A Guide to Low Impact Development within Utah

2019

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Retention and LID Requirements

Small MS4 Permit Retention Requirement - 4.2.5.3.4

March 1, 2020

Each Permittee shall develop and define specific hydrologic method or methods for calculating runoff volumes and flow rates to ensure consistent sizing of structural BMPs in their jurisdiction and to facilitate plan review. By March 1, 2019, new development or redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale must manage rainfall on-site, and prevent the off-site discharge of the precipitation from all rainfall events less than or equal to the 90th percentile rainfall event. This objective must be accomplished by the use of practices that are designed, constructed, and maintained to infiltrate, evapotranspire and/or harvest and reuse rainwater. The 90th percentile rainfall event is the event whose precipitation total is greater than or equal to 90 percent of all storm events over a given period of record. If meeting this retention standard is technically infeasible, a rationale shall be provided on a case by case basis for the use of alternative design criteria. The project must document and quantify that infiltration, evapotranspiration and rainwater harvesting have been used to the maximum extent technically feasible and that full employment of these control are infeasible due to site constraints.

LID Guidance Document

UTAH DEPARTMENT of ENVIRONMENTAL QUALITY
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A Guide to Low Impact Development within Utah

Prepared for:
Utah Department of Environmental Quality
Division of Water Quality

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epg

Accessing the LID Guidance Document

waterquality.utah.gov

Accessing the LID Guidance Document

roadways and other impervious areas onto pervious surfaces such as vegetated areas, reducing the amount of directly connected impervious areas and reducing the runoff volume and filtering out pollutants.

- **Streetside Practices: Curb cuts** – Openings created in the curb to allow storm water from the street (or any adjacent impervious surface, like a parking lot) to flow into a depressed infiltration and planting area.

Definitions

- **Bioretention**
  A bioretention area or rain garden is a shallow planted depression designed to retain or detain stormwater before it is infiltrated or discharged downstream.
- **Evapotranspiration**
  Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and waterbodies.
- **Hydrology**
  Hydrology is the science that includes the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the water cycle.

Links

- EPA's Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices
- Guide to Low Impact Development within Utah (10 MB)
- Low Impact Development Center
- Low Impact Development Center's LID Urban Design Tools
- Jordan Valley Water Conservation Garden Park

Agenda & Format

Q&A after each section

Overview of Permit Requirements

Low Impact Development

Storm Water Integration

BMP Overview

The 90th Percentile Volume

Group Exercise #1

Break

Land Use Examples

Local Examples

Storm Water Quality Report

Group Exercise #2

Final Q&A

Overview of Permit Requirements

Overview of Permit Requirements

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Low Impact Development

"The term *low impact development* (LID) refers to systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat."

-EPA

Low Impact Development

Description of Terms

Green Infrastructure

Low Impact Development

Site Design Practices

Best Management Practices (BMPs)

Low Impact Development

Description of Terms

Green Infrastructure

Broader principles

- Ecological services
- Air quality
- Storm water
- Enhance aesthetics
- Municipal planning
- Watershed management

Low Impact Development

Description of Terms

Low Impact Development

Project Level Planning

- Engineered systems (structural or natural)
- Site design practices
- Retain runoff onsite
- Infiltration, evapotranspiration, harvest and/or reuse

Low Impact Development

Description of Terms

Site Design Practices

- Reduction of impervious surfaces
- Disconnected impervious surfaces
- Curb cuts
- Other…

Best Management Practices (BMPs)

- Long-term BMPs
- Rain gardens, infiltration basins, etc

Low Impact Development

Questions?

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Storm Water Integration

Storm Water Integration

At the Jurisdictional Level

Jurisdictional Level

- General Master Plans
- Storm Water Management Programs
- Storm Water Master Plans
- Watershed Management Plans
- Development Standards
- Ordinances
- Technical Guidance Documents
- Maintenance Agreements
- Other Planning Documents

"Have responsibilities been assigned?"

"Does everybody know their role?"

Storm Water Integration

At the Jurisdictional Level

Ordinances

Should promote or mandate LID principles

- Promote/preserve open spaces
- Include LID analysis as part of site plan review
- Allow for pervious surfaces
- Encourage clustering development
- Allow appropriate vegetation
- Address maintenance agreements
  - Determine final ownership of LID features
  - Require maintenance schedule and activities
  - Allow for permittee access
  - Provide method of resolution if violation of agreement occurs

"Do we need a gap analysis of our ordinances?"

"Do our ordinances prevent LID?"

Storm Water Integration

At the Jurisdictional Level

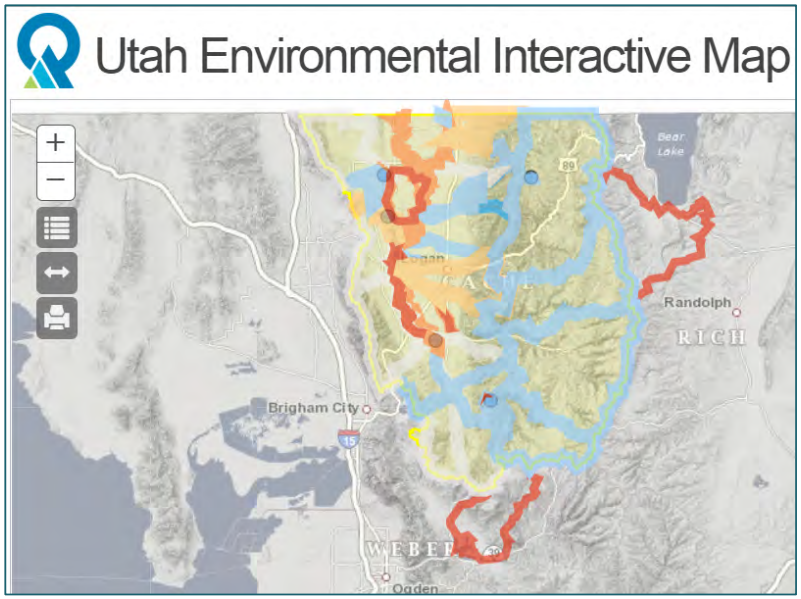
Other Jurisdictional Considerations

Impaired Waters

- Total Maximum Daily Loads (TMDLs)
- Focus on identified pollutants

Retrofit Planning

- Evaluation and prioritization of existing sites
- Adding curb cuts
- Dual-purpose basins



Cache County watersheds where a TMDL is required or approved.

Storm Water Integration

At the Project Level

Project Level

Site Considerations

Site Design Practices

Documentation

Storm Water Integration

At the Project Level

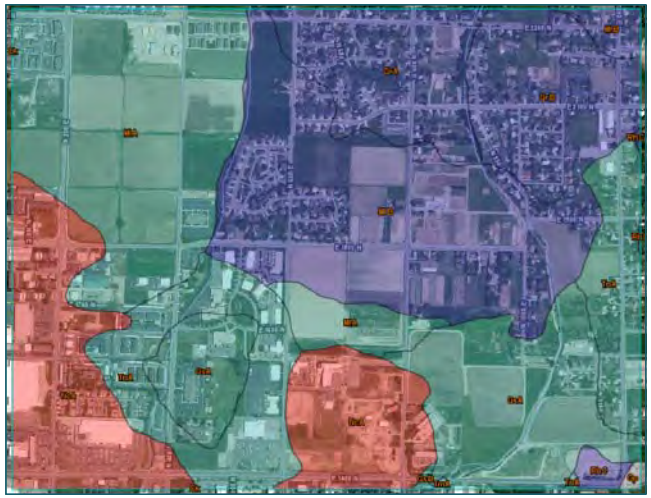
Site Considerations

1. **Soils**
2. **Groundwater**
3. Existing Drainage Patterns
4. Existing Pervious Areas and Vegetation

Groundwater

- Depth to groundwater
- Contaminated groundwater
- Wellhead protection areas
- Jurisdictions can decide what is appropriate

Soils



Web Soil Survey (B, C, & D soils in North Logan)

HSG	Infiltration	Soil Types
A	✓	90% Sand or Gravel – low runoff
B	✓	20% Clay, 50%-90% Sand or Gravel – moderately low runoff
C	✗	20%-40% Clay, < 50% Sand or Gravel – moderately high runoff
D	✗	>40% Clay, <50% Sand or Gravel – high runoff

Storm Water Integration

At the Project Level

Site Considerations

1. Soils
2. Groundwater
3. **Existing Drainage Patterns**
4. **Existing Pervious Areas and Vegetation**

Existing Drainage Patterns

- Preserve existing drainage patterns
- Mirroring hydrology is more likely

Existing Pervious Areas and Vegetation

- Maintain existing opportunities for retention

Storm Water Integration

At the Project Level

Site Design Practices

1. Reduction of Impervious Surfaces
2. Disconnected Impervious Surfaces
3. Curb Cuts

Others…

Reduction of Impervious Surfaces

Disconnected Impervious Areas

Curb Cuts

Storm Water Integration

At the Project Level

Documentation

Storm Water Quality Report Template

Documentation of decision making and calculations

Ensure consistent design

Will discuss in more detail later…

Storm Water Integration

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BMP Overview

BMP Overview

12 LID BMPs

- Rain Garden, BR-1
- Bioretention Cell, BR-2
- Bioswale, BR-3
- Vegetated Strip, BR-4
- Tree Box Filter, BR-5
- Green Roof, BR-6

Bioretention

- Pervious Surfaces, PS-1 — *Pervious Surfaces*
- Infiltration Basin, ID-1
- Infiltration Trench, ID-2
- Dry Well, ID-3
- Underground Infiltration Galleries, ID-4

Infiltration Devices

- Harvest and Reuse, HR-1 — *Harvest and Reuse*

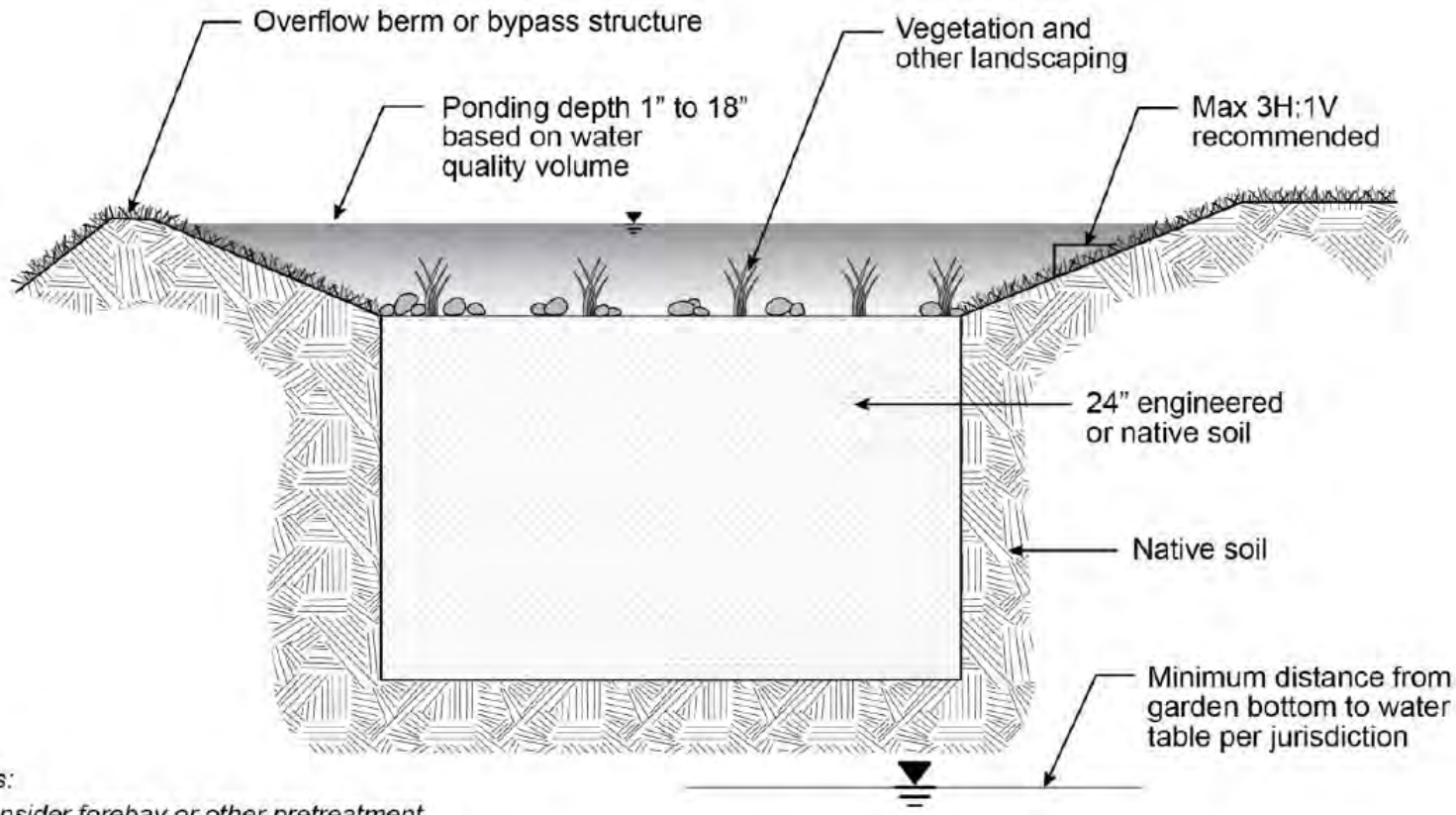
Retention vs Treatment

Retention BMPs retain and treat

Treatment BMPs treat but don't retain

BMP O

Retention



lotes:

Consider forebay or other pretreatment

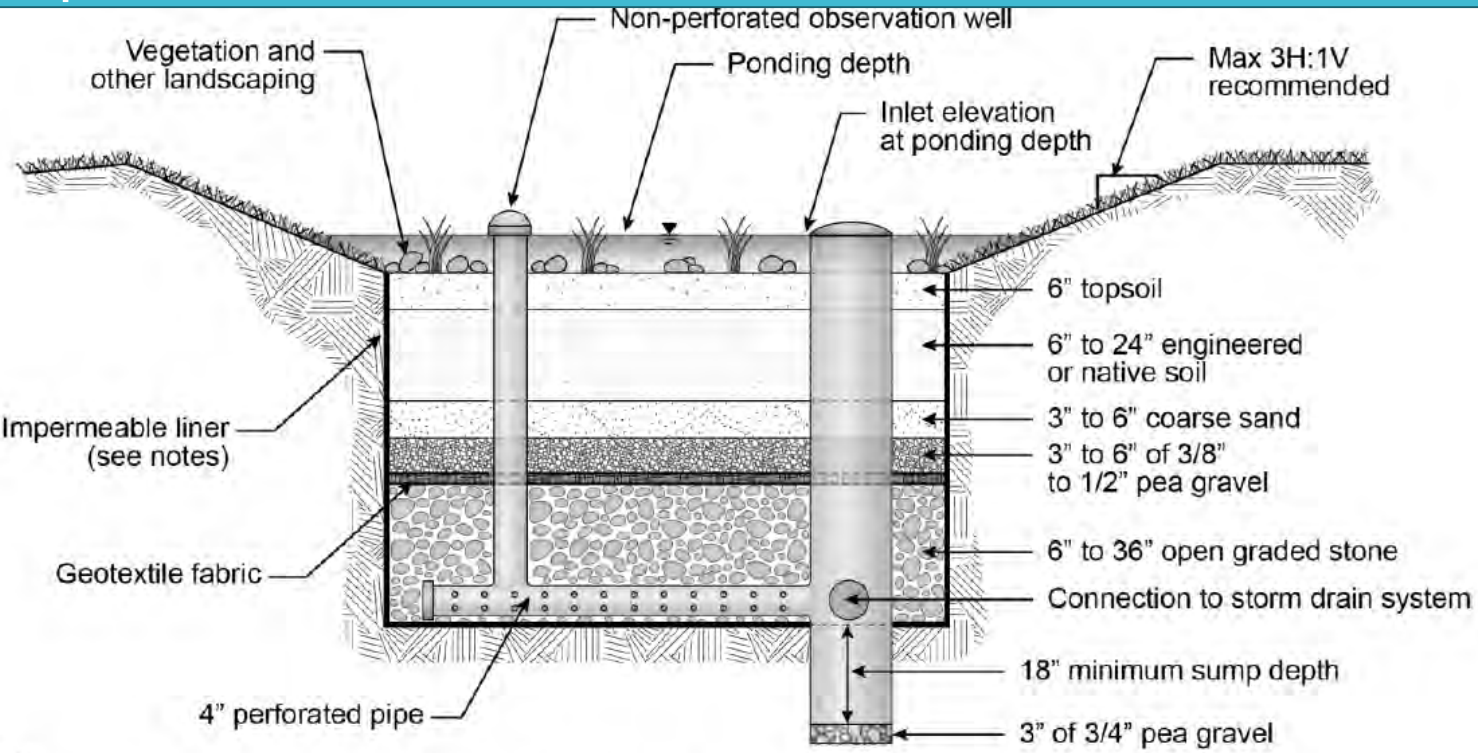
Consider upstream bypass for large storm events

Rain Garden in Native or Engineered Soils

Not to scale

BMP O

Treatment



Notes:

- *Impermeable liner around all sides and bottom of rain garden if groundwater concerns exist*
- *Dimensions shown may vary based on site conditions*
- *Consider forebay or other pretreatment*

Rain Garden with Underdrain System

Not to scale

BMP Overview

Fact Sheets

- Pollutant Removal Effectiveness
- Design Criteria
- Calculation Methods
- Sample Calculations
- Evaluating BMP Effectiveness
- Technical Infeasibilities
- Water Quality Concerns
- Designer Checklist
- Vegetation Selection
- Installation
- Installation Costs
- Maintenance
- Maintenance Activities
- Maintenance Costs
- Figures

BMP Overview

Fact Sheets

Pollutant Removal Effectiveness

Pollutant	Effectiveness
Sediment	High
Nutrients	High
Metals	High
Bacteria	High
Oil/Grease	High

Design Criteria

Parameter	Min. Value	Max. Value	Notes
Depth to Historical High Groundwater	2 ft	No maximum	-
Side Slopes	No minimum	3H:1V	-
Ponding Depth	No minimum	18 in	-
Drawdown Time	12 hours	72 hours	24 to 48 hours preferred. Drawdown time may also depend on local mosquito abatement regulations.
Design Infiltration Rate	0.25 in/hr	6 in/hr	Field testing required for final design. Infiltration rate should be low enough to allow biofiltration processes to occur. During design, infiltration rate, drawdown time, and the soil matrix depth will be directly related.
Freeboard	No minimum	No maximum	Freeboard per jurisdiction standards. For public safety, consider requiring freeboard and a minimum 6-inch embankment when ponding depth is greater than 6 inches.

