Perry

Level 2- Add Significant Street Tree Canopy

Multiple Shades of Green

Photo: Kevin Robert Perry

Level 2- Add Significant Street Tree Canopy

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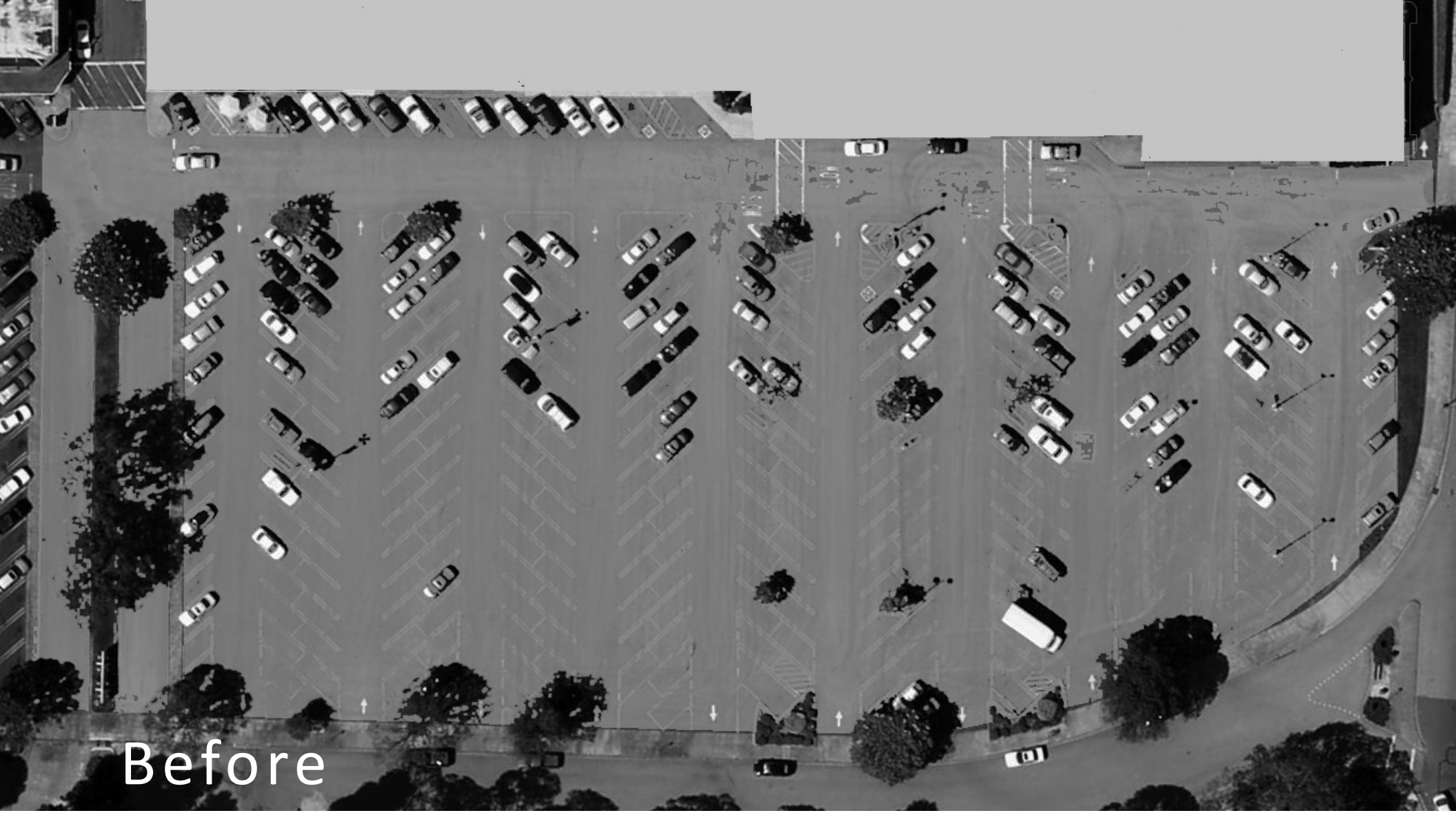
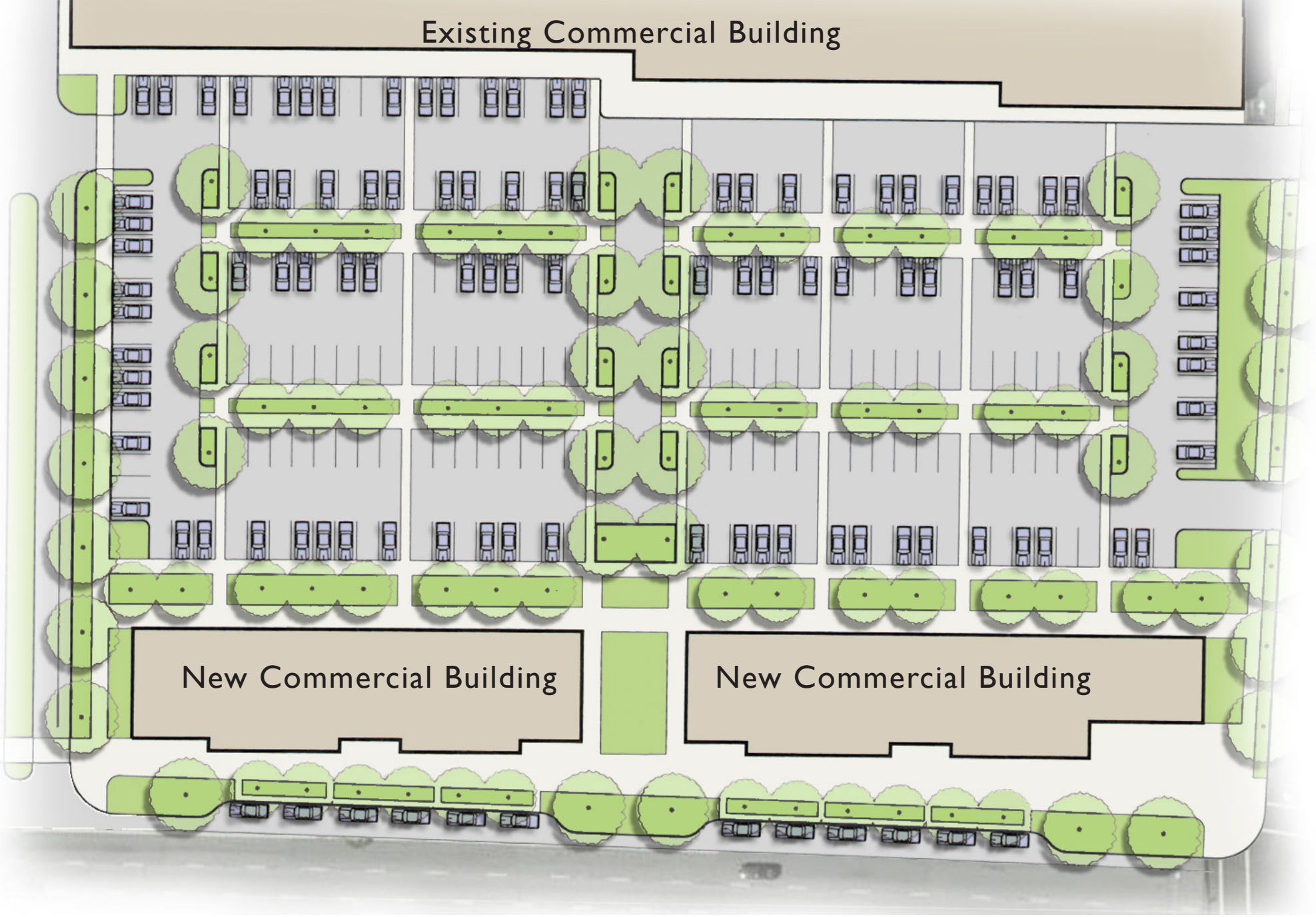
Multiple Shades of Green



