This presentation premiered at WaterSmart Innovations

watersmartinnovations.com

watersmart
INNOVATIONS

USGBC Stormwater Grant

Multi-Variate Study of Stormwater BMPs

USGBC WebEx | 23 August 2011

BNIM
2011 AIA NATIONAL ARCHITECTURE FIRM AWARD

Acknowledgements

- **USGBC**
  - Sean McMahon
  - Rick Fedrizzi
- **RESEARCH TEAM**
  - Jim Schuessler, BNIM
  - Phil Barnes, Kansas State University
  - David Dods, URS Corporation
- **TECHNICAL REVIEW TEAM**
  - Alex Wilson, BuildingGreen, Inc.
  - Bill Swietlek, EPA Green Building Program
  - Jason Ghidotti, FTN Associates, Ltd.

Agenda

- Project Goals
- Equipment
- Site Design
- Stormwater Monitoring Findings
- 10 Important Takeaways

Project Goals

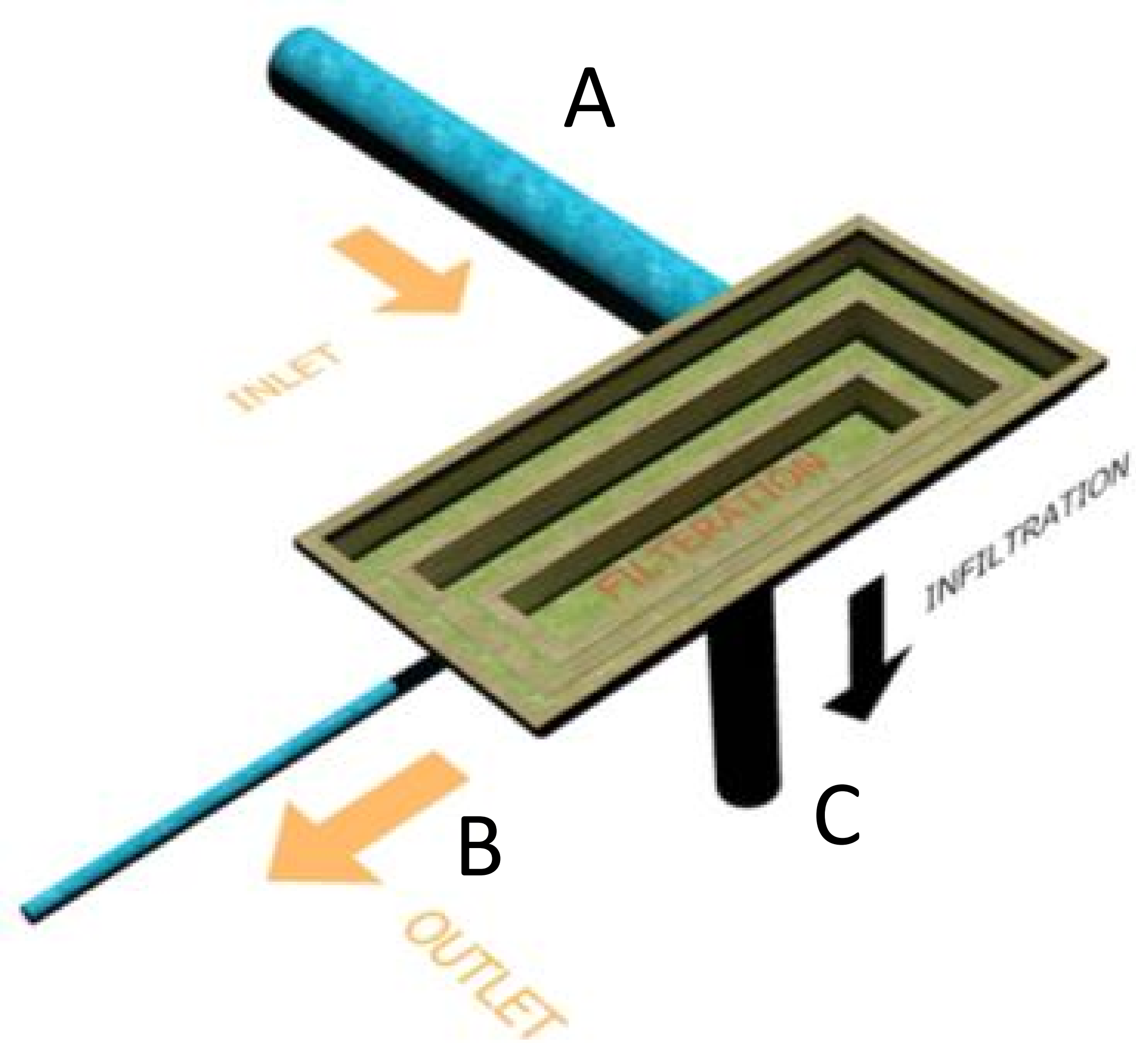
- Promote BMPs
- Raise Awareness of What is Possible
- Understand How Design and Site Features Affect Performance

Research Concepts

Storm Water Monitoring

- **Quality and Quantity of runoff is measured at both the Inflow (A) & Outflow (B) of Stormwater BMP's.**
- **Results from the outflow are compared to the results from the inflow, showing the degree of improved water quality and quantity (C).**

A – B = C



Testing and Equipment

- **Teledyne ISCO 6712 Portable Samplers**
  - Monitors flow and takes samples of runoff for lab quality tests.
  - Flow Measured by Bubble Tube and logged into the ISCO computer.

Photo: Jim Schuessler

Testing and Equipment

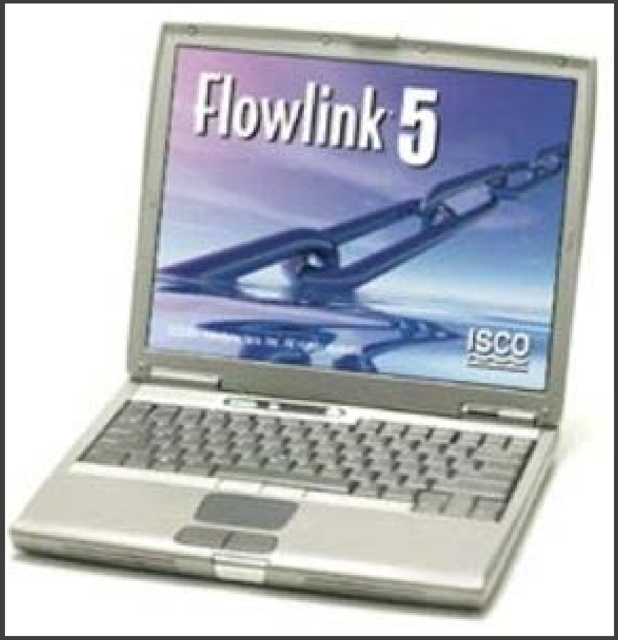
- **Infiltration Testing**
  - Piezometer: Measures and logs water level in detention area.

Photo: Jim Schuessler

Testing and Equipment

- **Onset Data Logging Rain Gauge (Rooftop Tipping Bucket)**
  - Monitors Rainfall Intensity
  - Rainfall Quantity Measurements and Logging
  - Total Volumes

- **Software**
  - Flow Link (ISCO)
  - HOBOware (Tipping Bucket & Piezometer)



Testing and Equipment

- **Soil Sampling**
  - Test Particle Size Distribution
  - pH
  - Zinc
  - Organic Mater
- **Soil Moisture**

Photo: Jim Schuessler

Data Collection

- **Properties Tested**
  - Total Suspended Solids (TSS)
  - Total Nitrogen (TN)
  - Total Phosphorus (TP)
  - Zinc (Zn)
  - Chloride (Cl)
  - Sulfate (S)
  - pH
  - Electrical Conductivity (EC µS)
  - Fecal Coliforms (Ecoli)