BMP Overview

Fact Sheets

Calculation Methods & Sample Calculations

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} \sqrt{S}$$

$$t = \frac{(D_T n_W + d)}{k}$$

$$A_{min} = \frac{12xSFxWQV}{kt}$$

Evaluating BMP Effectiveness

- Retention is occurring
- Treatment goals are met
- Signs of failure
  - Ponding
  - Sediment build up
  - Failing vegetation
  - Structural failure

BMP Overview

Fact Sheets

Technical Infeasibilities

- High groundwater
- Contaminated groundwater
- Soils that don't infiltrate
- Insufficient project space
- Proximity to structure foundations

Water Quality Concerns

- Mobilization of pollutants

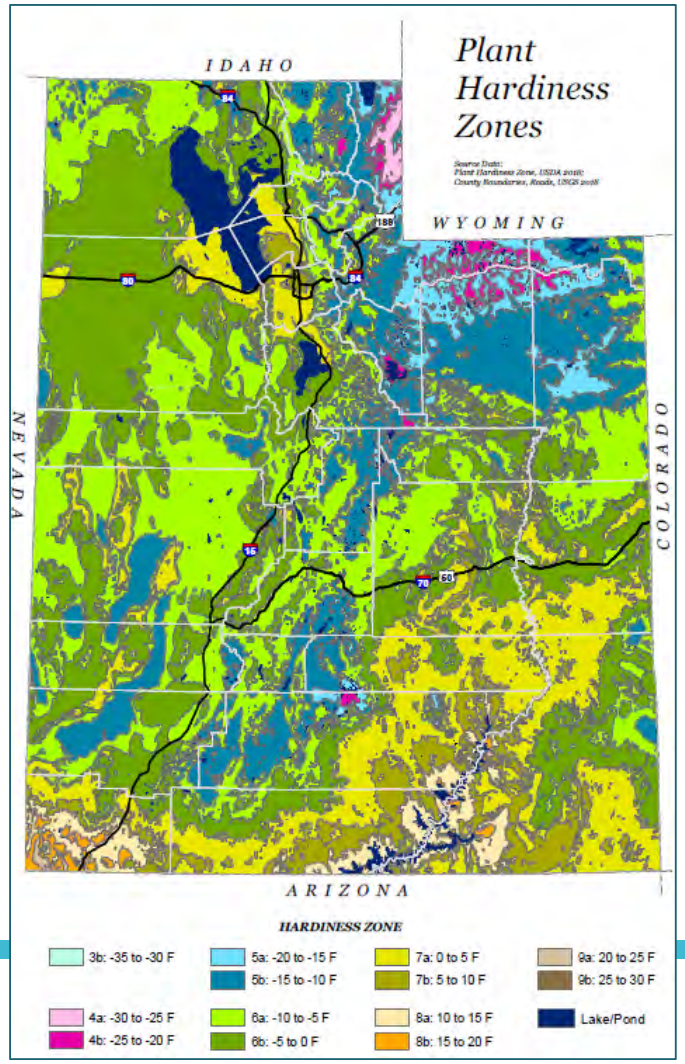
BMP Overview

Fact Sheets

Designer Checklist

	Yes	No
Does groundwater meet the minimum separation requirement?	☐	☐
Is there available right-of-way, property, or easement?	☐	☐
Is the design infiltration rate within acceptable rates?	☐	☐

Vegetation Selection



BMP Overview

Fact Sheets

Installation

- Excavation
- Grading
- Fine grading
- Granular borrow fill
- Landscaping and vegetation
- Top layer
- Outlet structure or upstream bypass structure (for larger storm events)
- Soil matrix (if needed)
- Impermeable liner (if needed)
- Underdrain system (if needed)
- Irrigation system (if needed)

Maintenance Activities/Frequencies

- Inspect for vegetative coverage
- Inspect side slopes for erosion
- Inspect for trash and debris
- Inspect for soil clogging
- Inspect for standing water

Inspection recommended twice a year (Fall and Spring)

Installation Costs

Maintenance Costs

Costs will vary

BMP Overview

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The 90th Percentile Volume

1. Why the 90th?
2. How to Calculate
3. WQV vs Vgoal

The 90th Percentile Volume

Why the 90th?

"Maximized" Water Quality Capture Volume

Guo & Urbonas

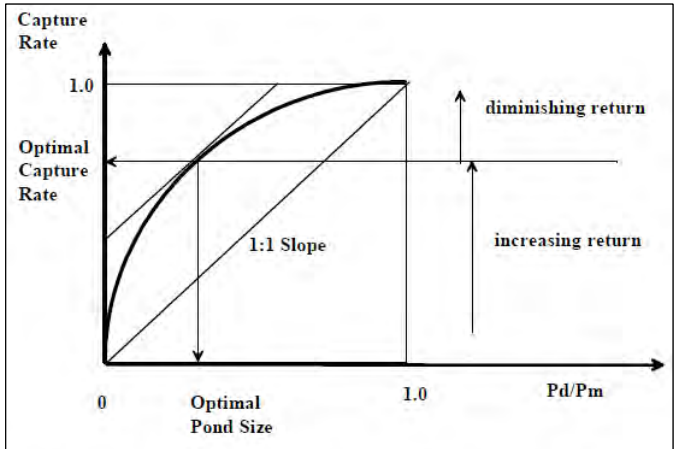
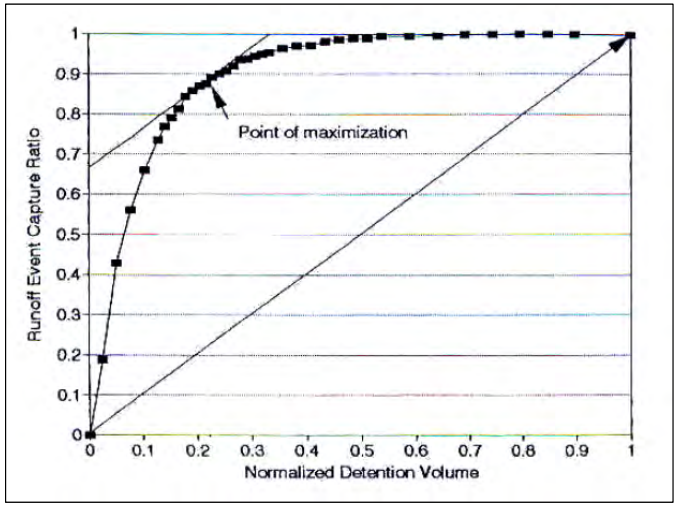


Figure 3. Determination of the Maximized Detention Size



The 90th Percentile Volume

How to Calculate

V_{goal} = 90th Percentile Volume

$V_{goal} = R_V dA$

Step 1	Determine the 90th Percentile Precipitation Depth	→	**d**
Step 2	Determine the project's imperviousness.	→	**imp & A**
Step 3	Volumetric Runoff Coefficient	→	R_V
Step 4	Determine 90th Percentile Volume	→	V_{goal}

The 90th Percentile Volume

Step 1 **Determine the 90th Percentile Precipitation Depth, d**

Obtain long-term reliable rainfall data.

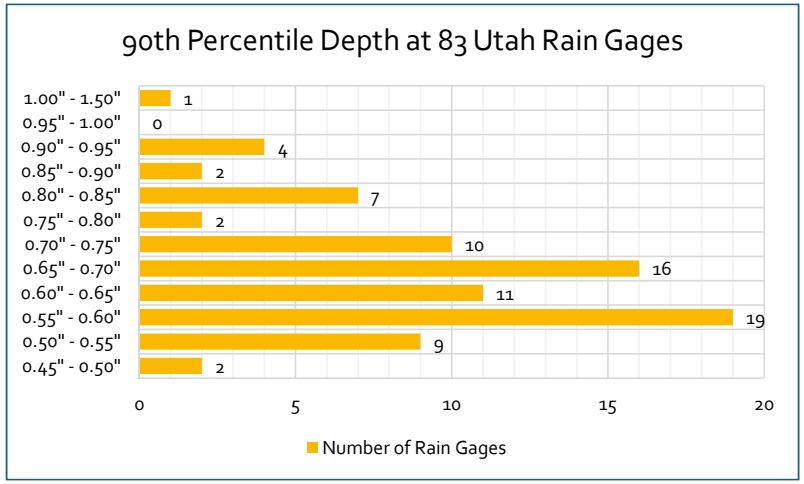
1. Active rain gage
2. 30 years of data
3. 90% data coverage

Rainfall data sources

Daily rainfall summaries

Other sources that meet criteria

Usually between 0.50" and 0.85"



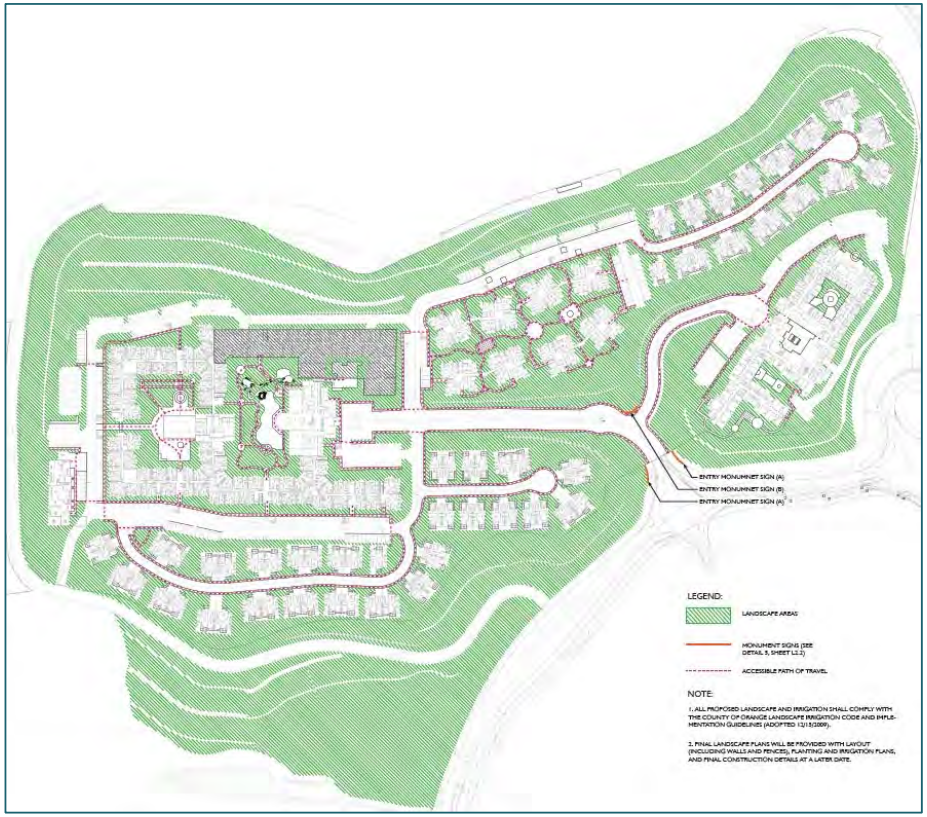
Appendix A

STATION	NAME	LATITUDE	LONGITUDE	ELEVATION (FT)	90TH PERCENTILE DEPTH (IN)
USC00420074	ALTAMONT, UT US	40.3670	-110.2986	6456	0.53
USC00420086	ALTON, UT US	37.4402	-112.4819	7098	0.81
USC00420168	ANGLE, UT US	38.2486	-111.9608	6410	0.53
USC00420336	ARCHES NATIONAL PARK HQS, UT US	38.6163	-109.6191	4093	0.56
USC00420527	BEAVER CANYON POWER HOUSE, UT US	38.2682	-112.4818	7275	0.74
USS0011J46S	BEAVER DIVIDE, UT US	40.6100	-111.1000	8280	0.70
USS0011H08S	BEN LOMOND PEAK, UT US	41.3800	-111.9400	8000	1.50
USS0012L07S	BIG FLAT, UT US	38.3000	-112.3600	10349	0.90

The 90th Percentile Volume

Step 2 **Determine the Project's Imperviousness**

$$\text{Imperviousness} = \frac{\text{Impervious Area within Project Limits}}{\text{Total Project Area}}$$



The 90th Percentile Volume

Step 3 **Determine the Volumetric Runoff Coefficient, R_V**

What is R_V?

$$R_V = \frac{\text{Monitored Runoff Volume}}{\text{Total Precipitation Volume}}$$

- Not the same as the Rational Method C
- R_V is more appropriate for smaller, more frequent storms
- Typically smaller values than C

Methods Used in the Manual

Method 1 – Reese
Applicable for urban development
$R_V = 0.91 \times imp - 0.0204$

Method 2 – Hydrologic Soil Groups
$R_{V\text{-}A} = 0.84 \times imp^{1.302}$
$R_{V\text{-}B} = 0.84 \times imp^{1.169}$
$R_{V\text{-}C/D} = 0.83 \times imp^{1.122}$

Method 3 – Granato Method
Applicable for highways
$R_V = 0.225 \times imp + 0.05$; when $imp < 0.55$
$R_V = 1.14 \times imp - 0.371$; when $imp \geq 0.55$

The 90th Percentile Volume

How to Calculate

V_{goal} = 90th Percentile Volume

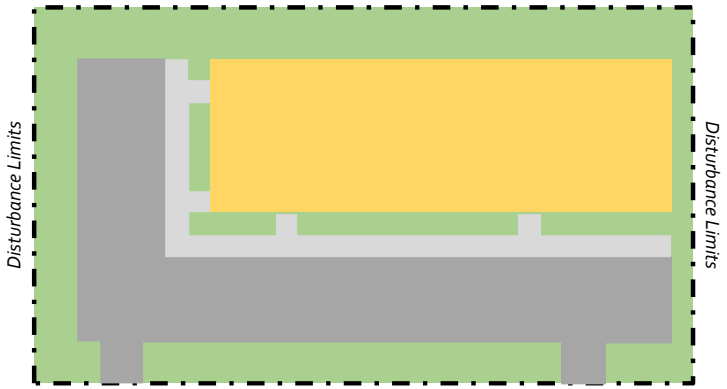
$$V_{goal} = R_V dA$$

Step 1	Determine the 90th Percentile Precipitation Depth →	**d**
Step 2	Determine the project's imperviousness. →	**imp & A**
Step 3	Volumetric Runoff Coefficient →	**R_V**
Step 4	Determine 90th Percentile Volume →	**V_{goal}**

The 90th Percentile Volume

V_{goal} vs Water Quality Volume (WQV)

V_{goal}



V_{goal} calculated from:

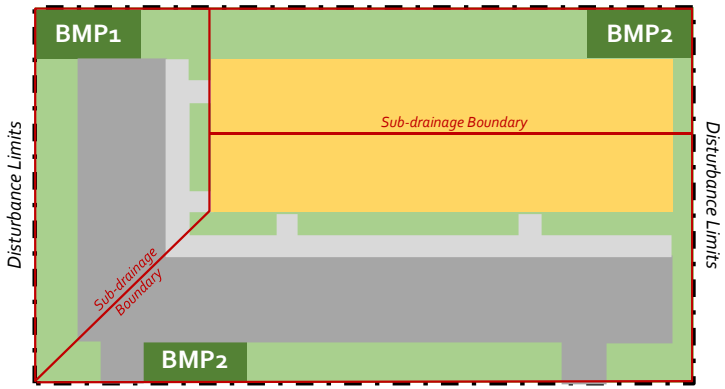
Project disturbance limits

Project imperviousness

90th Percentile Storm Depth

$V_{goal} = R_V dA$

WQV



WQV calculated from:

BMP's drainage area

Imperviousness of BMP's drainage area

90th Percentile Storm Depth

$WQV = R_V dA$

$$V_{goal} = \sum WQV$$

The 90th Percentile Volume

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Group Exercise

Calculate V_{goal}

Calculate WQV for 3 drainage areas

Review of Group Exercise

Given

90th Percentile Storm Depth: 0.60"

Disturbance Limits: 5.0 ac

Project Impervious Area: 3.27 ac

Project Imperviousness, i (decimal): 0.65

Volumetric Runoff Coefficient, R_V: use Reese method.