Level 2- Add Significant Street Tree Canopy

Multiple Shades of Green



Level 2- Add Significant Street Tree Canopy

Multiple Shades of Green

Photo: Kevin Robert Perry

Level 3- Landscape Actively Manages Water

Multiple Shades of Green

Photo: Kevin Robert Perry

Level 3- Landscape Actively Manages Water

Multiple Shades of Green

Photo: Kevin Robert Perry

Level 3- Landscape Actively Manages Water

Multiple Shades of Green

Photo: Kevin Robert Perry

Level 4- Focus on Alternative Transportation

Multiple Shades of Green

Photo: Nevue Ngan Associates/Kevin Robert Perry

Level 4- Focus on Alternative Transportation

Multiple Shades of Green

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Level 4- Focus on Alternative Transportation

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Multiple Shades of Green

Photo: Kevin Robert Perry

Level 4- Focus on Alternative Transportation

Multiple Shades of Green

Image: Ray Papa/Kevin Robert Perry

Level 4- Focus on Alternative Transportation

Multiple Shades of Green

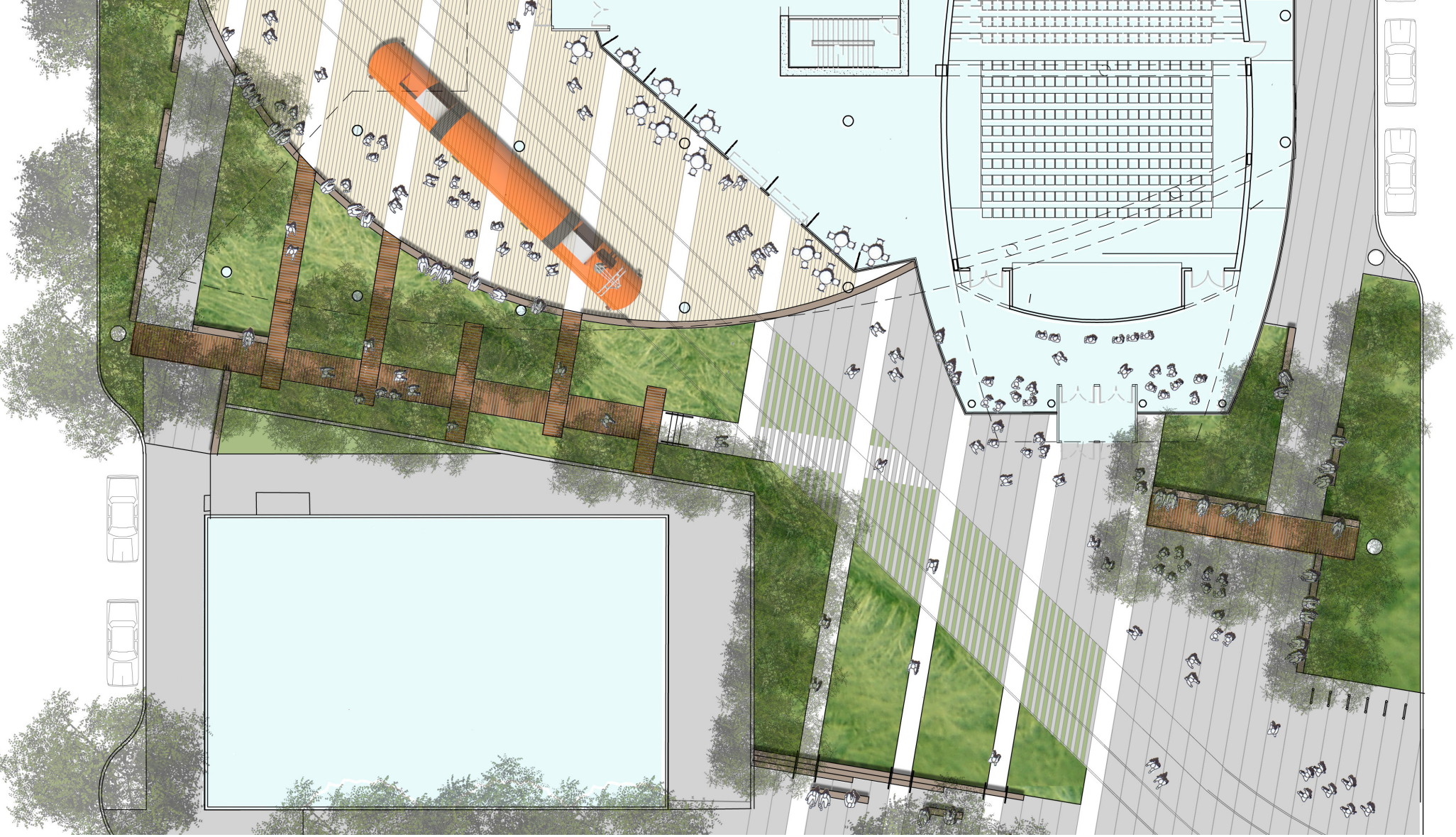

Image: Nevue Ngan Associates/Kevin Robert Perry

Level 5- Integrate the Building, Site, and Street

Multiple Shades of Green

Image: Nevue Ngan Associates/Kevin Robert Perry

Level 5- Integrate the Building, Site, and Street

Multiple Shades of Green

Micro-greening

Photo: Kevin Robert Perry, ASLA

Look to the Urban Landscape As A Design Model

The Micromanagement of Stormwater

Photo: Kevin Robert Perry, ASLA

Look to the Urban Landscape As A Design Model

Nature is Fighting Back

Accidental Pervious Surface

A crack in the asphalt accepts roof stormwater runoff

Accidental Pervious Surface

A crack in the asphalt accepts roof stormwater runoff

Accidental Pervious Surface

A 100-year old street. Is this street failing?