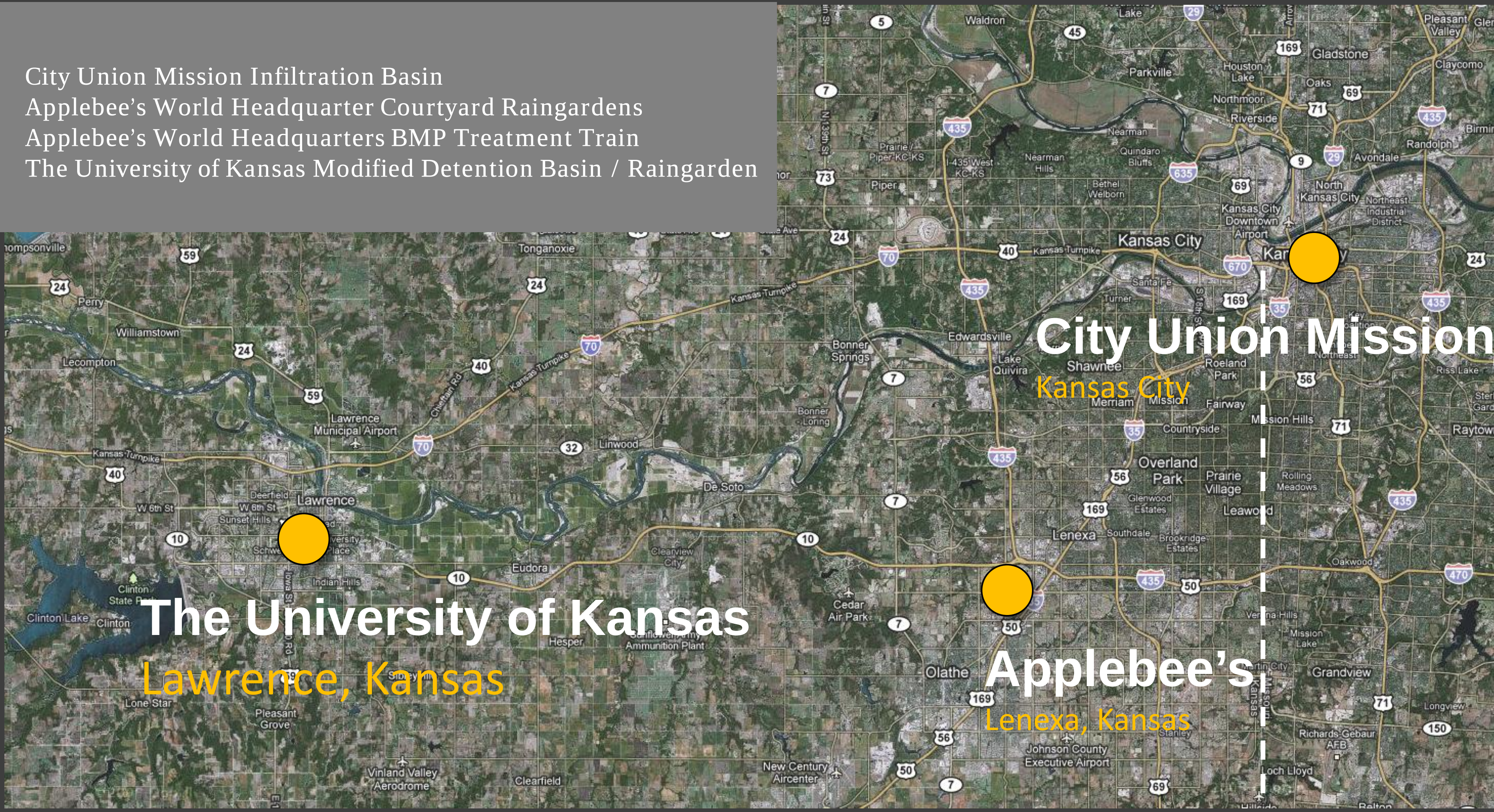
Photo: Jim Schuessler

Selected Sites

4 BMP Sites, 3 Locations

Urban, Suburban, and Small Community

City Union Mission Infiltration Basin
Applebee's World Headquarter Courtyard Raingardens
Applebee's World Headquarters BMP Treatment Train
The University of Kansas Modified Detention Basin / Raingarden



Monitoring Site #1

City Union Mission, Infiltration Basins
Completed 2008

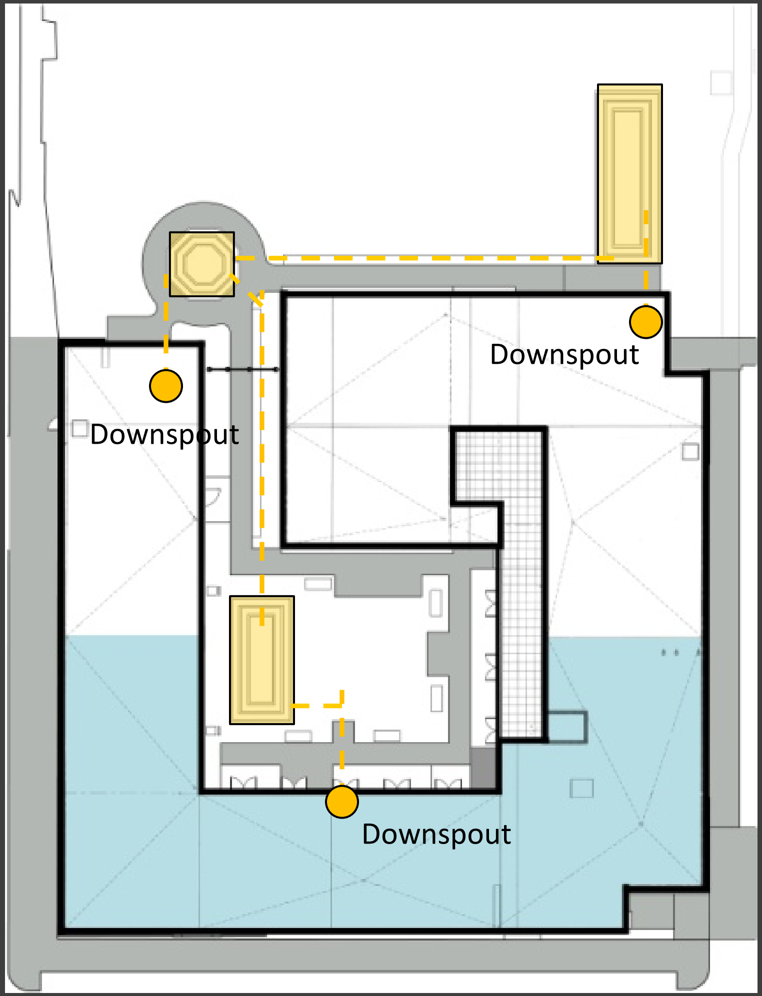
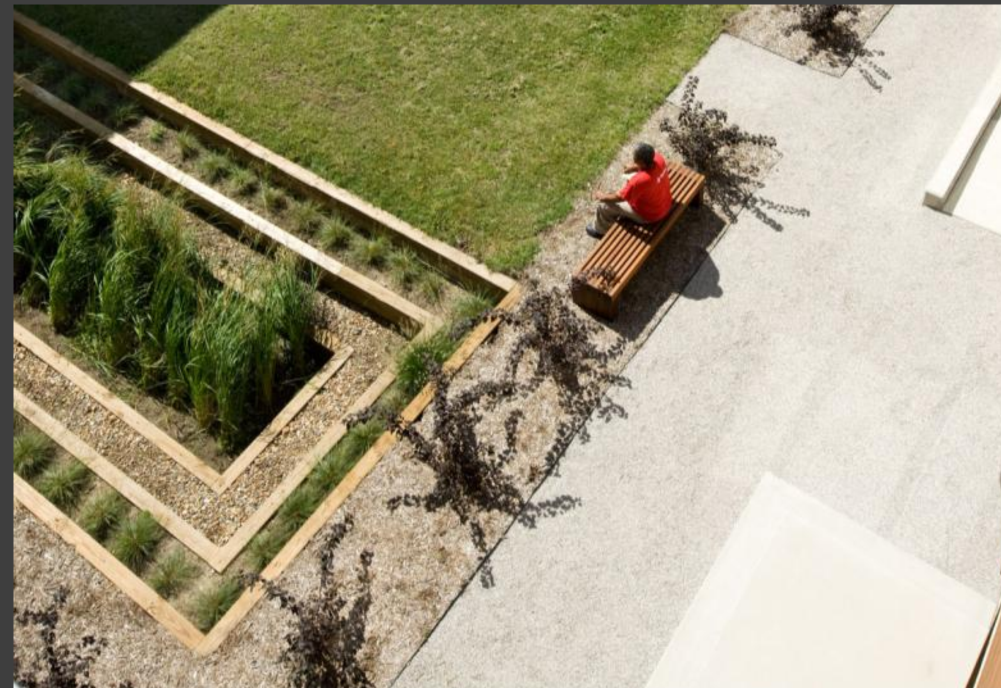