$R_V = 0.91i - 0.0204$

Volumetric Runoff Coefficient, R_V: 0.57

Project Volume Retention Goal, V_{goal} (cf)

$V_{goal} = R_V dA$

V_{goal} (cf): 6,259

Imperviousness

$$Imp = \frac{3.27\ ac}{5.00\ ac} = 0.65$$

Runoff Coefficient

$R_V = 0.91 \times imp - 0.0204$

$R_V = 0.91 \times (0.65) - 0.0204$

$R_V = 0.57$

Project Volume Retention Goal

$V_{goal} = R_V dA$

$V_{goal} = (0.57)(0.60''/12)(5.0\ ac \times 43{,}560\ sf/ac)$

$V_{goal} = 6{,}259\ cf$

Contributing Drainage Area	Area (ac)	Impervious Area (ac)	Imperviousness (decimal)	Volumetric Runoff Coefficient, R_V	Water Quality Volume, WQV (cf)
CDA 1	1.02	0.53	0.52	0.45	1,005
CDA 2	1.29	0.82	0.64	0.56	1,568
CDA 3	2.69	1.92	0.71	0.63	3,686
				Total WQV (cf)	6,259

Review of Group Exercise

Water Quality Volume

$WQV = R_V dA$

$WQV1 = (0.45)(0.60''/12)(1.02\ ac \times 43{,}560\ sf/ac)$

$WQV1 = 1{,}005\ cf$

$WQV2 = (0.56)(0.60''/12)(1.29\ ac \times 43{,}560\ sf/ac)$

$WQV2 = 1{,}568\ cf$

$WQV3 = (0.63)(0.60''/12)(2.69\ ac \times 43{,}560\ sf/ac)$

$WQV3 = 3{,}686\ cf$

$$\sum WQV = WQV1 + WQV2 + WQV3 = \boxed{6{,}259\ cf} = V_{goal}$$

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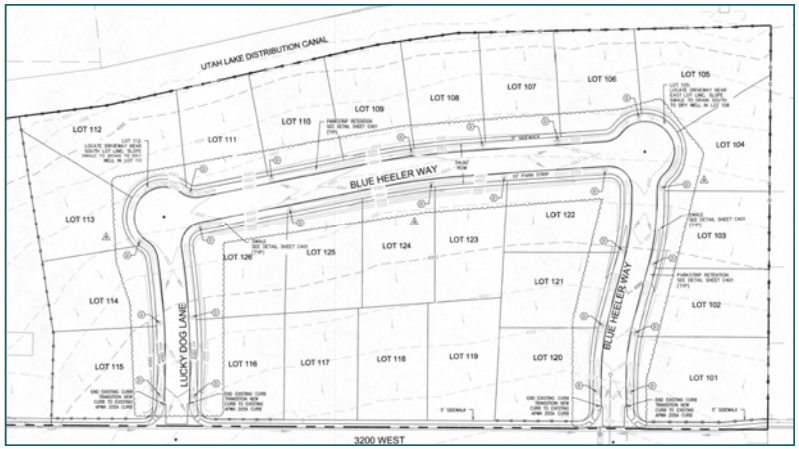
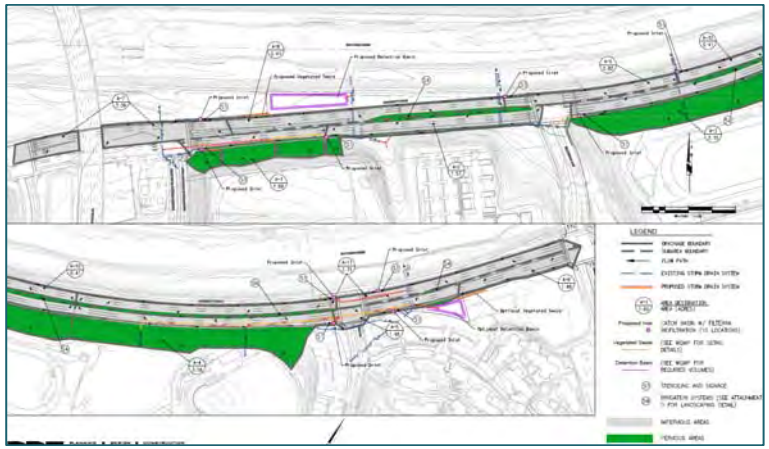
Land Use Examples