Photo: Kevin Robert Perry, ASLA

Accidental Pervious Surface

Nature is telling us that it wants to be pervious

Accidental Pervious Surface

Nature is telling us that it wants to be pervious

Photo: Kevin Robert Perry, ASLA

Accidental Pervious Surface

It can be beautiful

Formalized Pervious Surface

Nature Takes Pervious Pavers to the Next Level

Accidental Pervious Surface

Vegetation growing between the street and gutter intercepts runoff

Accidental Pervious Surface

It can also be functional

Photo: Adria Goula
Design: Lola Domenech

Formalized Pervious Surface

A Bold Streetscape Example from Barcelona, Spain

Photo: Google Earth

Formalized Pervious Surface

NW Kennedy Street Design Competition

Image: Kevin Robert Perry/Ray Papa

Formalized Pervious Surface

NW Kennedy Street Design Competition

Start Small, Think Big

UC Davis California Avenue Rain Garden:

A Simple and Cost Effective Student Green Infrastructure Project

Reduce Irrigation Use

Manage Stormwater Runoff

Provide Hands-on Learning for Students

Demonstrate Simple & Cost Effective Green Infrastructure

Integrate the Project into Larger Campus Retrofit Efforts

Photo: UC Davis

Project Location

California Avenue @ Robbins Hall

Photo: Kevin Robert Perry, ASLA

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California Avenue @ Robbins Hall