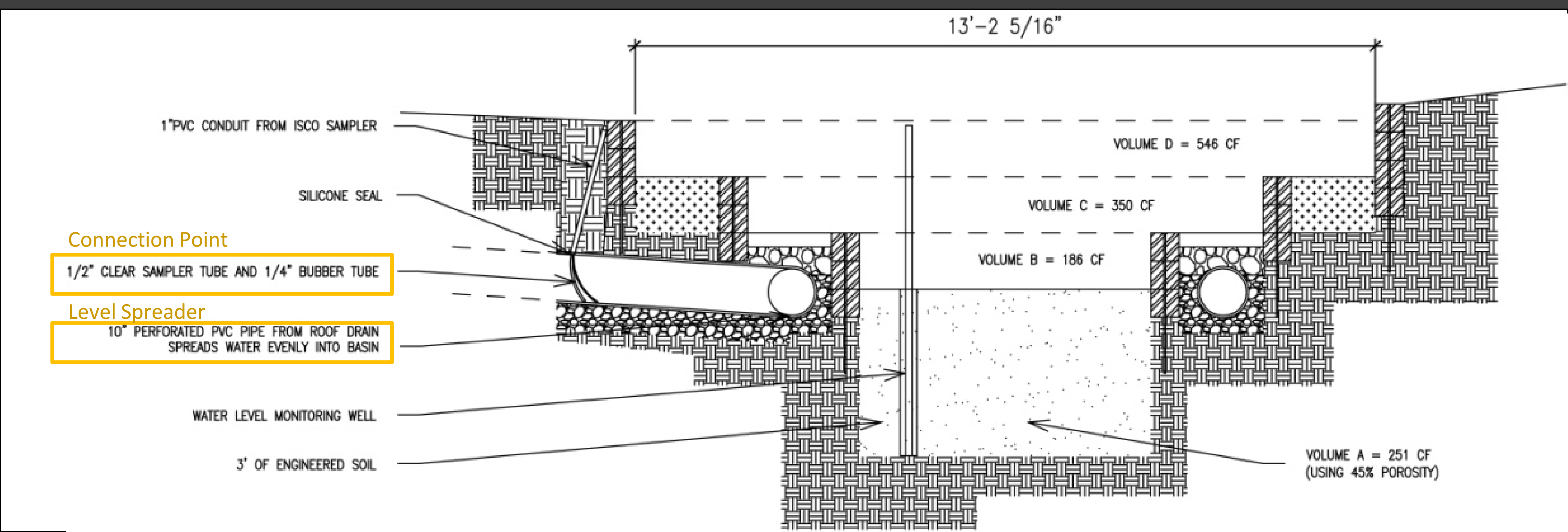
Photo: © Assassi

Infiltration Basin

Section

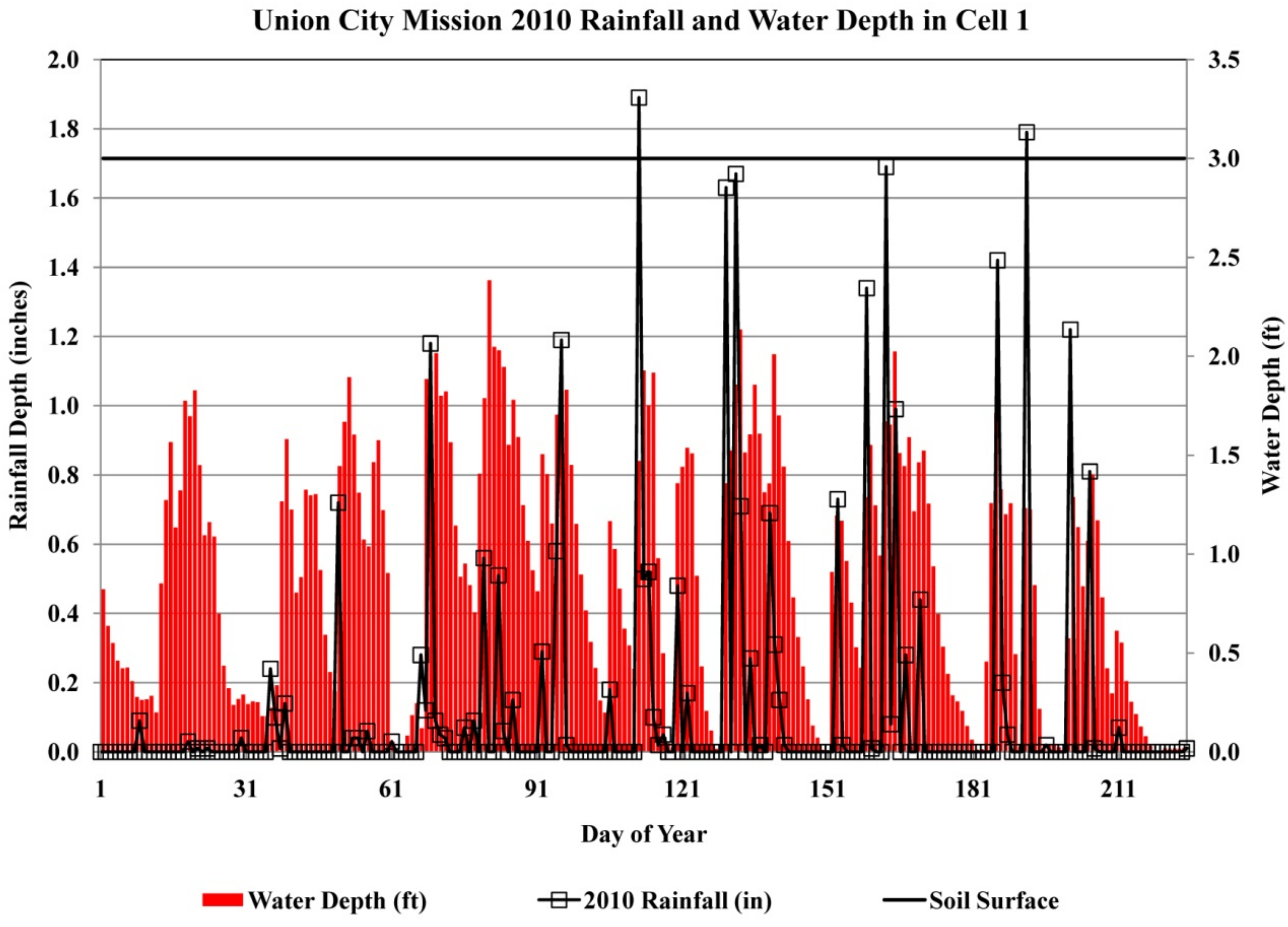
- Inlet Pipe
- Level Spreader
- 3' Engineered Soil
- 787 CF

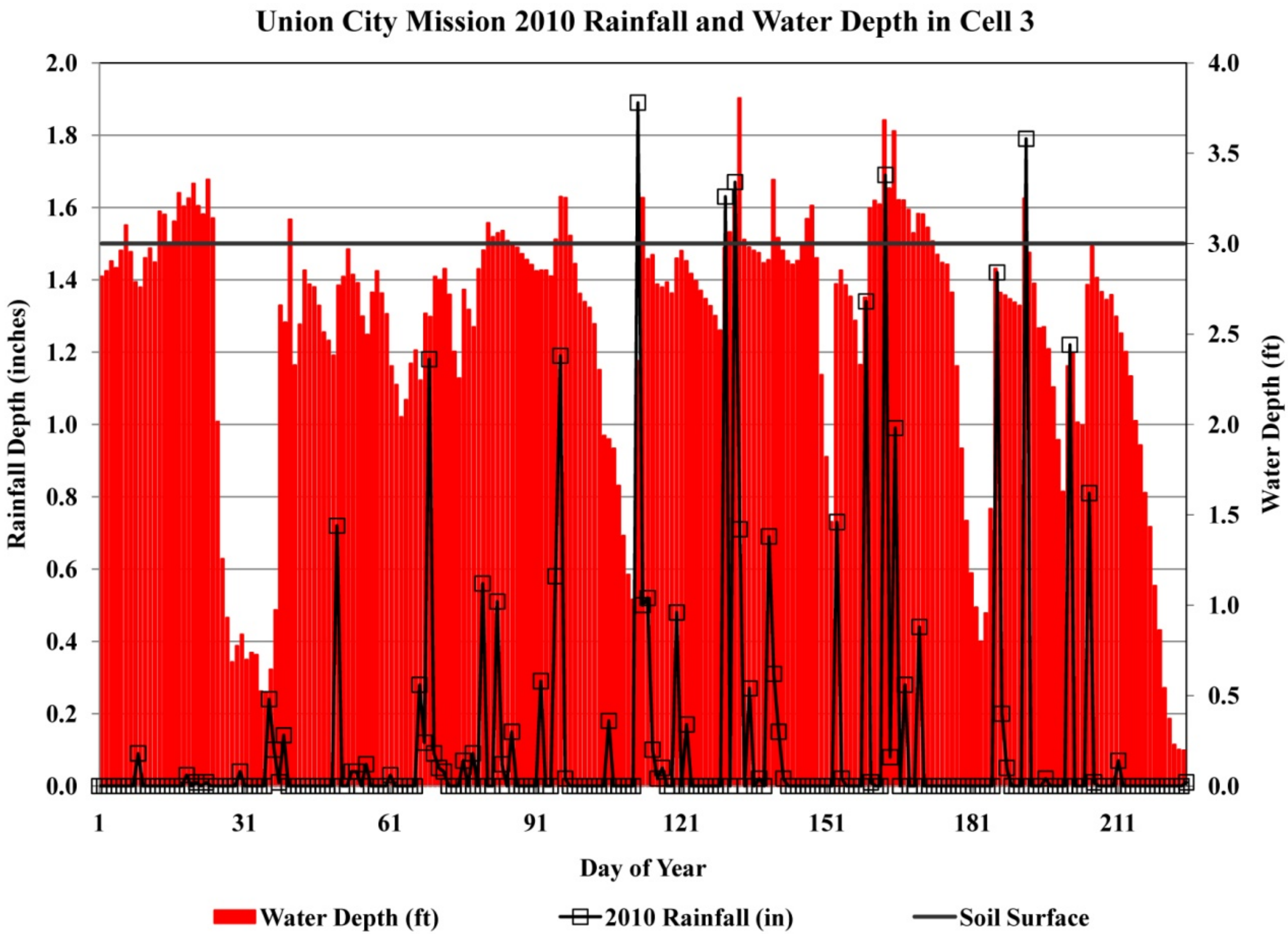




City Union Mission Cell No. 1				
Event	Date	Rain Depth (in)	Rain Depth (ft)	Flow Volume (ft^3)
1	3/24/10	0.56	0.047	327
	3/27/10	0.57	0.048	333
2	4/2/10	0.29	0.024	169
	4/6/10	0.58	0.048	338
	4/6/10	1.19	0.099	694
3	4/22/10	1.89	0.158	1103
	4/24/10	0.50	0.042	292
	4/24/10	0.52	0.043	303
4	5/10/10	1.63	0.136	951
	5/12/10	1.67	0.139	974
	5/13/10	0.71	0.059	414
	5/19/10	0.69	0.058	403
5	6/2/10	0.73	0.061	426
6	6/8/10	1.34	0.112	782
7	6/12/10	1.69	0.141	986
	6/14/10	0.99	0.083	578
8	7/5/10	1.42	0.118	828
9	7/11/10	1.79	0.149	1044
10	7/20/10	1.22	0.102	712
	7/24/10	0.81	0.068	473

According to this calculation we should have had standing water on 9 of 20 sampling events (with overflows on 5 of 20).