Land Use Examples

Residential



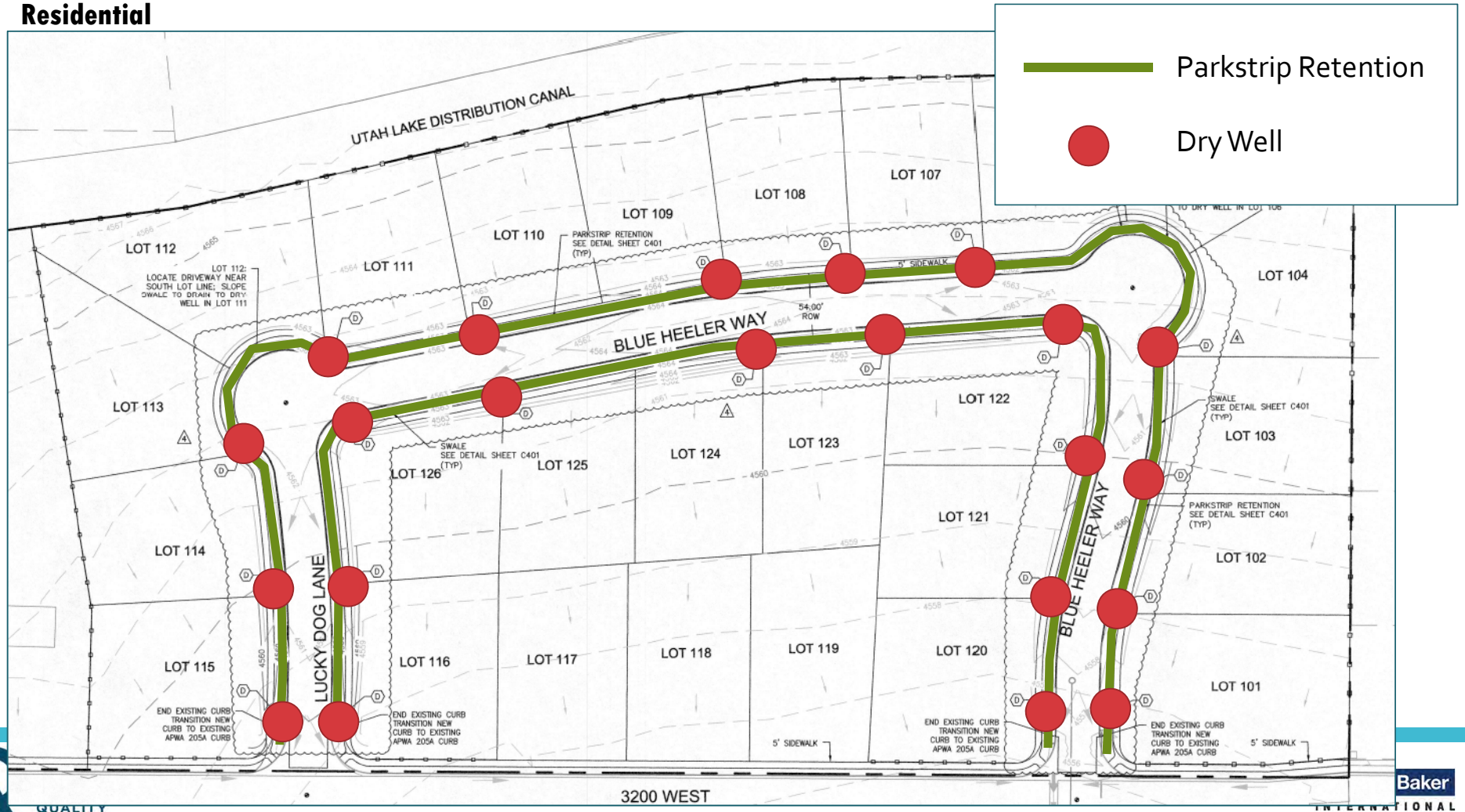
Highway



Public/Industrial

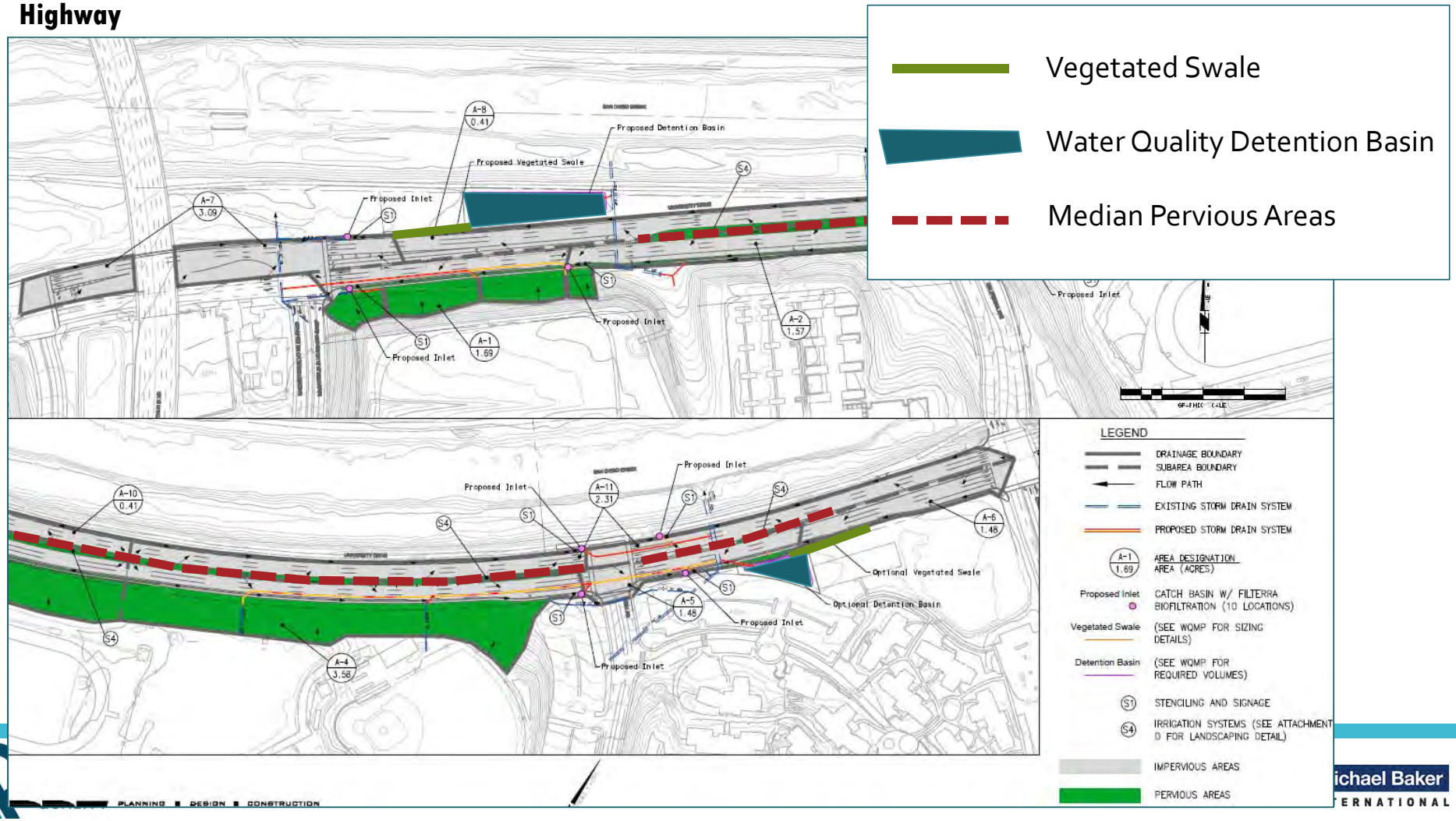
Land Use Examples

Residential



Land Use Examples

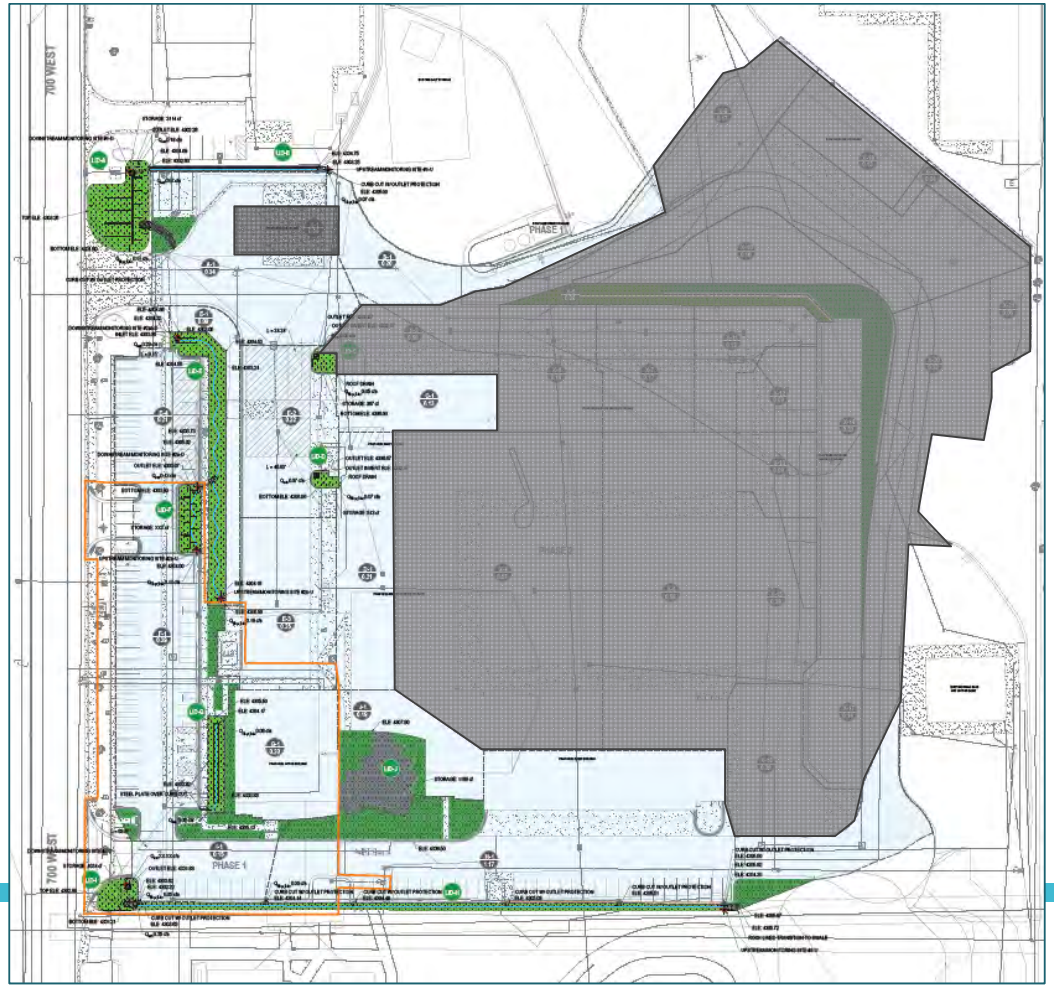
Highway



Land Use Examples

Public/Industrial

- 4 swales
- 3 rain gardens
- Pavers



Land Use Examples

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Local Examples

Lance Anderson, Kayenta Development – Ivins

James Darling, Spanish Fork SWMP Administrator

Steve Burian, PhD – University of Utah

Ryan Dupont, PhD – Utah State University

LID in Southern Utah

Reduced road width

Preserve open spaces

Remove curb cuts for sheet flow

Retention achieved with infiltration vaults

SPANISH FORK
PRIDE & PROGRESS

MS4 AND LOW IMPACT DEVELOPMENT IMPLEMENTATION

James Darling
SWMP Administrator

LID IMPLEMENTATION PERCEPTION

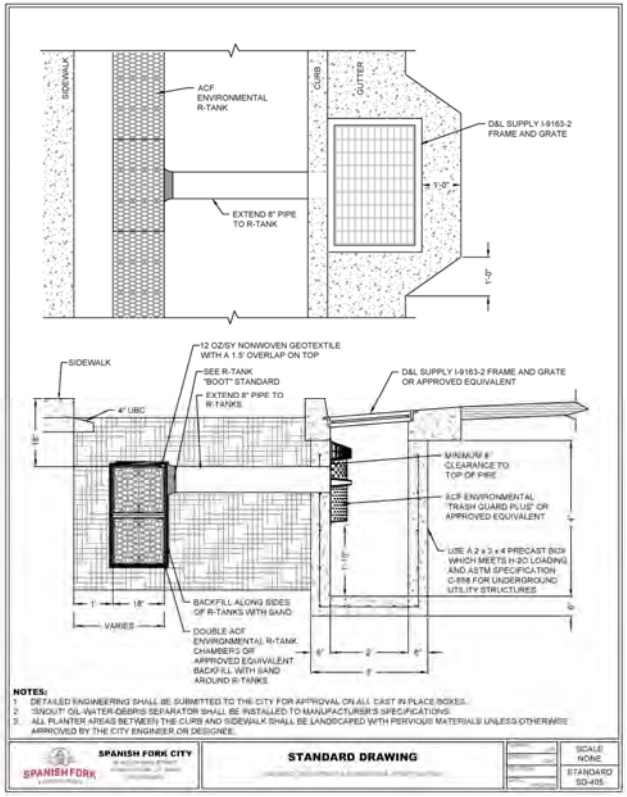
STARTING YOUR LID

Who, What, When, Where, Why, and How?

1. Who is required to install LID.
2. What product needs to be in place.
3. When should LID products be built or placed.
4. Where should LID be used.
5. Why should a particular LID be used and what purpose does it serve.
6. How can we maintain, afford, and enforce LID.

COLLABORATE

UNDERGROUND STORAGE - R-TANK



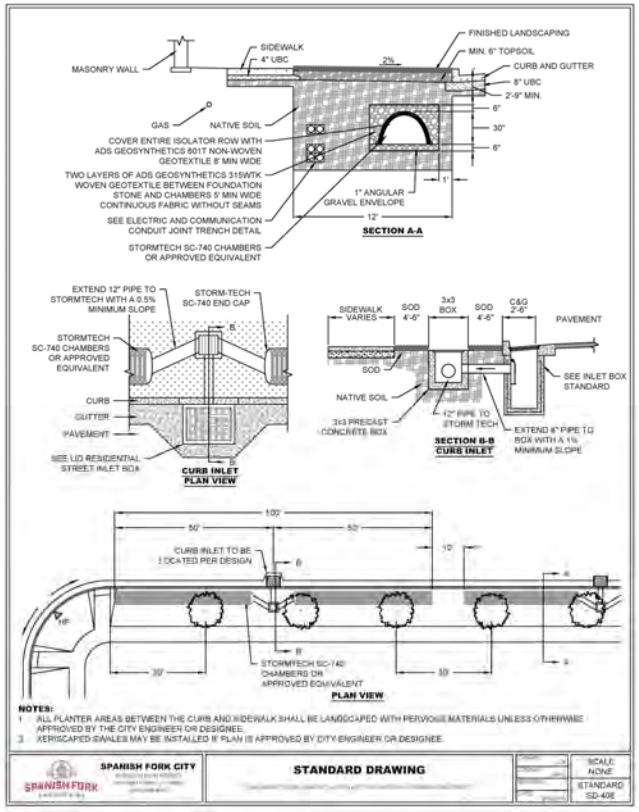
2014 INSTALL

2014 INSTALL

ALTERNATIVES

StormBrixx

ALTERNATIVES

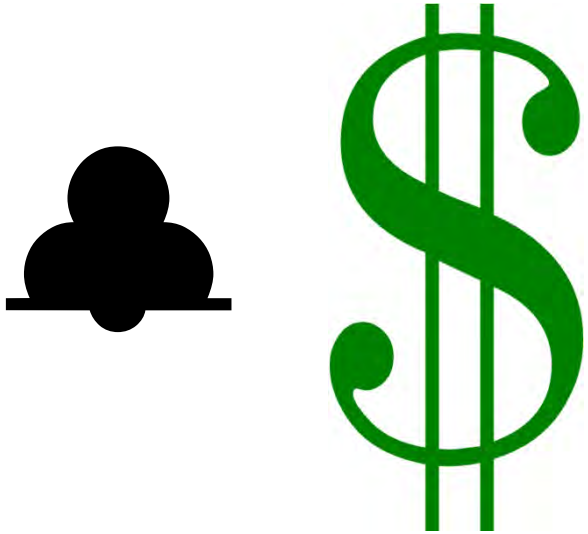


StormTech®
Detention • Retention • Water Quality
An ADS company

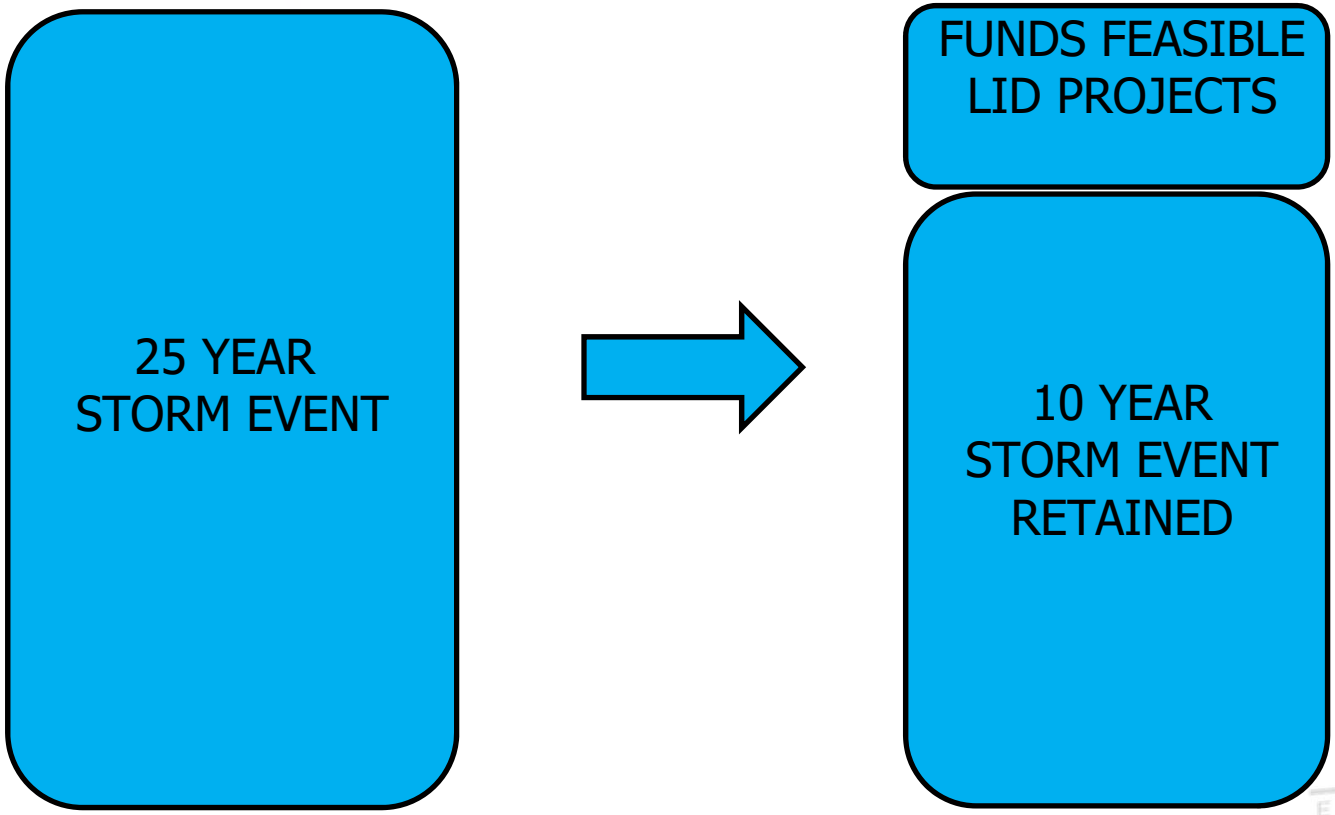
DEVELOPER/CONTRACTOR

Benefits:

- Very few Basins
- Extra footprint(s) for development
- Less and smaller piping
- Install costs are comparable
- Less Impervious Area(s)
- Impact Fees dropped around $1500 per/acre
- In compliance



LID BANK


25 YEAR
STORM EVENT
FUNDS FEASIBLE
LID PROJECTS
10 YEAR
STORM EVENT
RETAINED

ORDINANCES

FUTURE OF LID

Disposing of used engine oil can be a problem. Solution: Dig a hole in the ground with a posthole digger and fill it with fine gravel. Then pour in the oil. It will be absorbed into the ground before your next change. Cover the spot with soil.

166 POPULAR SCIENCE JANUARY 1963

phil-are-go.blogspot.com

QUESTIONS?

Research Guiding LID Design at Site-to-Watershed Scales in SLC

Steve Burian

Professor, Civil & Environmental Engineering
Director, Water Center
Project Director, U.S.-Pakistan Center for Advanced Studies in Water
Associate Director, Global Change and Sustainability Center
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This Stuff Works…in Utah!

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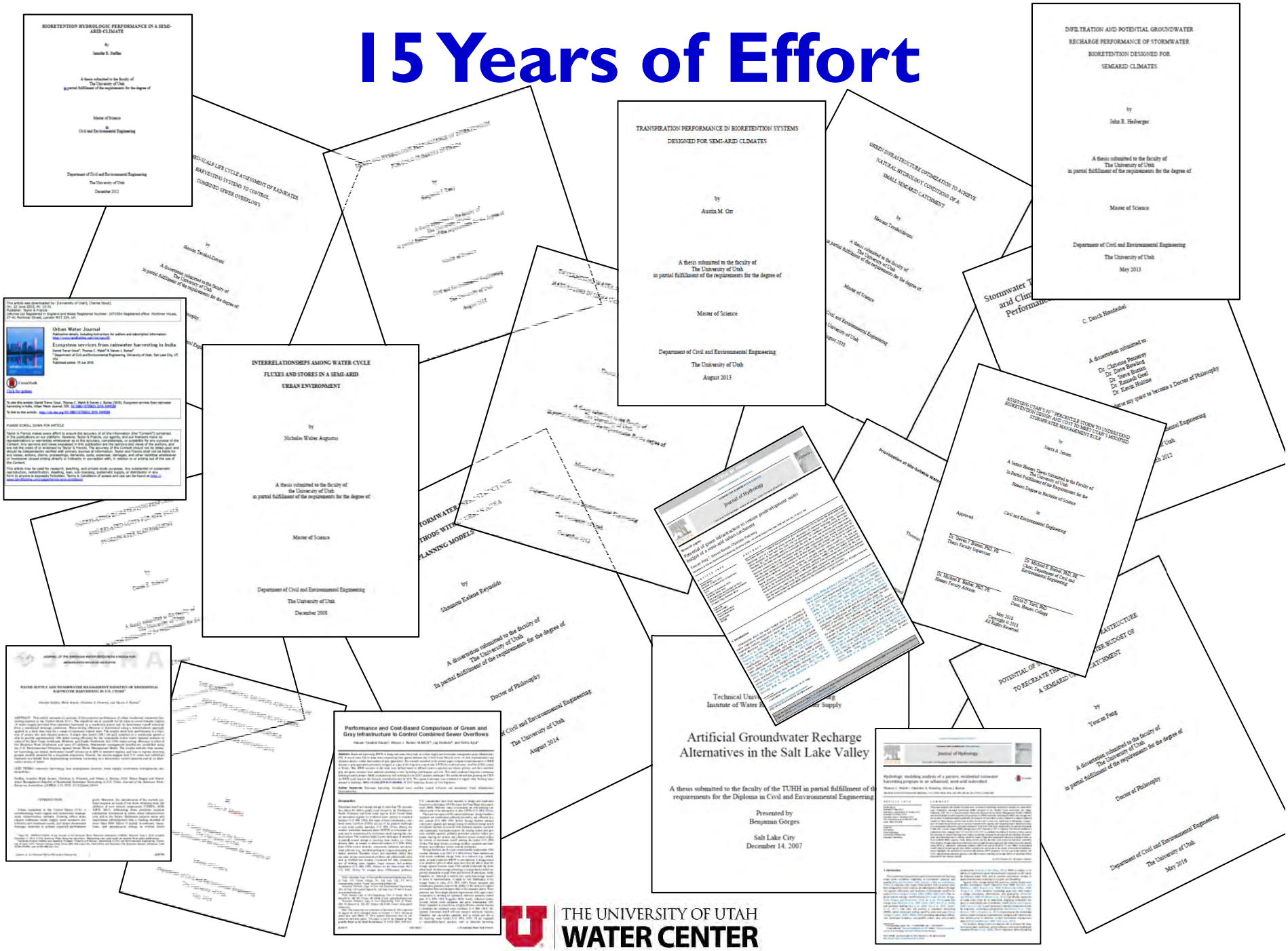
15 Years of Effort



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Key Points

1. Research-backed guidance for design of LID controls is available to meet hydrologic and pollutant removal objectives in SLC
2. Cost and performance optimized catchment scale LID control requirements have been produced for typical developed areas in SLC to meet 90th percentile criterion
3. More research is needed:
   1. winter performance
   2. long-term durability (and O&M strategies/costs)
   3. representation in capital improvements planning (e.g., failure, replacement cost)
   4. modifications for climate change

LID Control Study Sites

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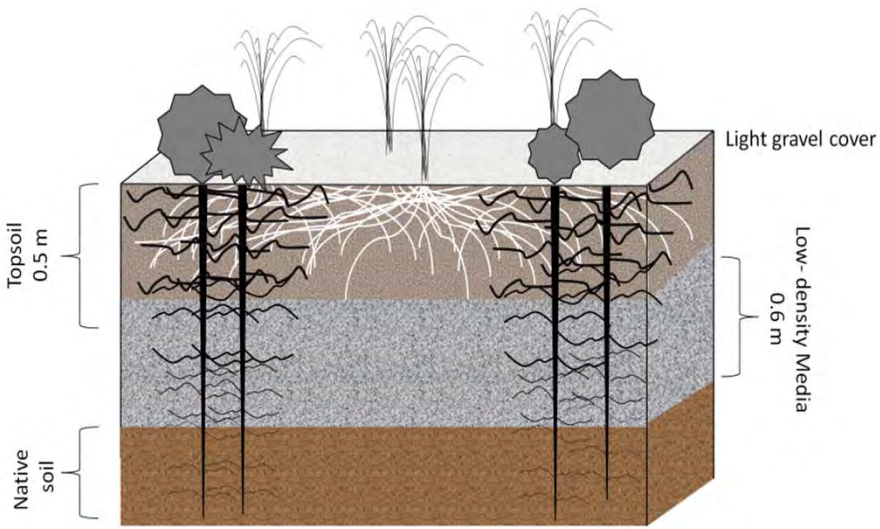
Research Thrust: Configuration

1. What is a recommended bioretention cross section?
2. What types and configurations of plants are recommended for semi-arid climate?