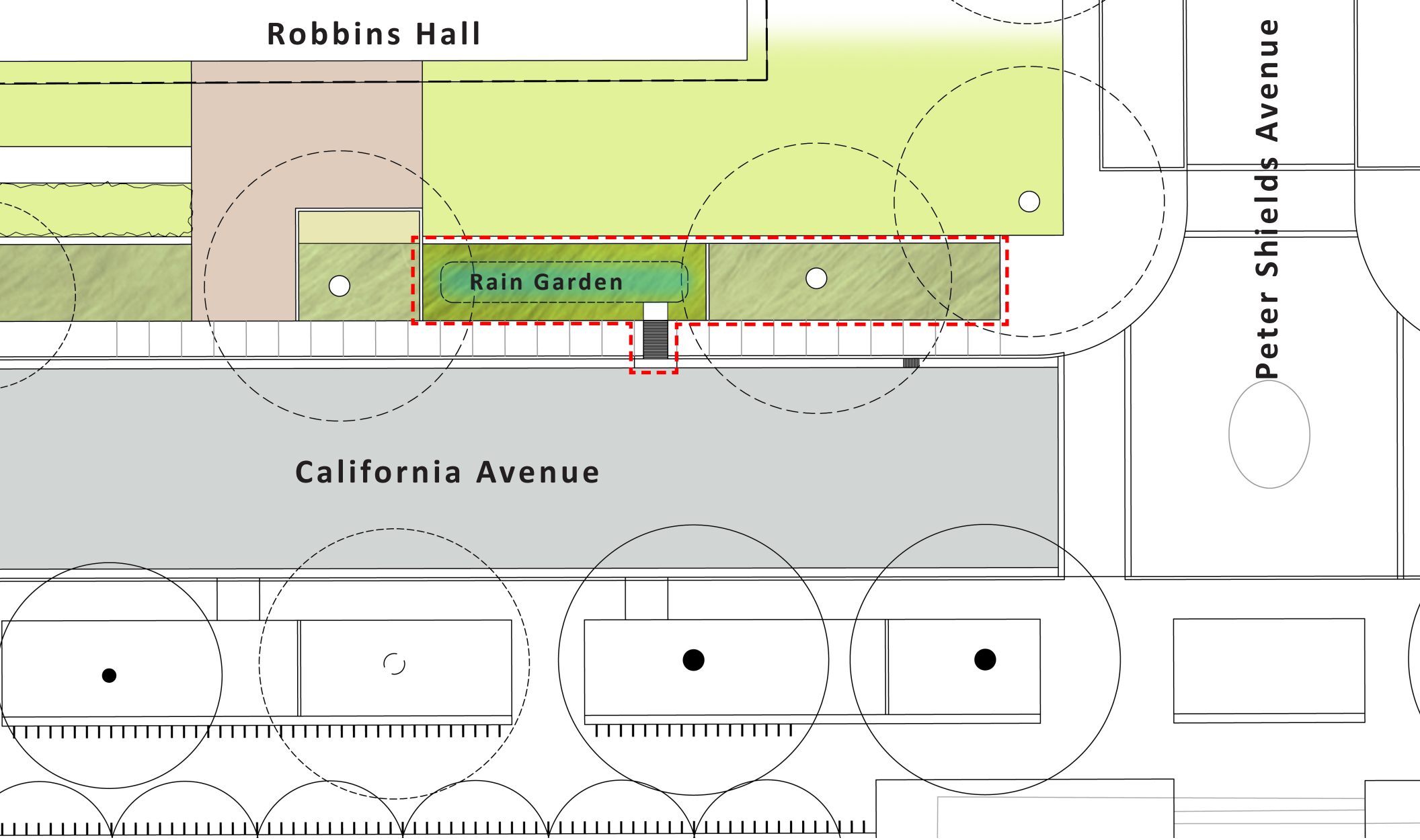
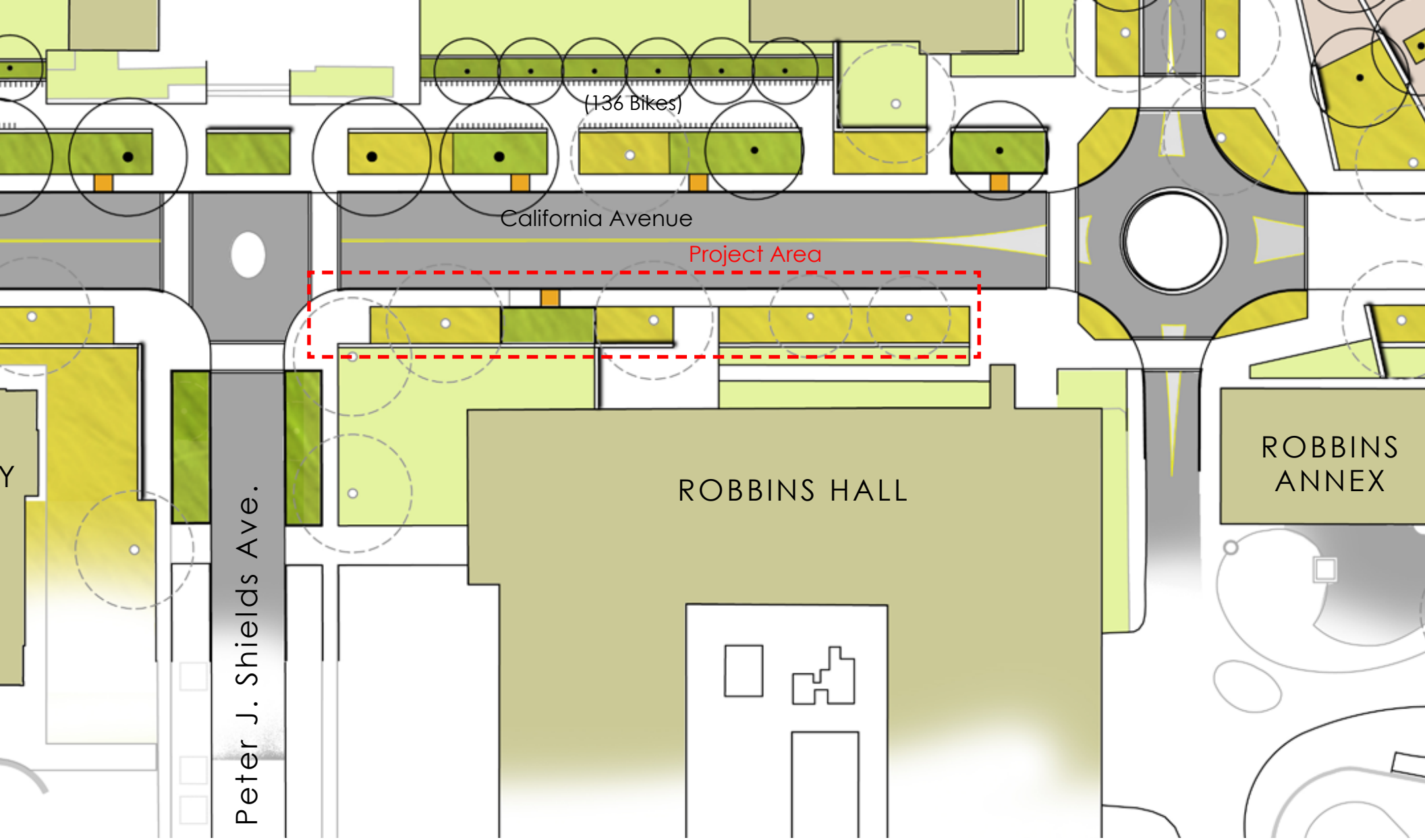