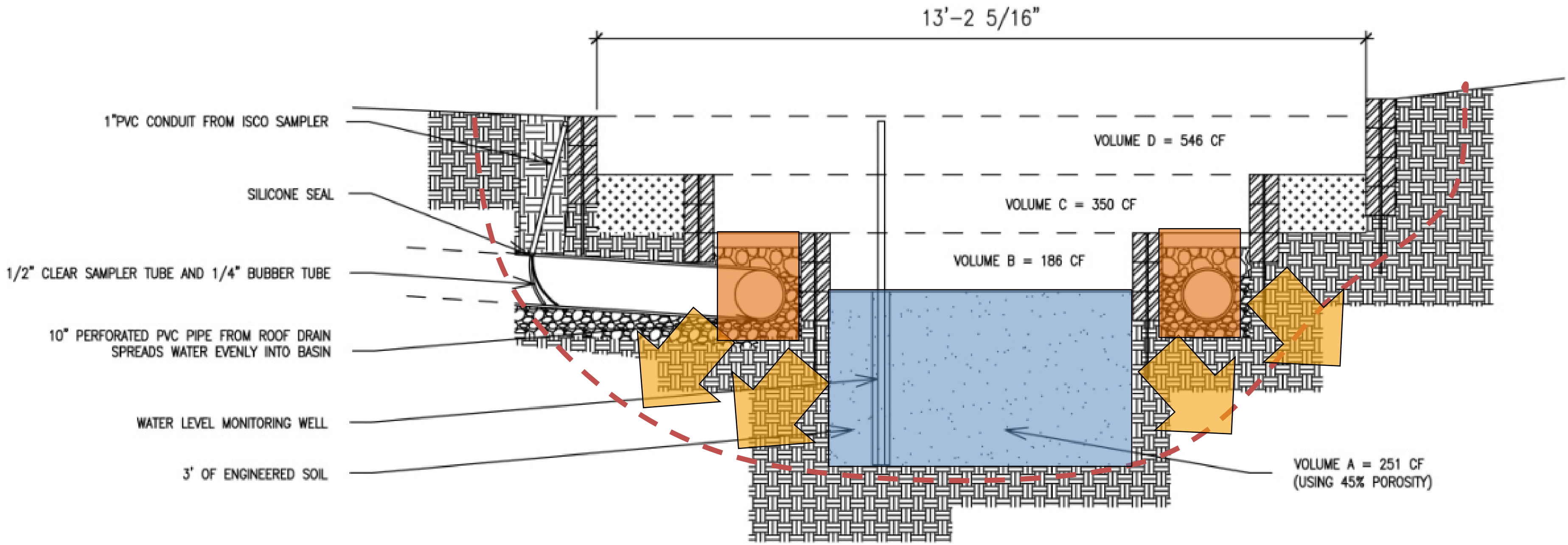

Union City Mission 2010 Rainfall and Water Depth in Cell 1
Rainfall Depth (inches)
Water Depth (ft)
Day of Year
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1
31
61
91
121
151
181
211
Water Depth (ft)
2010 Rainfall (in)
Soil Surface


Union City Mission 2010 Rainfall and Water Depth in Cell 3
Rainfall Depth (inches)
Water Depth (ft)
Day of Year
Water Depth (ft)
2010 Rainfall (in)
Soil Surface

Root Growth

- **Cordgrass roots reach 30 inches deep.**

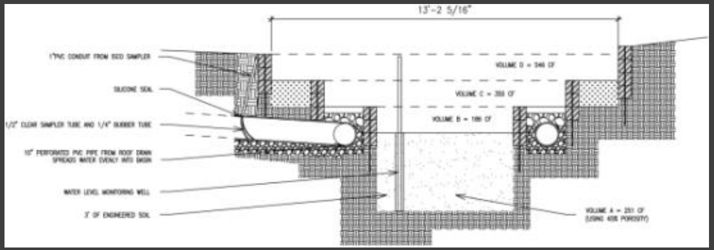
Photo: Barnes


13'-2 5/16"
1"PVC CONDUIT FROM ISCO SAMPLER
SILICONE SEAL
1/2" CLEAR SAMPLER TUBE AND 1/4" BUBBER TUBE
10" PERFORATED PVC PIPE FROM ROOF DRAIN
SPREADS WATER EVENLY INTO BASIN
WATER LEVEL MONITORING WELL
3' OF ENGINEERED SOIL
VOLUME D = 546 CF
VOLUME C = 350 CF
VOLUME B = 186 CF
VOLUME A = 251 CF
(USING 45% POROSITY)

Findings

City Union Mission, Infiltration Basins

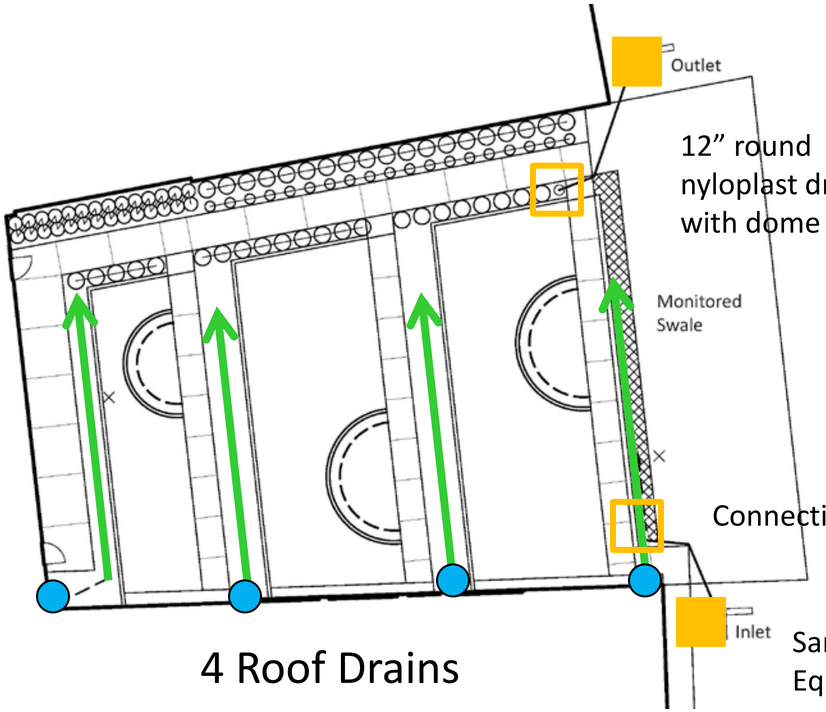
- **Site Characterization**
- **Plant Root Benefits**
- **Cost**



Monitoring Site #2

Applebee's Courtyard, Raingardens (Completed December 2007)

Photo: © Assassi



Typical Downspout

Equipment Attachment

Outlet Structure

Photo: Jim Schuessler

Water Quality

- **Modest pollutant removal**

  56% Reduction of TN

  50% Reduction of TP

- **Exported some constituents**

Applebee's Courtyard "In"											
Rain Event	Event	Location	Precip	TN ppm	TP ppm	Zn ppm	Cl ppm	S ppm	pH	EC µS	TSS
5/15/2009		First Flush	1.01	3.91	0.11	0.11	5.46	ND	6.8	85	11
6/15/2009		First Flush	1.47	5.3	0.06	0.14	2.94	1.00	6.8	74	19
6/27/2009	1	First Flush	0.48	4.33	1.07	0.02	ND	ND	6.8	46	97
4/2/2010			0.43	No Sample							
5/12/2010	3		0.58	No Sample							
5/26/2010	4	First Flush	0.34	1.14	0.06	ND	0.23	0.24	7.33	23	43
5/26/2010		First Flush	0.34	1.54	0.07	ND	0.15	0.72	7.40	46	68
6/2/2010	5	First Flush	0.49	1.46	0.06	ND	0.15	0.31	7.38	25	4
6/8/2010	6	First Flush	1.60	1.26	0.04	ND	0.19	0.48	7.29	20	20
6/14/2010		Bottle 1	1.31	No Sample							
6/14/2011	7	Composite	1.31	0.71	0.04	ND	0.15	ND	7.00	18	36
6/14/2011		First Flush	1.31	0.69	0.06	ND	0.15	ND	7.25	13	60