Houdeshel, Hultine and Pomeroy (2012). "Bioretention Design for Xeric Climates Based on Ecological Principles." *Journal of American Water Resources Association*.

95th percentile storm	20 mm (0.78")
storage layer depth	0.6 m (2')
garden area as % drainage area	5 %
expected annual runoff captured	97%

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Research Thrust: Plant Selection

TABLE 1. Recommendations for Plants to Be Used in Bioretention in Arid Climates.

Species Name	Common Name	Form	Rooting Pattern	AMF Host	Recommended Region
Schizachyrium scoparium	Little bluestem	WG	E	Likely	1,2,3,4
Bouteloua gracilis	Blue gramma	WG	E	Likely	1,2,3,4
Sorghastrum nutans	Indiangrass	WG	E	Likely	1,2,3,4
Pascopyrum smithii	Western wheat grass	CG	E	Likely	1
Pseudoroegneria spicata	Bluebunch wheat grass	CG	E	Likely	1
Rosa woodsii	Wood rose	S	E	Likely	1,2,3,4
Rhus Aromatica	Fragrant sumac	S	E	Yes	1,2,3,4
Fallugia paradoxa	Apache plume	S	E	Likely	1,2,3
Chrysothamnus nauseosus	Rubber rabbitbrush	S	P	Likely	1,2,3
Atriplex canescense	Four-winged saltbrush	S	P	Likely	1,2,3
Juniperus osteosperma	Utah juniper	T	E and P	Yes	1,2,3
Cercocarpus ledifolius	Curly mahogany	S, T	P	Likely	1,2
Larrea tridentata	Creosote	S	E	Likely	2,3
Artemisia tridentata	Sagebrush	S	E and P	Yes	1,2
Cercocarpus montanus	Mountain mahogany	S, T	P	Likely	1,3
Eschscholzia californica	California poppy	F	E and P	Unknown	1,4
Epilobium angustifolium	Fireweed	F	E	Yes	1,4
Baileya multiradiata	Desert marigold	F	P	Unknown	2,3
Eschscholzia glyptosperma	Desert poppy	F	P	Unknown	2,3
Tulipia sp.	Tulips	F	Bulb	Unknown	1
Arctostaphylos glauca	Bigberry manzanita	S, T	E	Likely	4
Solidago californica	California goldenrod	S	E	Likely	4
Delphinium bicolor	Low larkspur	F	E	Unknown	1

Notes: Recommendations are based on literature review and favorable plant traits. Rooting pattern codes signify: E, shallow, extensive; P, phreatophyte; B, bulb. In the Form column: G, bunchgrass; S, shrub, T, tree, F, perennial flowering forbs. In the Recommended Region column: 1. Basin and Range (Salt Lake City, Boise, Denver); 2. Mojave (Las Vegas); 3. Warm Deserts (Phoenix); and 4. Coastal southern California (Anaheim and San Diego, California).

Houdeshel, Hultine and Pomeroy (2012). "Bioretention Design for Xeric Climates Based on Ecological Principles." *Journal of American Water Resources Association*.

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Research Thrust: Plant Selection

- **Vegetation Cost**
  - Variable ~ $30/square yard
- **Timing of plant incorporation**
  - Dormant period - late fall, very early spring
- **Maintenance**
  - Comparatively very low, once native or drought tolerant vegetation is established
  - Irrigation may or may not be required
  - Weed removal and pruning

(Bush and Burian 2018)

WATER-WISE PLANTS FOR UTAH

*The following plant list was compiled by the Utah Water-Wise Plants Committee for use with its **Water-Wise Plant Tagging Program**. Please use this list to find plants that are appropriate for Utah's climate and conditions. For specific plant information and design ideas please visit **www.waterwiseplants.utah.gov**.*

ALPHA BY LATIN NAME

CONIFEROUS TREES			
Abies concolor	White Fir	*Pinus aristata*	Bristlecone Pine
Calocedrus decurrens	Incense Cedar	*Pinus edulis*	Pinyon Pine
Cedrus atlantica glauca	Blue Atlas Cedar	*Pinus flexilis*	Limber Pine
Cedrus libani	Cedar of Lebanon	*Pinus monophylla*	Single-Needled Pinyon
Cupressus arizonica	Arizona Cypress	*Pinus nigra*	Austrian Pine
Juniperus osteosperma	Utah Juniper	*Pinus ponderosa*	Ponderosa Pine
Juniperus scopulorum	Rocky Mountain Juniper	*Pinus sylvestris*	Scotch Pine
DECIDUOUS TREES			
Acer campestre	Hedge Maple	*Gymnocladus dioicus*	Kentucky Coffee Tree
Acer ginnala	Amur Maple	*Koelreuteria paniculata*	Goldenrain Tree
Acer grandidentatum	Bigtooth Maple	*Maclura pomifera*	Osage Orange
Acer tataricum	Tatarian Maple	*Parrotia persica*	Persian Ironwood
Acer truncatum	Shantung Maple	*Ptelea trifoliata*	Hop Tree
Amelanchier sp.	Serviceberry	*Quercus gambelii*	Gambel Oak
Catalpa speciosa	Western Catalpa	*Quercus macrocarpa*	Bur Oak
Celtis occidentalis	Common Hackberry	*Quercus muehlenbergii*	Chinkapin Oak
Chilopsis linearis	Desert Willow	*Robinia neomexicana*	New Mexico Locust
Corylus colurna	Turkish Filbert	*Sophora japonica*	Japanese Pagoda Tree
Cotinus obovatus	American Smoke Tree	*Syringa reticulata*	Japanese Lilac Tree
Crataegus douglasii	Douglas Hawthorne	*Ulmus parvifolia (parviflora)*	Lacebark/Chinese Elm
Fraxinus anomala	Single-Leaf Ash	*Zelkova serrata*	Zelkova
Ginkgo biloba	Ginkgo		
SHRUBS			
Agave utahensis	Utah Agave	*Krascheninnikovia lanata*	Winterfat
Amorpha canescens	Leadplant	*Mahonia aquifolium*	Oregon Grape
Artemisia cana	Silver Sage	*Mahonia fremontii*	Fremont Holly
Artemisia filifolia	Sand Sage	*Peraphyllum ramosissimum*	Sqaw Apple
Artemisia frigida	Fringed Sage	*Philadelphus microphyllus*	Littleleaf Mockorange
Artemisia nova	Black Sage	*Physocarpus malvaceus*	Mallow-leaved Ninebark
Artemisia tridentata	Big Sage	*Physocarpus opulifolius*	Ninebark
Atriplex canescens	Fourwing Saltbrush	*Pinus mugo*	Mugo Pine
Atriplex confertifolia	Shadscale	*Potentilla fruticosa*	Shrubby Cinquefoil
Buddleia davidii	Butterfly Bush	*Prunus pumila v. besseyi*	Sand Cherry
Caragana arborescens	Siberian Peashrub	*Purshia mexicana*	Cliffrose
Caryopteris x clandonensis	Blue Mist Spirea	*Quercus turbinella*	Shrub Live Oak
Ceanothus martinii	Utah Mountain Lilac	*Rhus aromatica*	Fragrant Sumac
Cercocarpus intricatus	Little-Leaf Mtn Mahogany	*Rhus glabra*	Smooth Sumac
Cercocarpus ledifolius	Curl-Leaf Mtn Mahogany	*Rhus trilobata*	Squawbush
Cercocarpus montanus	Alder-Leaf Mtn Mahogany	*Rhus typhina*	Staghorn Sumac
Chamaebatiaria millefolium	Fernbush	*Ribes aureum*	Golden Currant
Cotinus coggygria	Smoke Bush	*Rosa glauca (rubrifolia)*	Shrub Rose
Cotoneaster apiculatus	Cranberry Cotoneaster	*Rosa rugosa*	Rugosa Rose
Cotoneaster dammeri	Bearberry Cotoneaster	*Rosa woodsii*	Woods Rose
Cotoneaster divaricatus	Spreading Cotoneaster	*Rubus deliciosus*	Rocky Mtn Thimbleberry
Cotoneaster horizontalis	Rock Cotoneaster	*Salvia dorrii*	Dorr Sage
Cytisus scoparius	Scotch Broom	*Shepherdia argentea*	Silver Buffaloberry
Ephedra viridis	Green Mormon Tea	*Sorbaria sorbifolia*	False Spirea
Ericameria nauseosus	Rubber Rabbitbrush	*Symphoricarpos orbiculatus*	Coralberry
Fallugia paradoxa	Apache Plume	*Symphoricarpos oreophilus*	Mountain Snowberry
Forestiera neomexicana	New Mexican Privet	*Symphoricarpos x chenaultii*	Snowberry
Genista hispanica	Spanish Broom	*Syringa vulgaris*	Lilac
Genista pilosa	Silky-Leaf Broom	*Viburnum lantana*	Wayfaring Tree
Genista tinctoria	Common Woadwaxen	*Viburnum rhytidophylloides*	Blackhaw
Holodiscus dumosus	Mountain Spray	*Viburnum rhytidophyllum*	Leather-Leaf Viburnum
Iliamna rivularis	Maple Mallow	*Yucca sp.*	Yucca
Juniperus sp.	Juniper	*Zizophora clinopodioides*	Blue Mint Bush
Kolkwitzia amabilis	Beauty Bush		

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Research Thrust: Water Fluxes

1. What is partition of water fluxes from bioretention site into ET and infiltration?
2. What is rate of vertical and horizontal exfiltration from stored water in bioretention site?

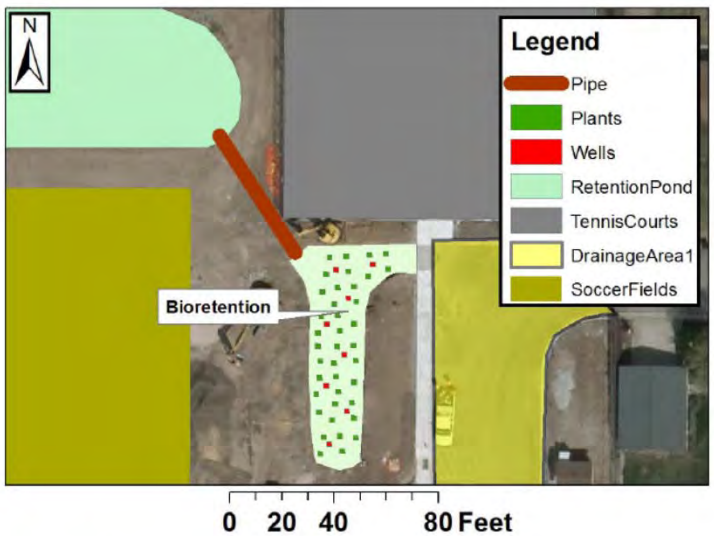
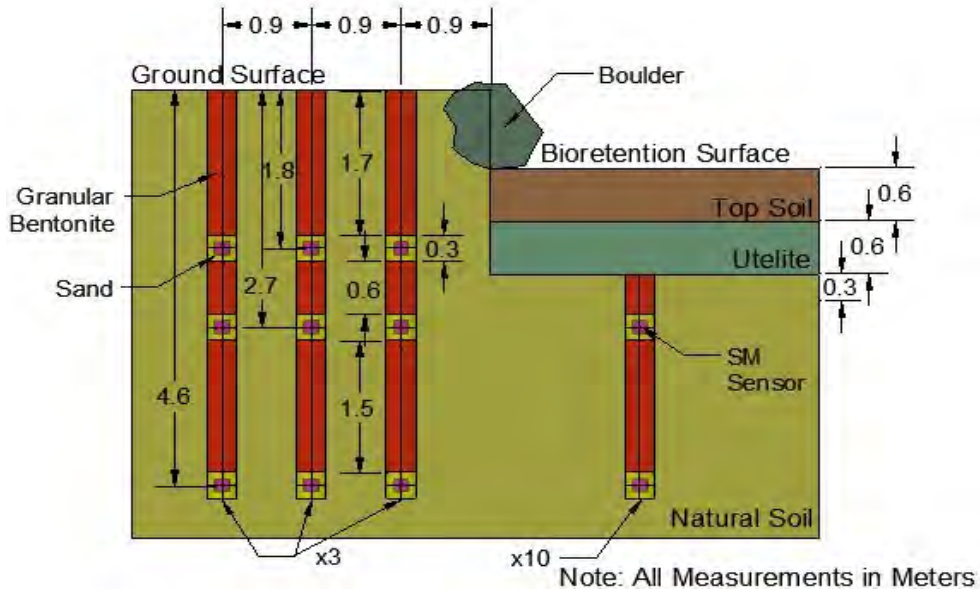


Figure 4. Mountview Park Bioretention Plant and Well Layout



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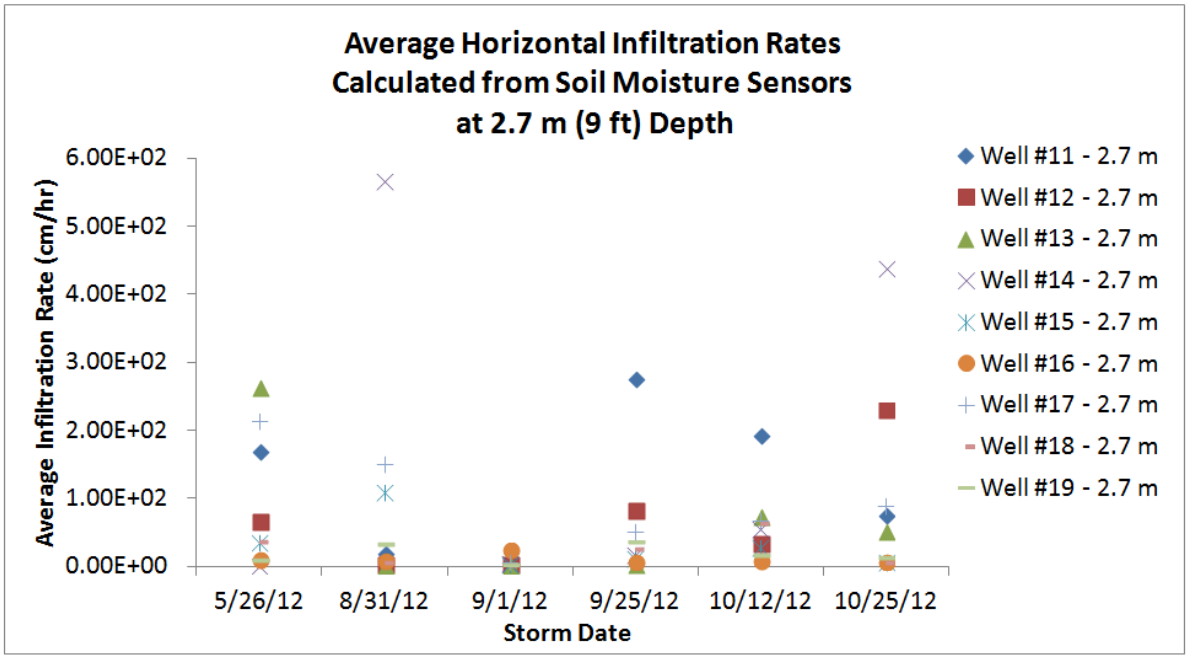
Research Thrust: Water Fluxes

1. Infiltration dominated ET at two study sites (Mountainview Park and UU campus)
2. Avg vertical exfiltration rate of 3 ft/day
3. Avg horizontal exfiltration rate of 10 ft in 3 days