Photo: Kevin Robert Perry, ASLA

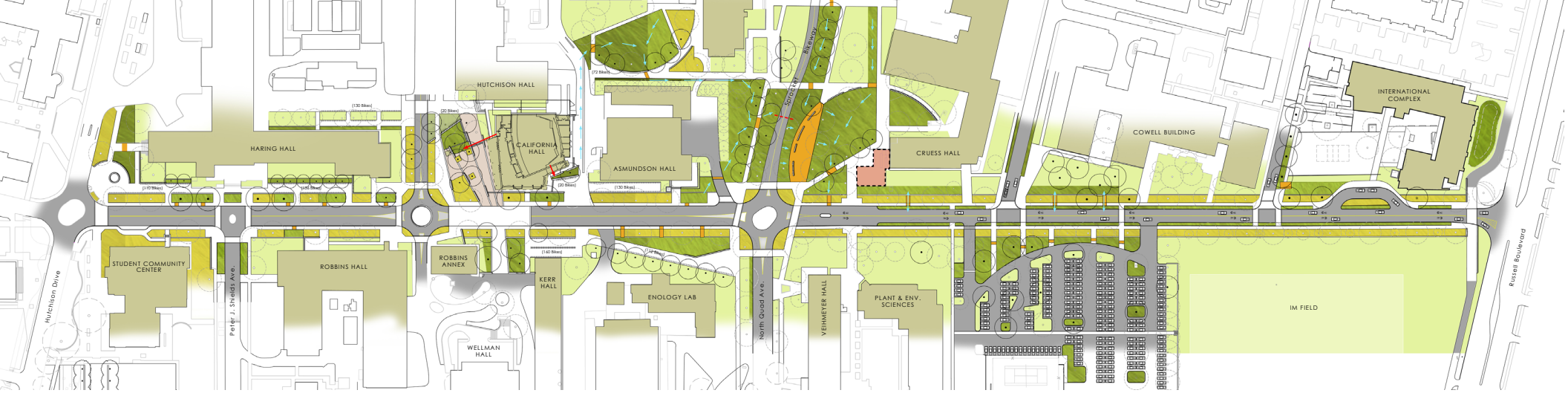
Project Concept Plan

California Avenue @ Robbins Hall



California Avenue Green Street Concept Plan

One of Many Projects Envisioned

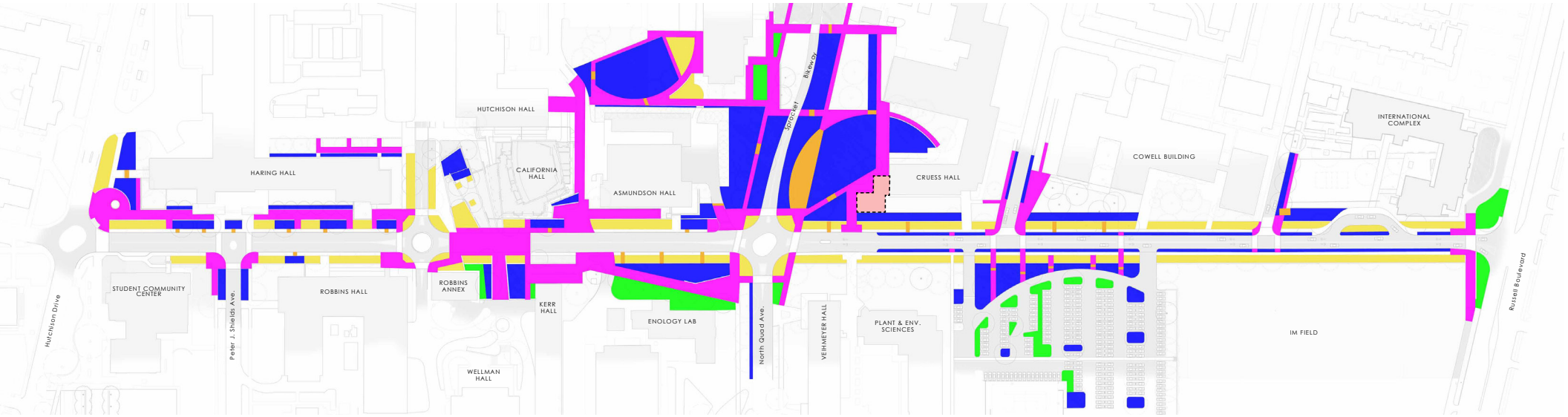


Plan View Concept

Legend

- Stormwater Capture Landscape Zone
- Drought Tolerant Landscape Zone (Arboretum All-Star Showcase)
- Conventional Lawn/Shrub Zone
- Boardwalk for Stormwater Conveyance
- Specialty Paving

Note: Plan currently shows 644 bikes supporting the new lecture hall and 245 bikes supporting Haring Hall.



New Hardscape and Landscape Project Improvements

Legend

- New Stormwater Landscape Area
- New Drought Tolerant Landscape Area
- New Hardscape Area
- New Conventional Lawn/Shrub Zone
- New Stormwater Conveyance/Boardwalk

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

February 2015

California Avenue Green Street Concept Plan

One of Many Projects Envisioned

Photo: Kevin Robert Perry, ASLA

Before Conditions

Thirsty Lawn, Low Plant Diversity

Photo: Kevin Robert Perry, ASLA

Before Conditions

Thirsty Lawn, Low Plant Diversity

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Before Conditions

Stormwater Runoff From Street, Sidewalk, and Plazas

Photo: Kevin Robert Perry, ASLA

Before Conditions

Stormwater Runoff From Street, Sidewalk, and Plazas

Photo: Kevin Robert Perry, ASLA

Construction

Layout the Grass Removal Boundary

Photo: Kevin Robert Perry, ASLA

Construction

Define the Grass Removal Boundary

Photo: Kevin Robert Perry, ASLA

Construction

Removal of Lawn Progress

Photo: Kevin Robert Perry, ASLA

Construction

Rain Garden Grading

Photo: Kevin Robert Perry, ASLA

Construction

Rain Garden Grading

Photo: Kevin Robert Perry, ASLA

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Rain Garden Grading