Applebee's Courtyard "Out"											
Rain Event	Event	Location	Precip	TN ppm	TP ppm	Zn ppm	Cl ppm	S ppm	pH	EC µS	TSS
6/27/2009	1	First Flush	0.48	1.39	0.06	0.08	0.77	1.87	7.2	95	112
5/10/2010	2		1.06	No Sample							
5/12/2010	3	First Flush	0.58	1.03	0.10	0.04	13.70	1.53	7.28	73	48
5/13/2010			0.88	No Sample							
5/26/2010	4	First Flush	0.34	2.09	0.10	0.02	1.74	1.74	7.40	72	116
6/2/2010	5	Composite	0.49	1.43	0.08	ND	1.33	2.35	7.72	73	44
6/2/2010		First Flush	0.49	1.43	0.08	ND	0.37	1.07	7.73	52	16
6/8/2010	6	First Flush	1.60	0.96	0.04	0.02	0.21	2.90	7.92	115	72
6/8/2010		First Flush	1.60	1.53	0.07	ND	0.78	1.67	7.42	76	48
6/14/2010			1.31	No Sample							
6/14/2010	7	Composite	1.31	1.12	0.05	ND	0.23	0.94	7.44	79	60

Findings

- Undersized for Larger Storm Events
- Distribution of Flows

Photo: Jim Schuessler

Monitoring Site #3

Applebee's Treatment Train

Sand Filter and Sediment Forebays Completed 2008

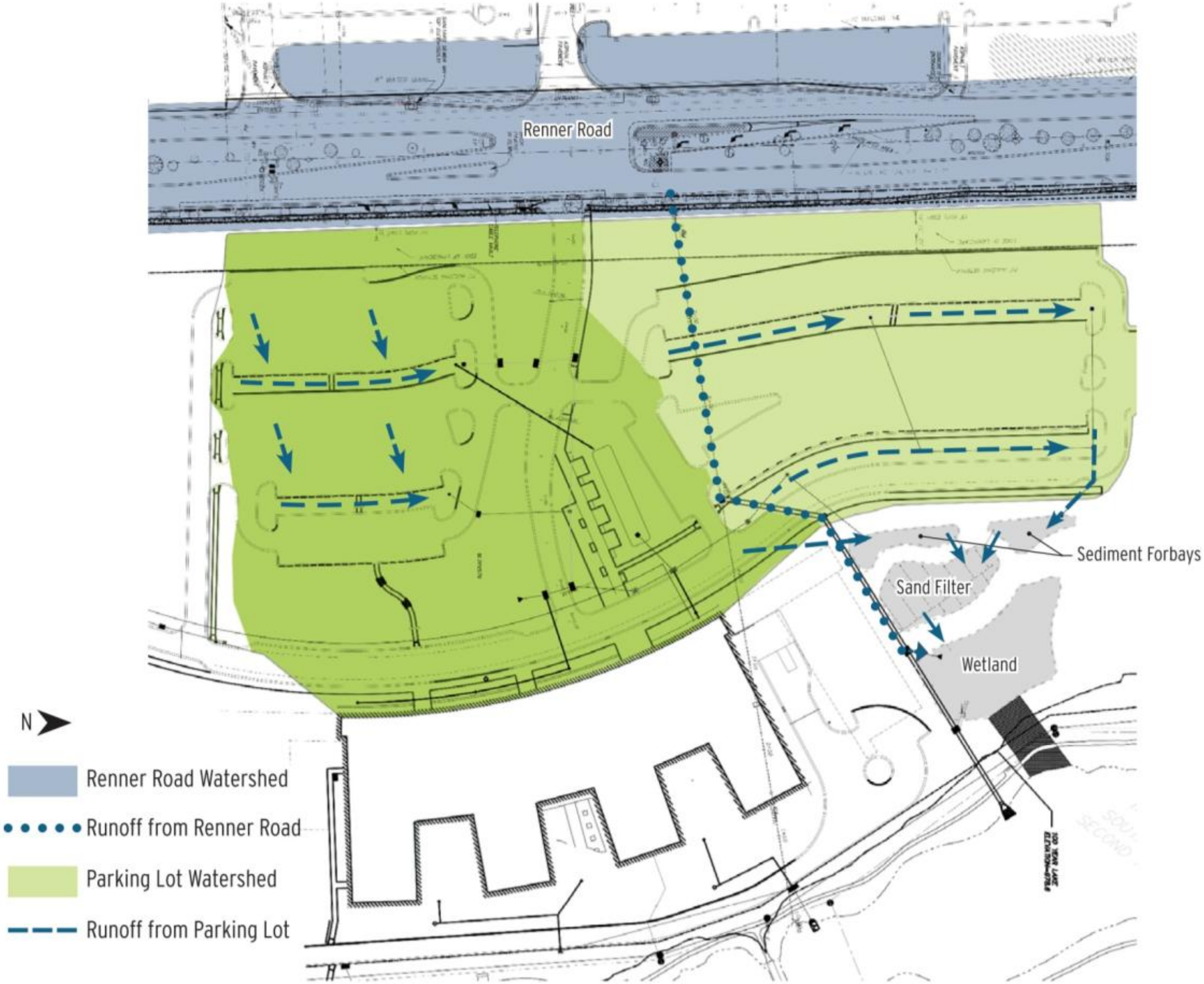
Wetland Planted Fall 2009

Watershed

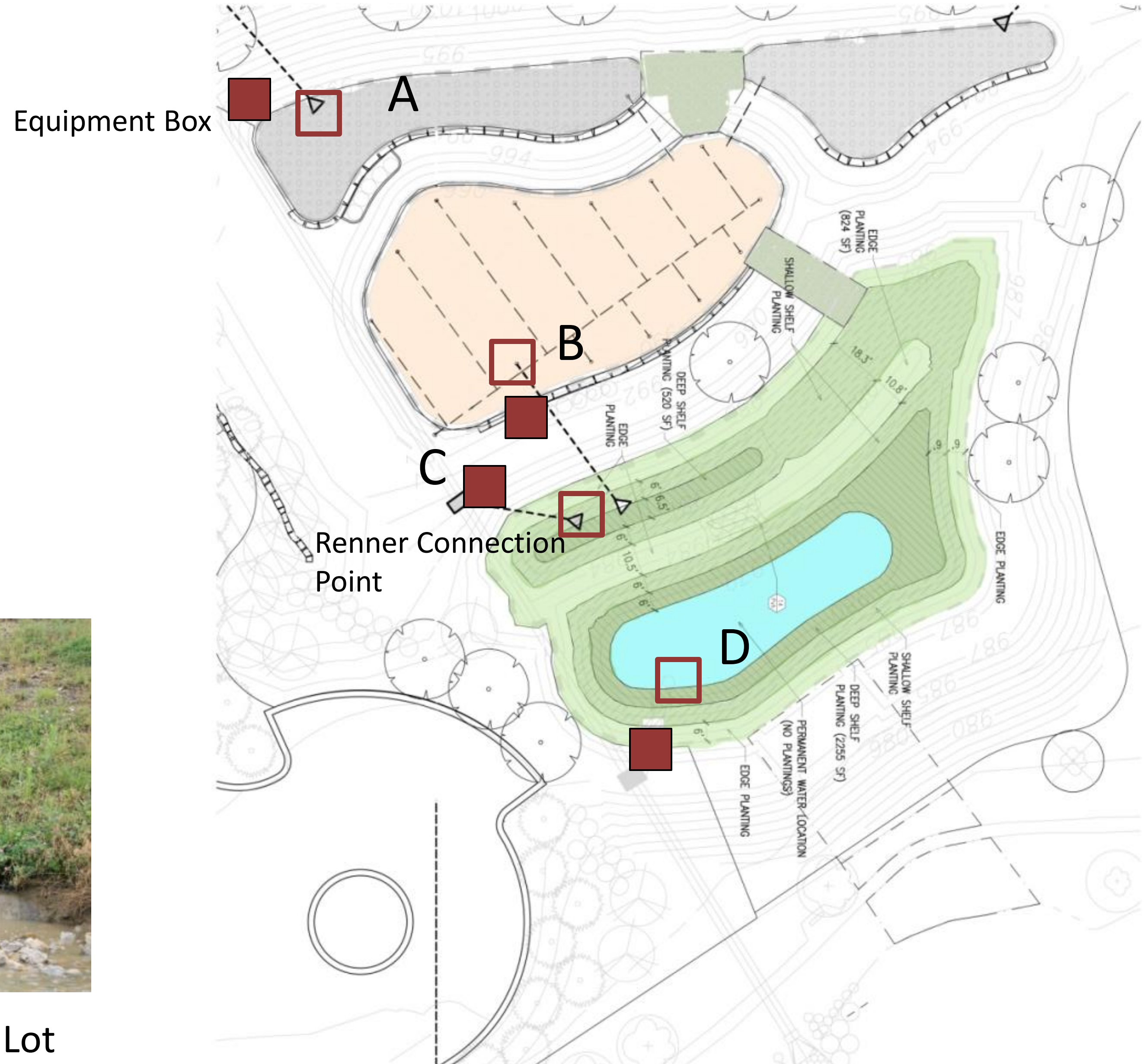
Legend

- Renner Road Watershed
- Parking Lot Watershed
- BMPs

Water Flow Diagram



Treatment Train



30” Inlet from Parking Lot

Sand filter w/ Sediment Forebay

Photos Jim Schuessler

Wetland

½ Acre

- **Sand Filter Runoff**
- **First Flush from Renner Road**

Photos: Jim Schuessler

Water Quality

Sand Filter and Sediment Forebay

- **Removal**

  Average of 117 mg/l of TSS

  Reduction of TN and TP

- **Compared to Renner Runoff**

  Better Water Quality

  (except Chloride and Sulfur)