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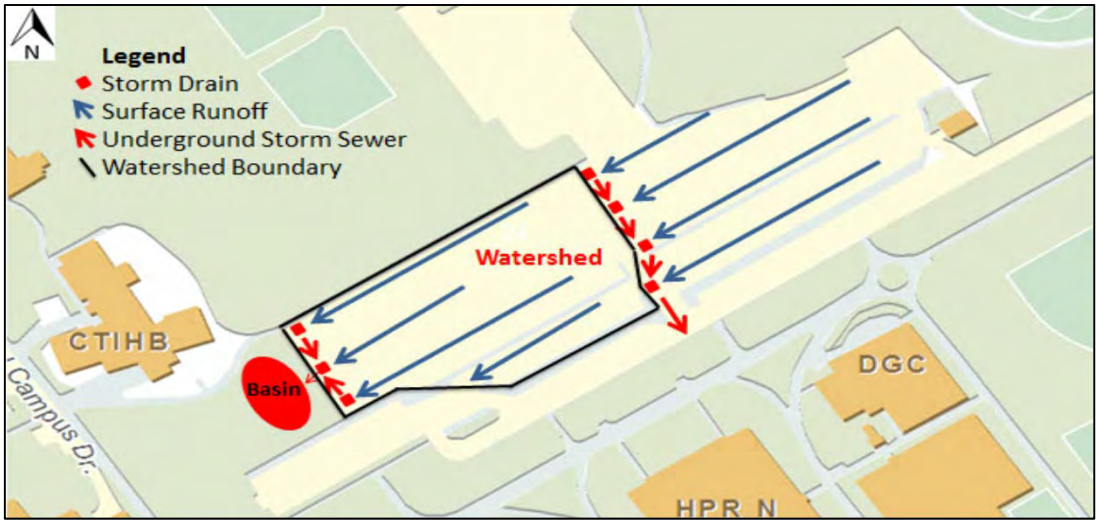
Research Thrust: Water Fluxes

1. Recommend vulnerable underground infrastructure at least 20 ft from bioretention
2. Recommend higher density of plants for more ET
3. Recommend engineered soil for greater storage retention and pollutant removal



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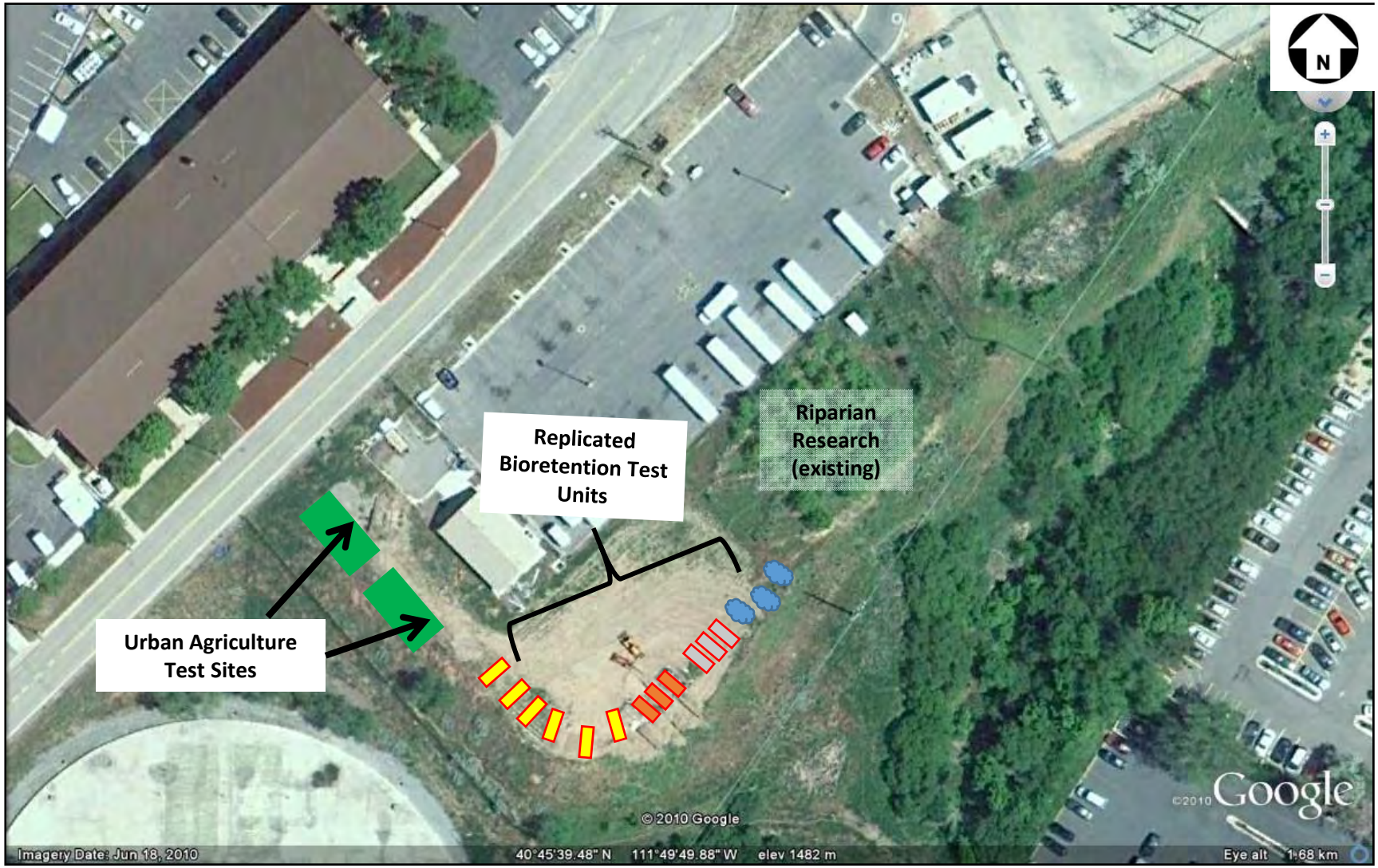
Green Infrastructure Research Facility



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Research Thrust: Nutrient Removal

1. How well do wetland vs. native upland plantings control nutrients?
2. Semi-arid designs use fewer plants – are plants helpful?

1) **Native Upland: 9 bunchgrasses, 8 shrubs – no irrigation**
2) **Wetlands: densely planted cattails, willows, and bulrushes**
3) **Control: no plants**

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Research Thrust: Nutrient Removal

"Upland"			"Wetland"			"Control"
Species name	**Common Name**	**Form**	**Species name**	**Common Name**	**Form**	No plants
Schizachyrium scoparium	Little Blue Stem	Bunchgrass	*Juncus effuses*	Common rush	Rush	
Bouteloua gracilis	Buffalo Grass	Bunchgrass	*Dactylis glomerata*	Orchardgrass	Bunchgrass	
Sorghastrum nutans	Indiangrass	Bunchgrass	*Typha sp.*	Cattail	Bunchgrass	
Amelanchier utahensis	Utah Serviceberry	Shrub	*Phragmities sp.*	Phragmites	Bunchgrass	
Cercocarpus ledifolius	Curl-leaf mahogany	Evergreen	*Salix exigua*	Coyote willow	Shrub, Tree	
Artemisia cana	Silver sage	Shrub	*Medicago sativa*	Alfalfa	Forb	

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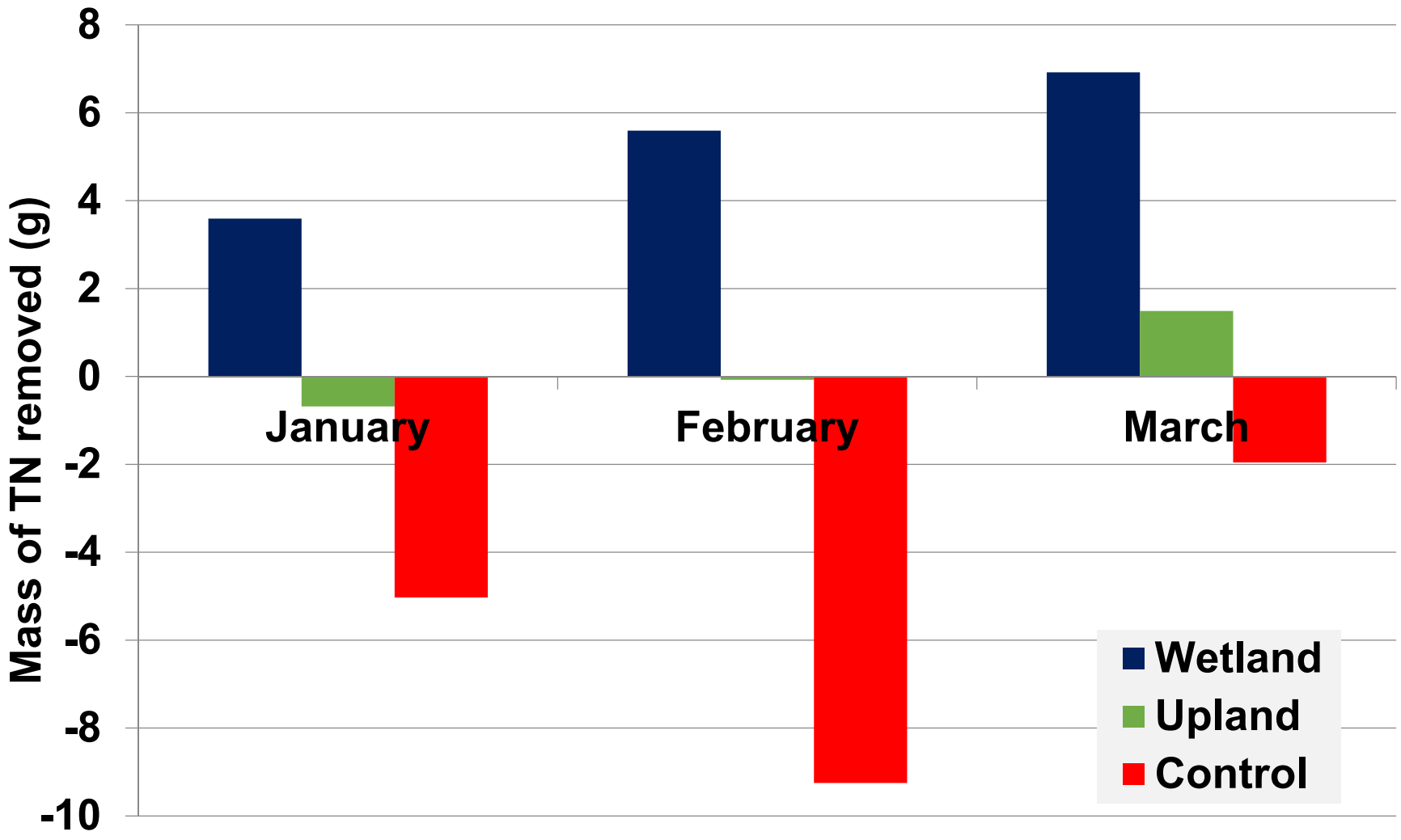
Research Thrust: Nutrient Removal



(Houdeshel et al. 2012)

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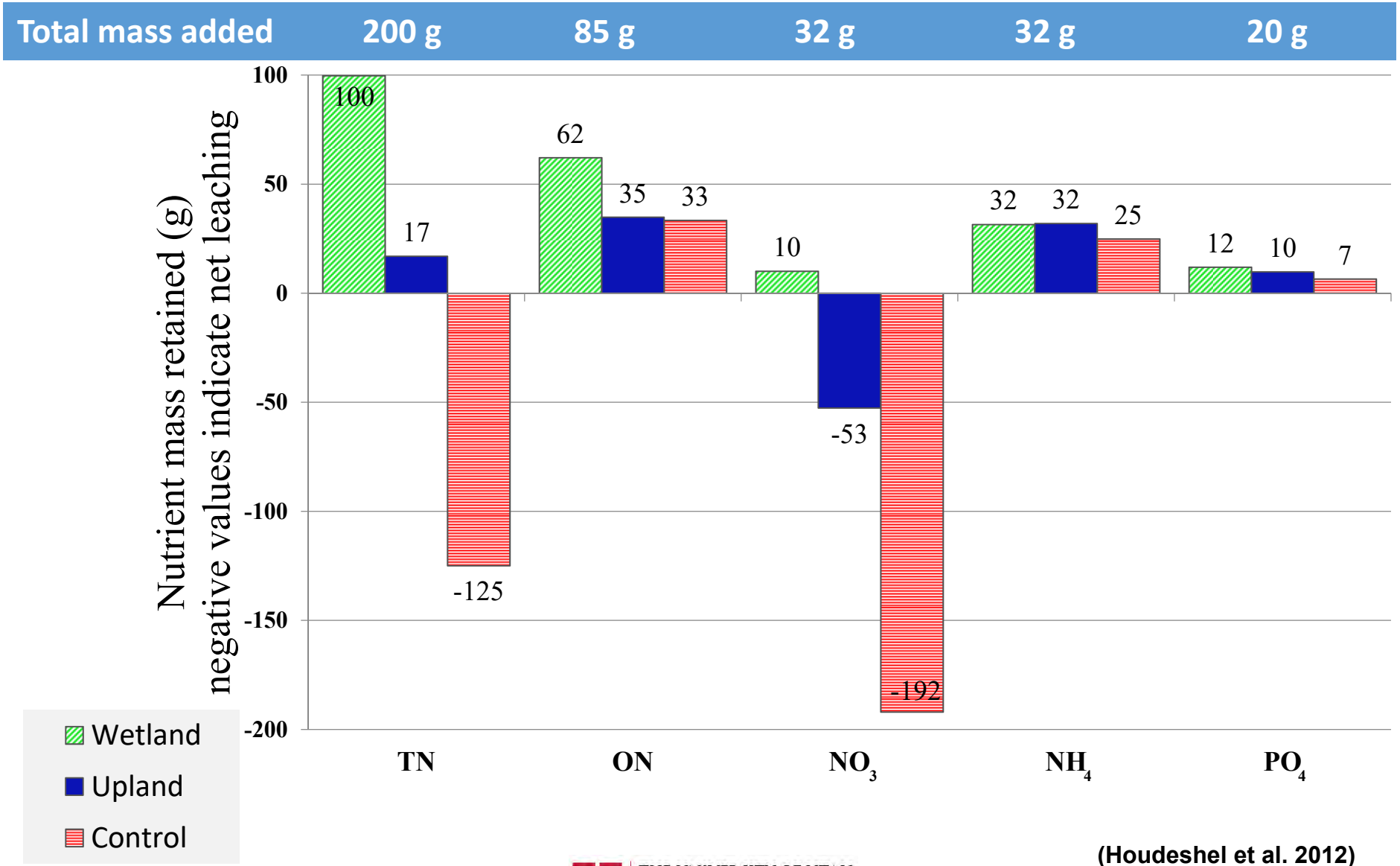
Research Thrust: Nutrient Removal



(Houdeshel et al. 2012)

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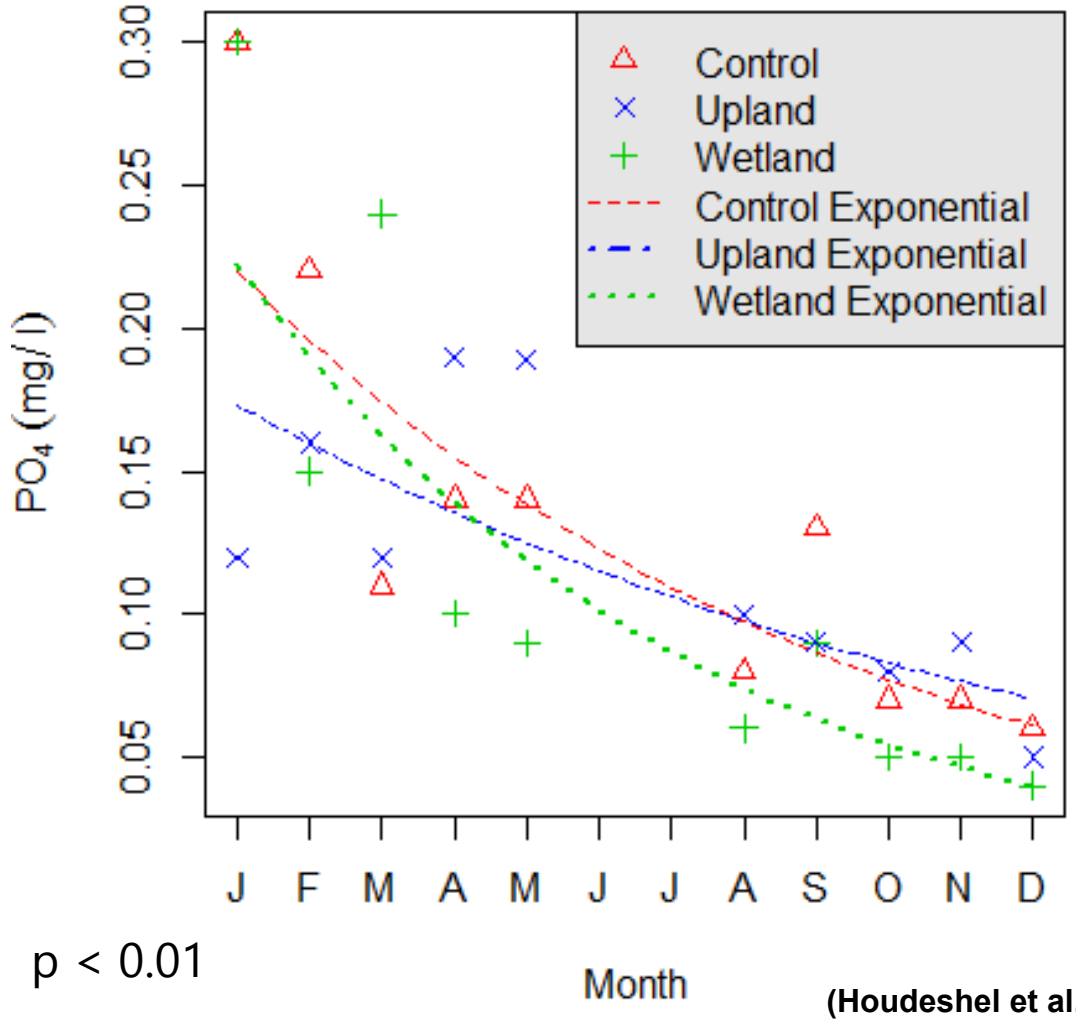
Research Thrust: Nutrient Removal