Photo: Kevin Robert Perry, ASLA

Construction

Drip Irrigation System Installation

Photo: Kevin Robert Perry, ASLA

Construction

Drip Irrigation System Installation

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Construction

Paver Walkway Installation

Photo: Kevin Robert Perry, ASLA

Construction

Paver Walkway Installation

Photo: Kevin Robert Perry, ASLA

Construction

Phase I Plant Installation

Photo: Kevin Robert Perry, ASLA

Construction

Phase I Plant Installation and Mulching

Photo: Kevin Robert Perry, ASLA

Construction

Phase I Plant Installation and Mulching

Photo: Kevin Robert Perry, ASLA

Construction

Keeping Plants Alive Over Summer 2015!

Photo: Kevin Robert Perry, ASLA

Plant Establishment

Keeping Plants Alive Over Summer 2015

Photo: Kevin Robert Perry, ASLA

Plant Establishment

Ready for El Nino!

Photo: Kevin Robert Perry, ASLA

Trench Drain Installation

UC Crews Cut the Street Curb Making the Project “Active”

Photo: Kevin Robert Perry, ASLA

Trench Drain Installation

UC Crews Cut the Street Curb Making the Project “Active”

Photo: Kevin Robert Perry, ASLA

Trench Drain Installation

UC Crews Install New Trench Drain From Curb

Photo: Kevin Robert Perry, ASLA

Project Completion

First Rainfall is Captured by the Trench Drain

Photo: Kevin Robert Perry, ASLA

Project Completion

First Rainfall is Captured by the Trench Drain

Photo: Kevin Robert Perry, ASLA

Project Completion

First Rainfall is Captured by the Trench Drain

Photo: Kevin Robert Perry, ASLA

Project Completion

Project is Infiltrating Stormwater Very Effectively

Photo: Kevin Robert Perry, ASLA

Project Completion

Plant Material Is Thriving

Photo: Kevin Robert Perry, ASLA

Project Completion

A Great Campus Demonstration Project!