Applebee's Sand Filter "In"											
Rain Event	Event	Note	Precip	TN ppm	TP ppm	Zn ppm	Cl ppm	S ppm	pH	EC µS	TSS
6/27/2009		First Flush	0.48	3.17	0.29	0.04	42.95	16.26	7.4	315	47
9/21/2009		First Flush	0.97	5.02	0.32	0.09	21.37	11.57	7.3	282	45
4/2/2010			0.43	No Sample							
4/23/2010	2	First Flush	0.46	1.10	0.07	ND	62.40	15.78	7.36	348	116
4/23/2010		First Flush	0.46	1.10	0.07	ND	112.70	13.61	7.41	449	48
4/24/2010	3	First Flush	0.47	2.37	0.05	0.02	148.30	28.92	7.14	654	48
5/10/2010	4	First Flush	1.06	3.53	0.12	0.02	143.40	32.62	7.62	695	160
5/10/2010		First Flush	1.06	1.63	0.07	ND	64.30	11.23	7.51	312	172
5/12/2010	5	First Flush	0.58	1.13	0.05	ND	47.90	9.26	7.51	267	444
5/13/2010			0.88	No Sample							
5/15/2010			0.35	No Sample							
5/19/2010	6	First Flush	0.9	1.12	0.02	0.02	100.50	18.25	7.43	489	90
5/20/2010	7	First Flush	0.26	2.07	0.27	ND	22.10	4.19	7.21	149	480
5/26/2010	8	First Flush	0.34	2.99	0.24	ND	26.53	19.72	7.79	337	168
6/1/2010	9	First Flush	0.16	2.09	0.13	ND	12.87	7.70	8.02	201	196
6/2/2010	10	First Flush	0.49	3.69	0.23	ND	57.57	25.38	8.28	499	136
6/2/2010		Bottle 6	0.49	2.73	0.36	ND	48.25	7.05	8.17	235	480
6/8/2010	11	First Flush	1.60	3.02	0.10	ND	20.73	15.12	7.90	514	128
6/8/2010		First Flush	1.60	2.43	0.50	ND	40.47	8.44	7.92	257	752
6/14/2010			1.31	No Sample							
6/14/2010			1.31	No Sample							
7/11/2010			0.85	No Sample							
7/11/2010			0.85	No Sample							
7/16/2010	12	First Flush	0.7	0.97	0.04	ND	2.70	0.33	7.55	18	32
7/16/2010			0.7	No Sample							
7/20/2010		First Flush	0.83	0.75	0.03	ND	2.60	0.30	7.33	18	40

Applebee's Sand Filter "Out"											
Rain Event	Event	Notes	Precip	TN ppm	TP ppm	Zn ppm	Cl ppm	S ppm	pH	EC µS	TSS
6/27/2009		First Flush	0.48	2.92	0.07	0	63.92	17.57	7.5	442	12
4/2/2010	1	First Flush	0.43	3.77	0.22	ND	208.00	56.87	7.52	940	80
4/23/2010	2	First Flush	0.46	0.56	0.06	ND	91.20	9.85	7.42	361	20
4/23/2010			0.46	No Sample							
4/24/2010	3		0.47	No Sample							
5/10/2010	4	First Flush	1.06	0.65	0.06	0.01	81.30	9.16	7.37	343	108
5/12/2010	5		0.58	No Sample							
5/26/2010	8	First Flush	0.34	3.46	0.06	ND	631.90	69.06	7.85	2590	24
5/26/2010	8	Composite	0.34	1.62	0.07	ND	97.96	16.41	7.54	496	36
5/26/2010		First Flush	0.34	1.98	0.09	ND	118.36	18.66	7.62	578	72
6/2/2010	10	First Flush	0.49	1.29	0.09	ND	59.44	10.78	8.06	343	44
6/8/2010	11	First Flush	1.60	1.36	0.08	ND	68.76	14.69	8.08	489	60
7/11/2010			0.85	No Sample							
7/11/2010			0.85	No Sample							
7/16/2010			0.7	No Sample							
7/16/2010			0.7	No Sample							
7/20/2010	13	Grabbed	0.83	1.13	0.09	ND	42.30	8.87	7.46	324	15

Water Quality

Wetland

- **Poor Performance**

  Unstabilized spillway

  Newly planted vegetation

  Water fowl

Applebee's Wetland												
Rain Event	Event	Notes	Precip	TN ppm	TP ppm	Zn ppm	Cl ppm	S ppm	pH	EC µS	TSS	ECoIi
4/22/2010	1	Composite	1.28	1.37	0.08	ND	308.30	31.14	7.44	1040	52	0
4/24/2010	2	Composite	0.47	1.47	0.07	ND	166.80	23.46	7.32	712	48	0
4/30/2010	3	First Flush	0.40	1.87	0.04	ND	362.50	49.61	7.53	139	96	8
5/10/2010	4	First Flush #9	1.06	2.57	0.10	ND	306.80	44.47	7.70	1180	96	10
5/12 - 5/13			0.58	No Sample								
5/19/2010	5	Composite	0.90	2.38	0.05	ND	262.90	38.33	7.55	109	116	25
5/26/2010	6	Composite	0.34	2.57	0.35	ND	109.07	21.69	7.67	596	688	1921
5/26/2010	6	First Flush #1	0.34	5.03	1.28	ND	134.94	27.99	7.80	720	2552	3842
6/1/2010	7	First Flush #1	0.16	2.69	0.28	ND	67.32	14.61	8.04	429	420	2180
6/2/2010	8	Composite	0.49	1.79	0.18	ND	44.18	9.36	7.74	259	180	4045
6/2/2010		First Flush	0.49	2.09	0.14	ND	171.35	29.17	7.78	851	200	2757
6/8/2010	9	Grab Sample	1.60	0.97	0.12	ND	101.85	10.56	8.18	326	188	1659

Findings

Applebee's Treatment Train

- **Success of Sand Filter**
- **Wetland Performance**
- **Calcium Chloride**
- **Renner Road**