$p < 0.01$

(Houdeshel et al. 2012)

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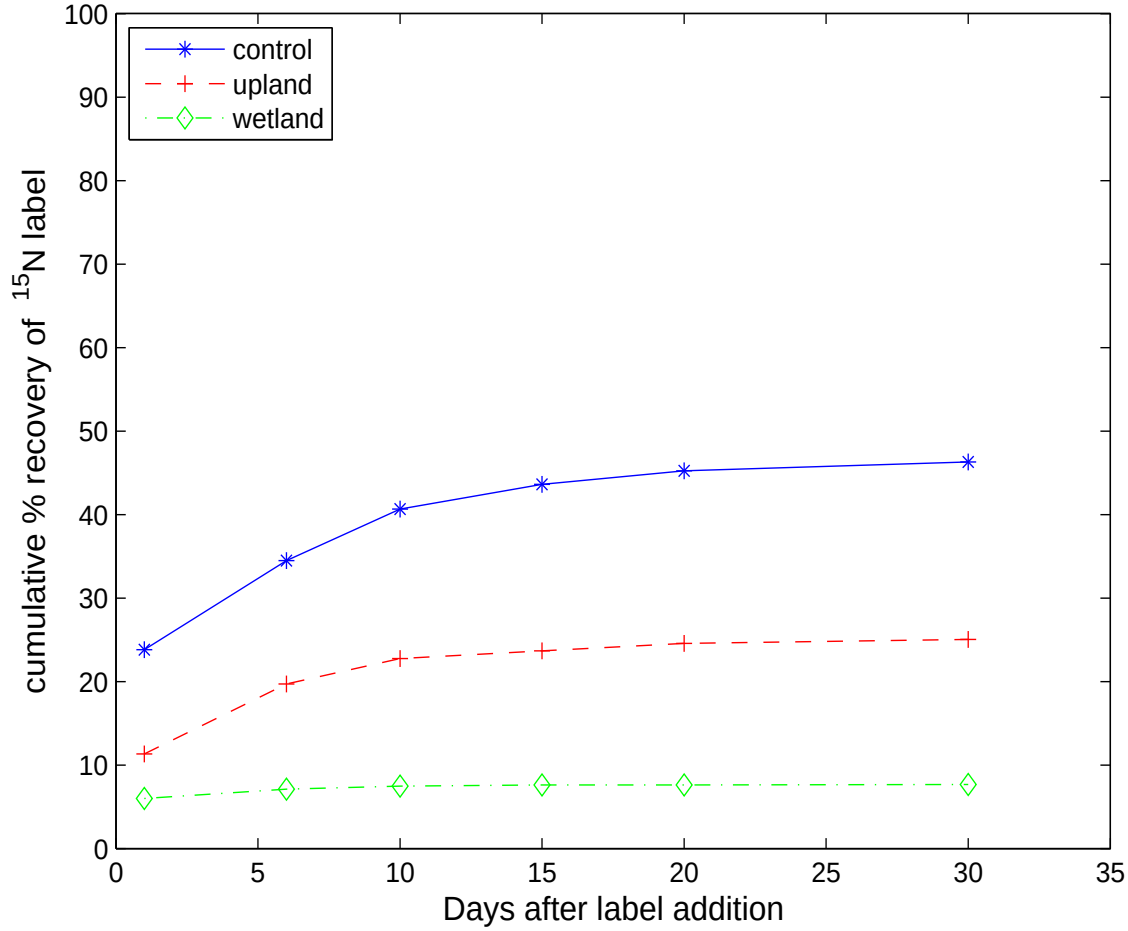
Research Thrust: Nutrient Removal

Cumulative ^{15}N label recovered from effluent

Cumulative % recovery of ^{15}N label from garden effluents



Days after label addition **(Houdeshel et al. 2012)**

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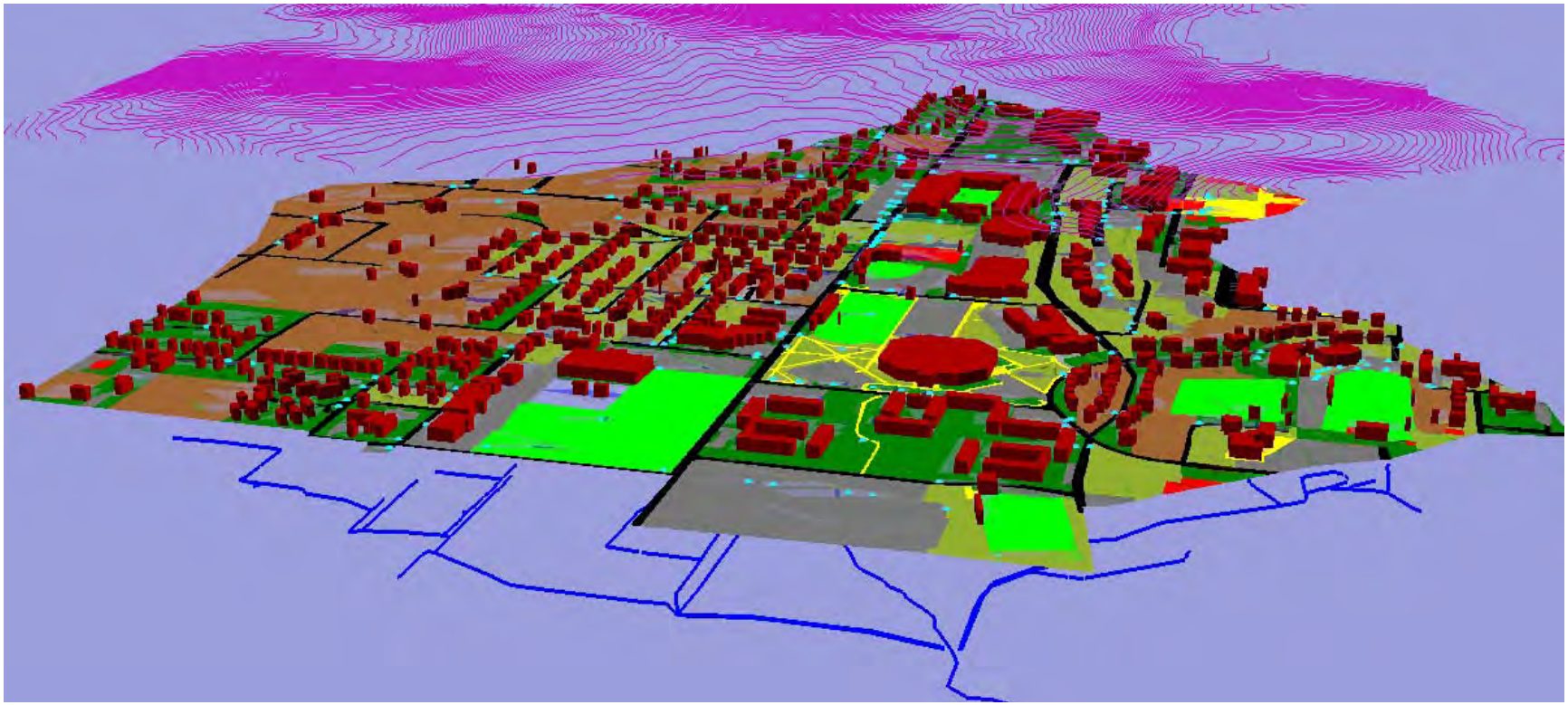
Summary of Field Research

1. Bioretention garden design produced from synthesis of engineering and ecology literature
2. This semi-arid design does improve N and P water quality, but not as well as wetlands
3. Plants assimilate stormwater N into biomass

Catchment Scale Modeling Research



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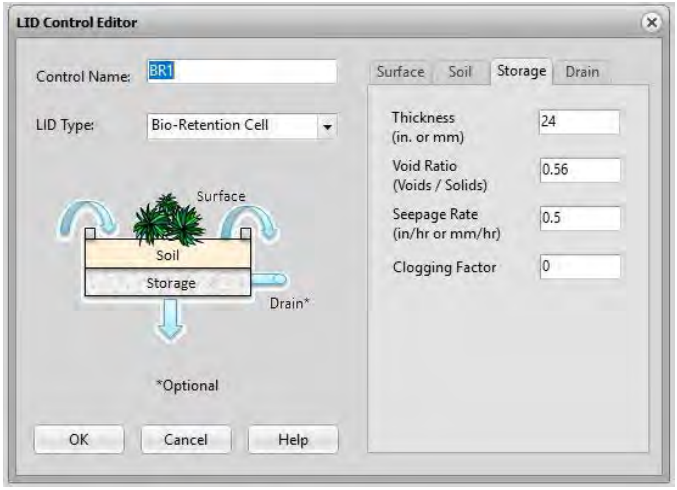
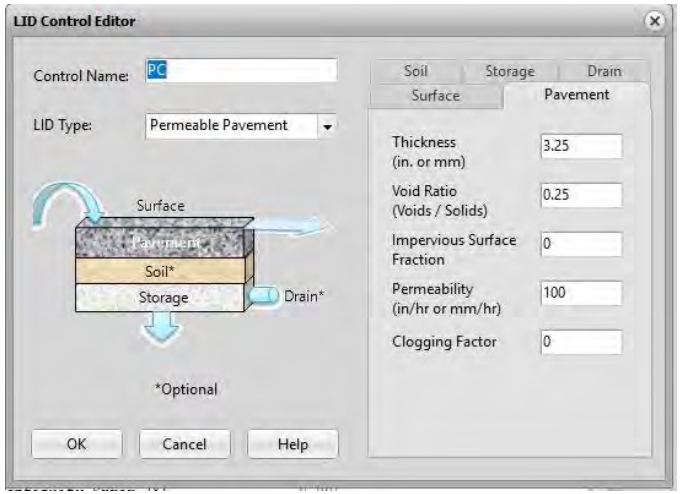
Research Thrust: 90th %ile Design

1. What amount of LID is needed for 90th percentile control?

SWMM Model Inputs	
Area (ac)	100
Width (ft)	1893
% Slope	2.07
% Impervious	49
N Impervious	0.014
N Pevious	0.10
D Store	0.05
D Store	0.05
% Zero Impervious	25
Curve Number	77





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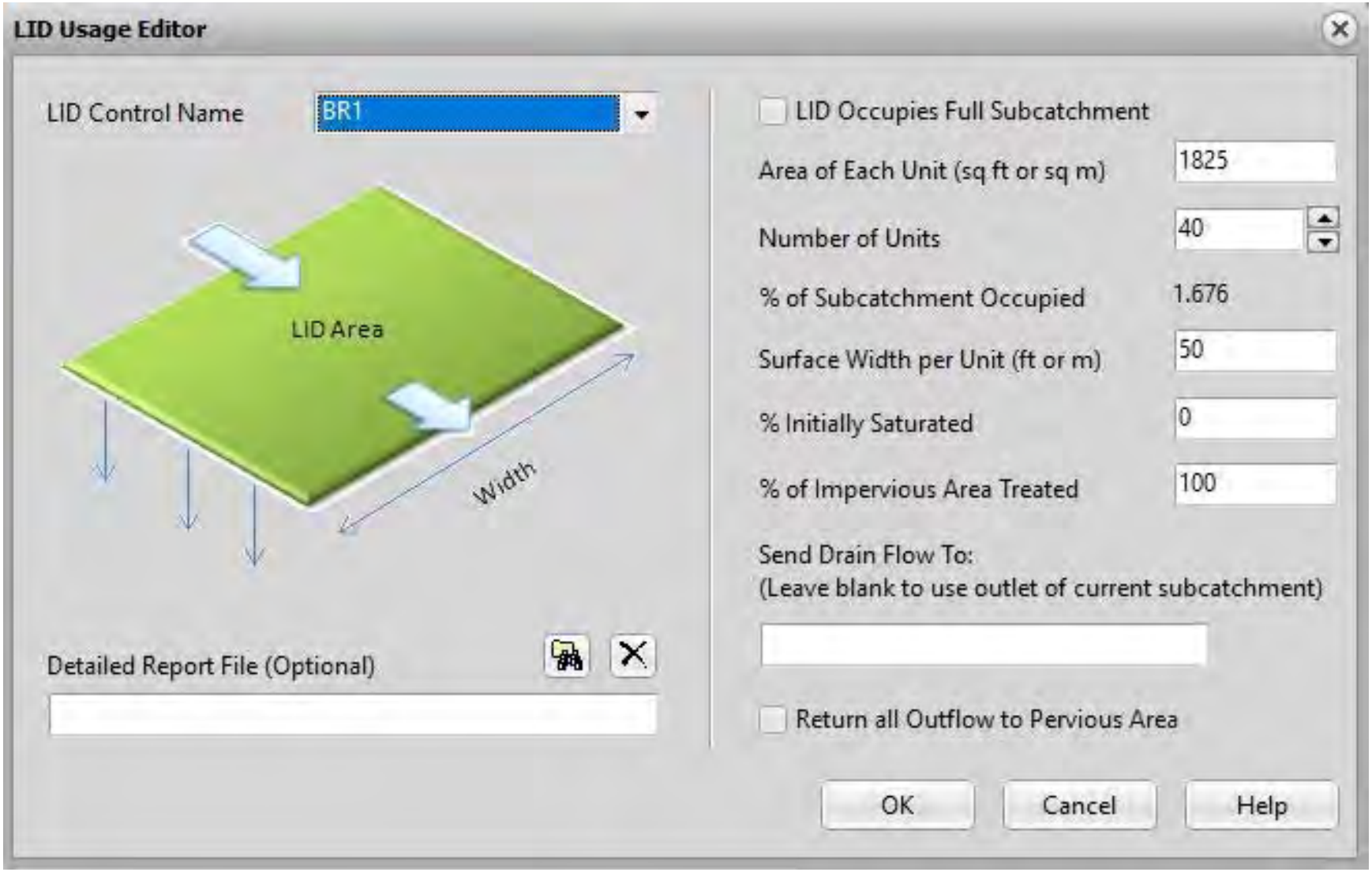
Research Thrust: 90th %ile Design