Photo: Kevin Robert Perry, ASLA

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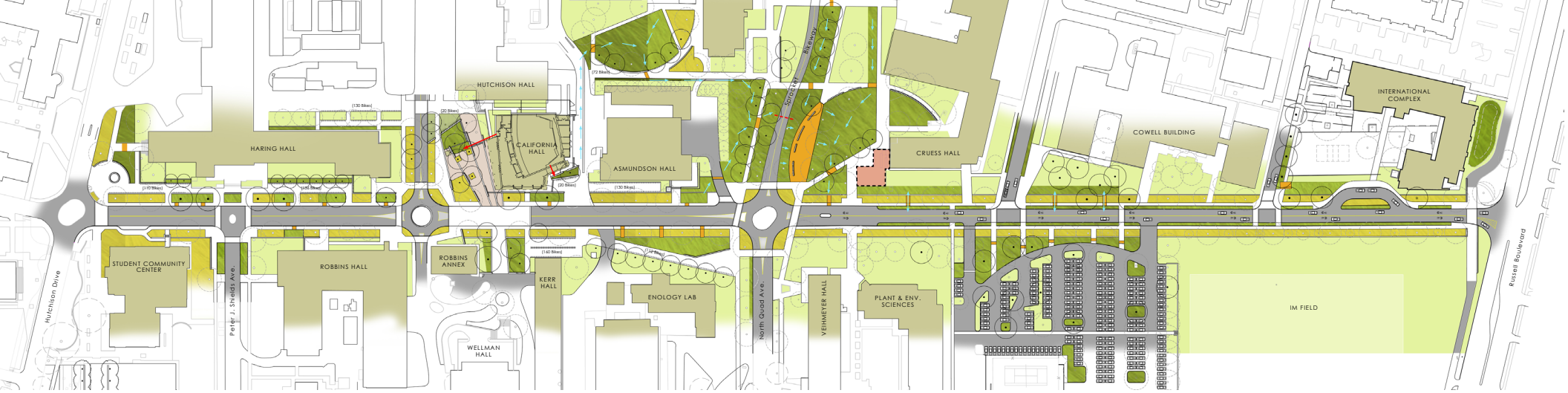

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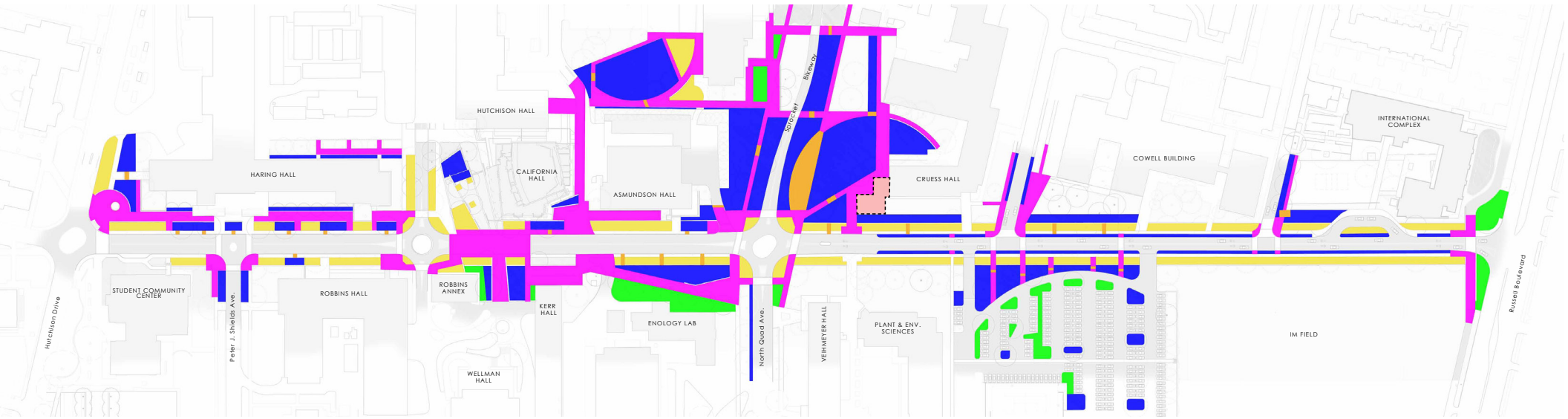

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