Photos: Jim Schuessler

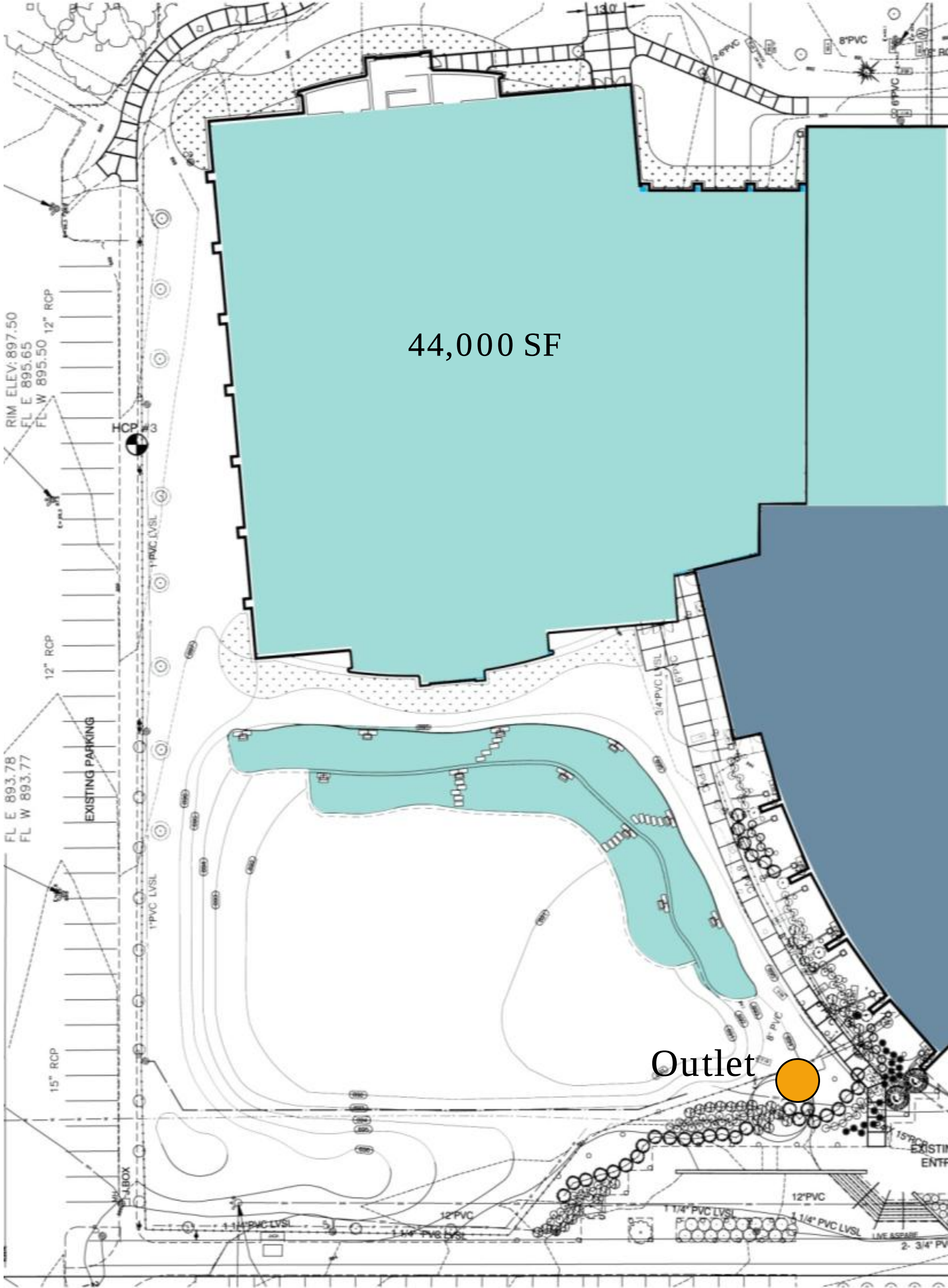
Monitoring Site #4

The University of Kansas, Modified Detention Basin / Raingarden

Planted Spring 2008

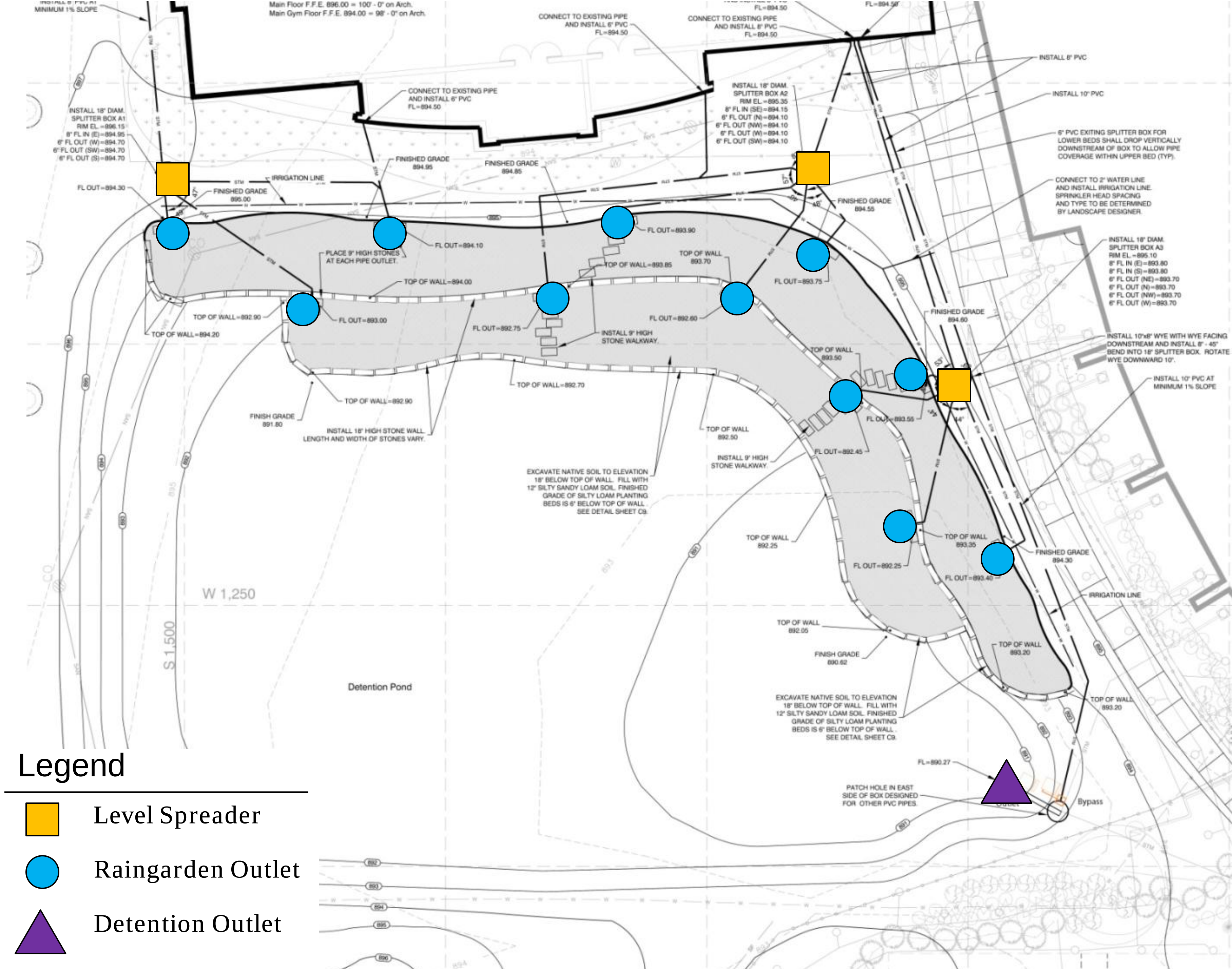
Photo: Jim Schuessler

Watershed

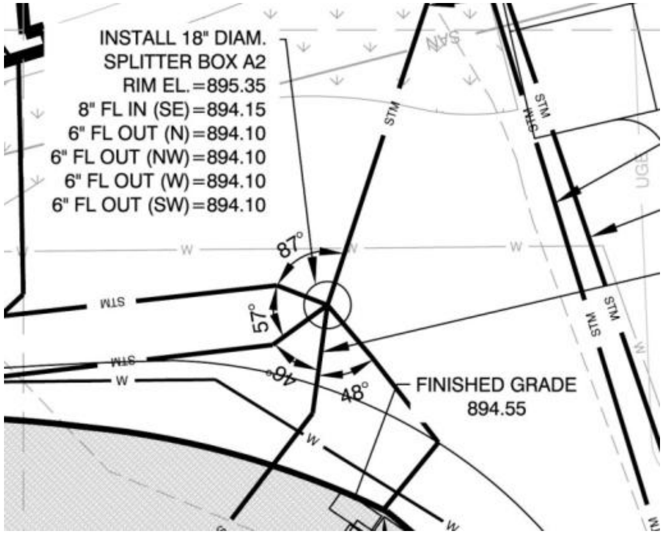


Legend

- Raingarden Watershed
- Roof Watershed (Control Area)


Legend
Level Spreader
Raingarden Outlet
Detention Outlet
Detention Pond
W 1,250
S 1,500
Bypass
Outlet
IRRIGATION LINE
INSTALL 8" PVC
INSTALL 10" PVC
INSTALL 9" HIGH STONE WALKWAY
INSTALL 18" HIGH STONE WALL. LENGTH AND WIDTH OF STONES VARY.
PLACE 9" HIGH STONES AT EACH PIPE OUTLET.
EXCAVATE NATIVE SOIL TO ELEVATION 18" BELOW TOP OF WALL. FILL WITH 12" SILTY SANDY LOAM SOIL. FINISHED GRADE OF SILTY LOAM PLANTING BEDS IS 6" BELOW TOP OF WALL. SEE DETAIL SHEET C9.
PATCH HOLE IN EAST SIDE OF BOX DESIGNED FOR OTHER PVC PIPES.
FL=890.27
INSTALL 10" PVC AT MINIMUM 1% SLOPE
CONNECT TO 2" WATER LINE AND INSTALL IRRIGATION LINE. SPRINKLER HEAD SPACING AND TYPE TO BE DETERMINED BY LANDSCAPE DESIGNER.
Main Floor F.F.E. 896.00 = 100' - 0" on Arch.
Main Gym Floor F.F.E. 894.00 = 98' - 0" on Arch.

Level Spreader

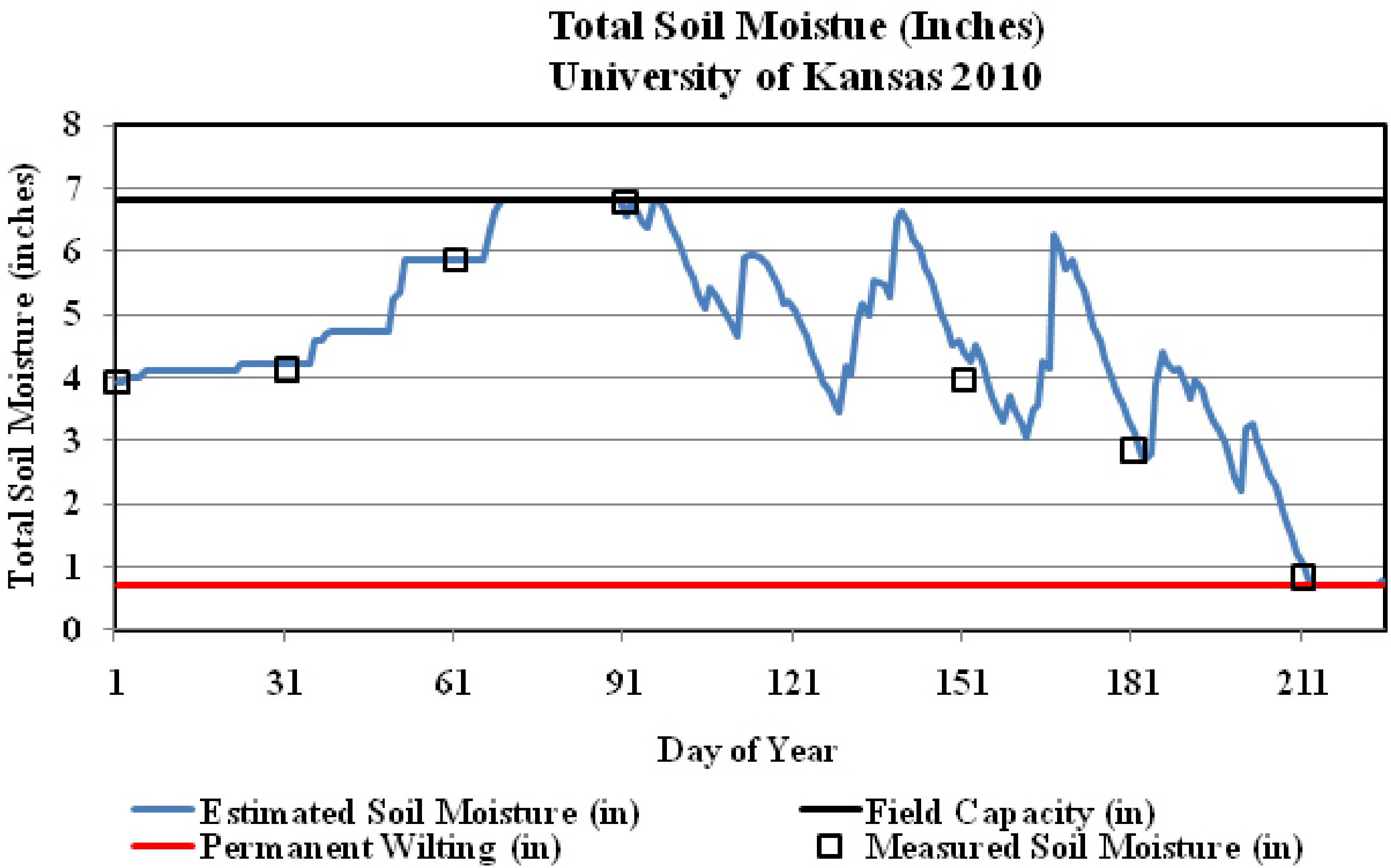


Manhole with Multiple Outlets

Outlet into Raingarden

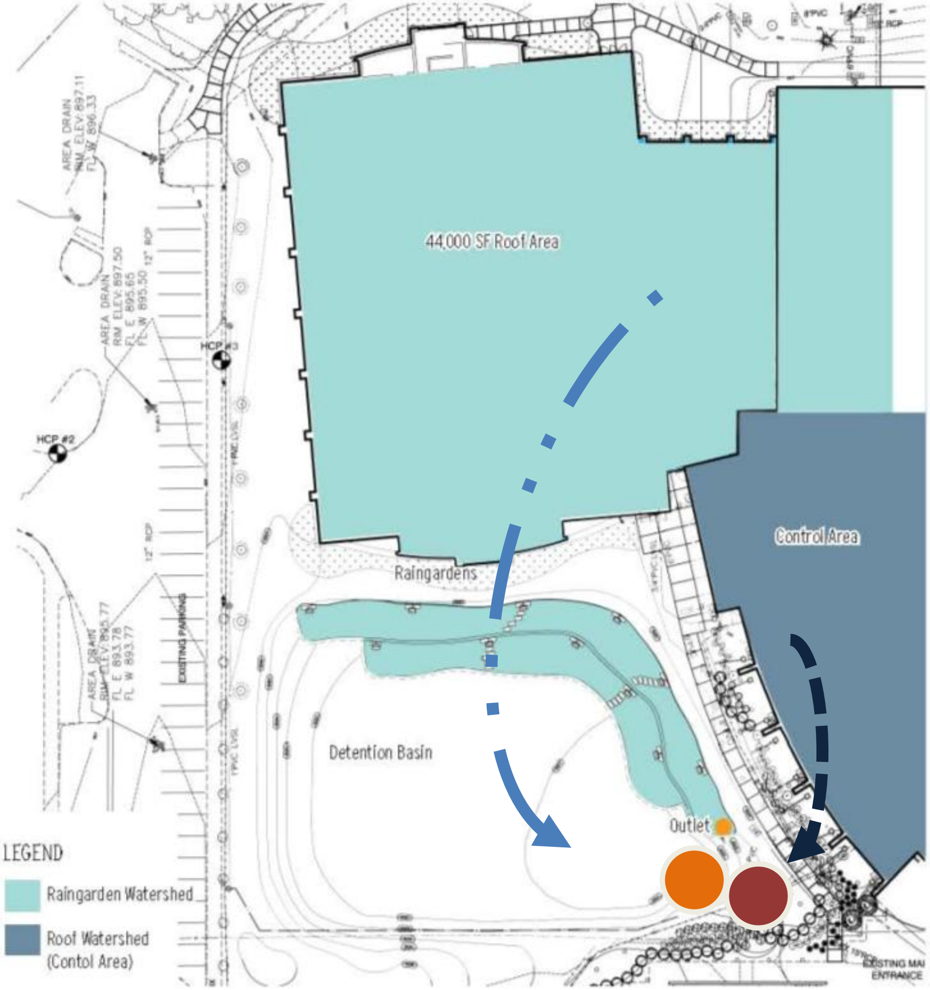
1st Growing Season

2nd Growing Season


Total Soil Moistue (Inches)
University of Kansas 2010
Total Soil Moisture (inches)
8
7
6
5
4
3
2
1
0
1
31
61
91
121
151
181
211
Day of Year
Estimated Soil Moisture (in)
Field Capacity (in)
Permanent Wilting (in)
Measured Soil Moisture (in)

Time to Recorded Runoff

- **1 hr, 20 min Longer Through Rain Garden**



USGBC Stormwater Grant

10 Important Takeaway

USGBC WebEx | 23 August 2011

10 Important Takeaways

1) Preserve the Existing Landscape

- It is easier to preserve the landscape than to rebuild it

2) Development Significantly Disturbs Site Soils

- Construction causes loss of plants, topsoil, and soil structure
- Stabilize sites before finishing BMPs. Erosion is the enemy of BMPs.
- Restore site soils to promote healthy plants

Photos: David Dods

10 Important Takeaways

3) Site Characterization Informs Design

- Soil type and compaction
- Fill material
- Depth to bedrock and groundwater

4) Size is Important. Properly Sized BMPs:

- More effectively remove pollutants
- Convey large storms without erosion

Photo: © Assassi

10 Important Takeaways

5) Learning from Mother Nature (1): Distributed Systems

- Distributed systems are less prone to overall failure if one part has problems

6) Learning from Mother Nature (2): Diversity

- Diverse systems are more resilient than monocultures
- If you lose one plant, the entire system doesn't fail

Photos: Jim Schuessler, David Dods

10 Important Takeaways

7) Plant Material is Important

- Plants promote infiltration, prevent erosion, remove pollutants, and build soil
- Match plants to moisture zones in the garden

8) Keep Designs Simple

- The more complex the system, the more difficult to build and maintain
- This is especially important if BMPs are new to the construction industry

Photo: David Dods, Jim Schuessler

10 Important Takeaways

9) Low Cost Can Still be Effective

10) Stormwater Management Can be Beautiful

Photo: David Dods, Assassi

Photo: © Assassi

Photo: © Assassi

Thank You

Jim Schuessler
BNIM
Kansas City, MO
816.783.1608
jschuessler@bnim.com
Twitter: jamesschuessler

Phil Barnes
Kansas State University
Manhattan, KS
785.532.2921
lbarnes@ksu.edu

David Dods
URS Corp.,
Overland Park, KS
913.344.1022
david_dods@urscorp.com

Document Location
http://issuu.com/bnim/docs/bmp_full_report

Or
Scan the QR Code above using
a smart phone **QR code scanner**