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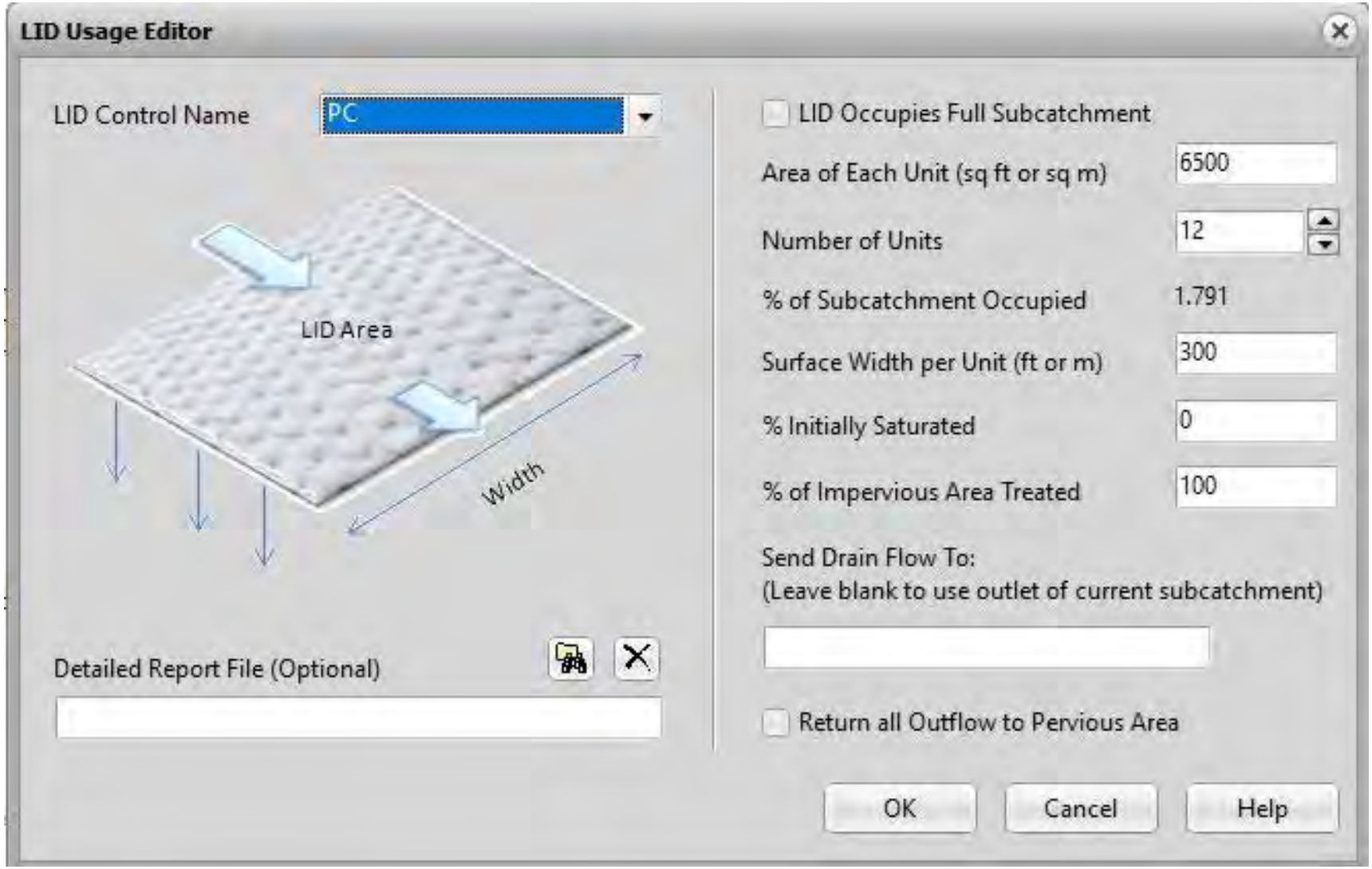
Research Thrust: 90th %ile Design



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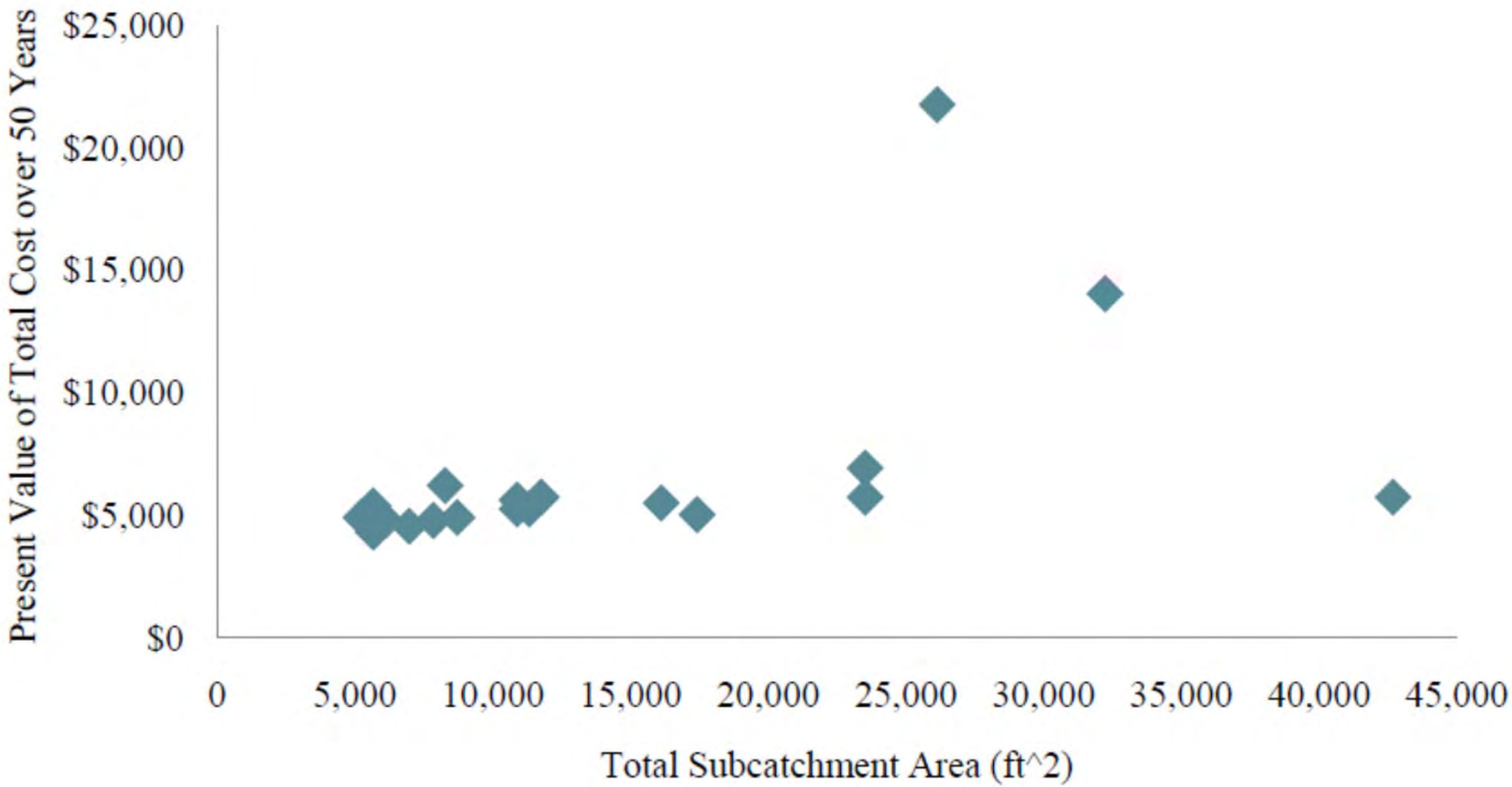
Research Thrust: 90th %ile Design



(Jensen 2018)

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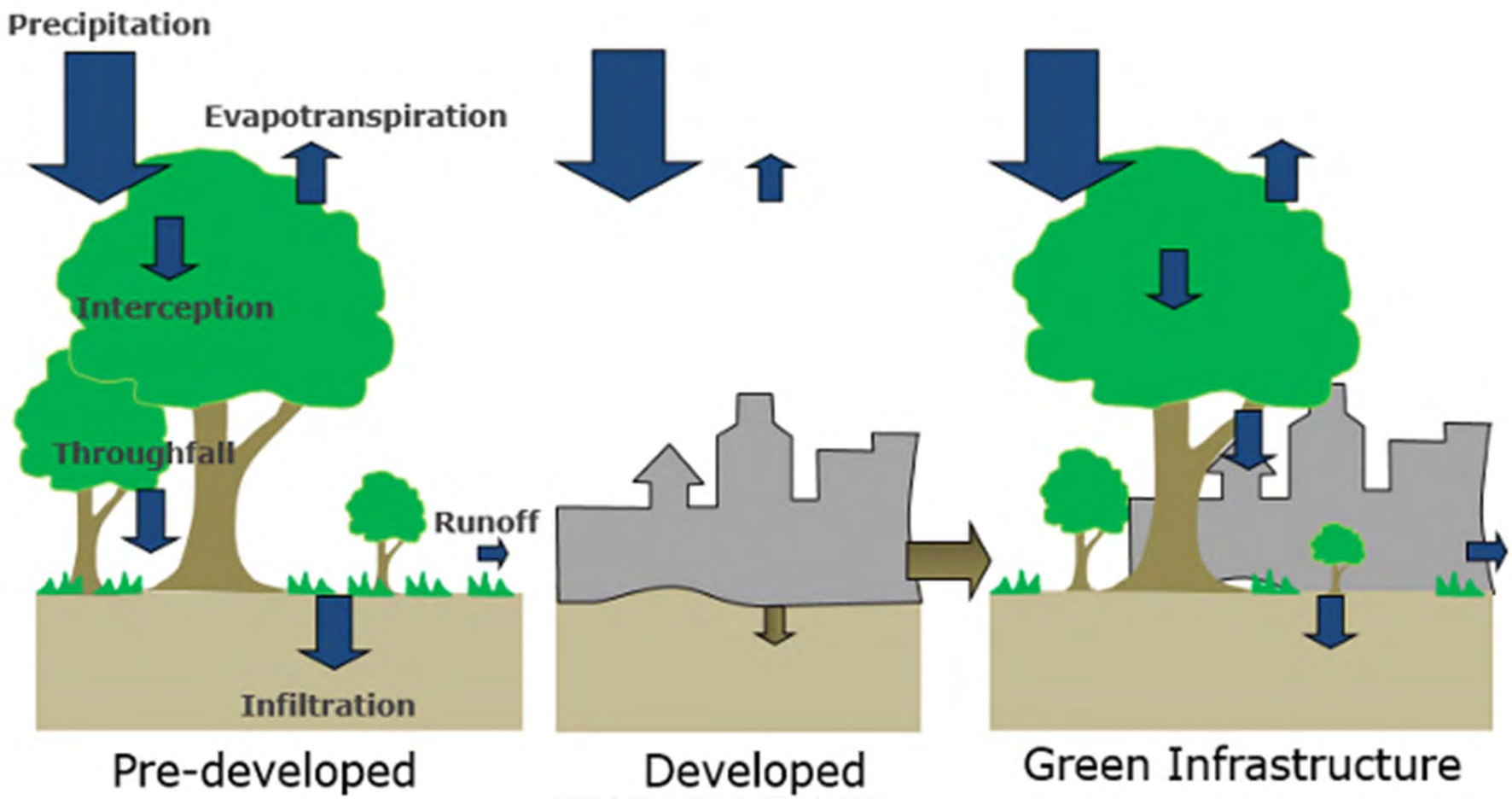
Research Thrust: 90th %ile Design

1. 1.7 acres of bioretention per 100 acres of developed land (1.7% of the area), very roughly $2500/acre capital cost
2. 1.5 acres of pervious concrete per 100 acres of developed land (1.5% of the area), very roughly $3500/acre capital cost

Research Thrust: Natural Hydrology

1. Can LID controls installed in new development match pre-development catchment hydrology?



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(Source: itree-tools.org)

Research Thrust: Natural Hydrology

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Research Thrust: Natural Hydrology

Roadmap

Hourly potential evapotranspiration (PET)

$$PET = \frac{0.408\Delta(R_n - G) + \Upsilon\frac{C_n}{T+273}(e_s - e_a)}{\Delta + \Upsilon(1 + C_d)}$$

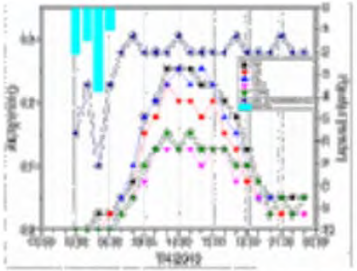
Penman-Monteith equation based Python program

Water stress coefficient

$$K_s = \frac{ln\left[\left(1-\frac{D_r}{TAW}\right)100+1\right]}{ln(101)}$$

Modified SWMM C++ program

Actual evapotranspiration (AET) and the water budget



$$AET = K_s \times PET$$

Modified SWMM C++ program

(Feng et al. 2016)

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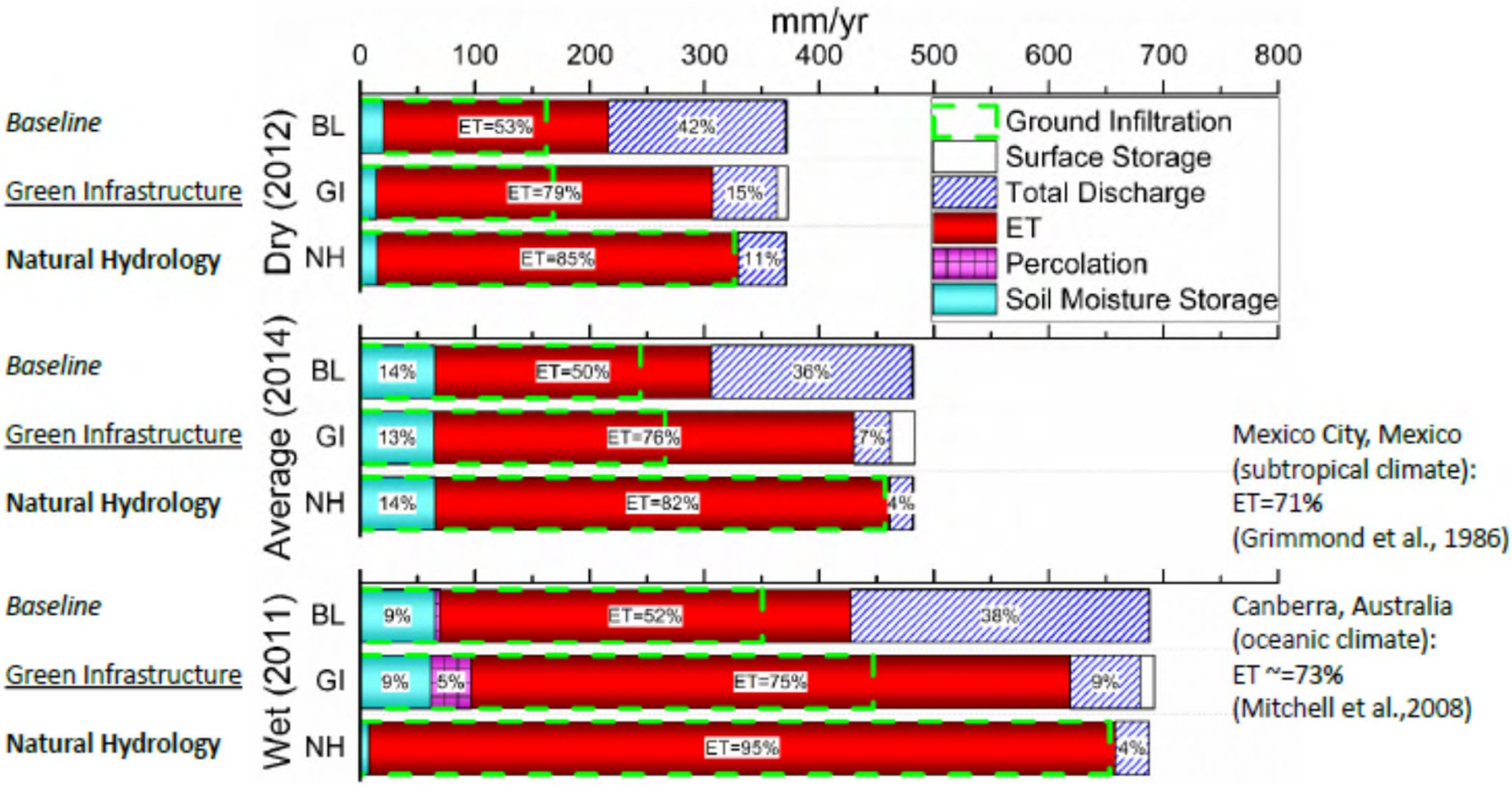
Research Thrust: Natural Hydrology



Water budgets of three scenarios in three years by the updated SWMM

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(Feng et al. 2017)

Research Thrust: Natural Hydrology

- Green infrastructure has been shown to be more effective in restoring the water budget in this climate than other climates.
  - Compared to the development condition in the dry, average, and wet water years:
    - GI annually reduces surface runoff by 64%, 82%, and 76%,
    - GI restores ET amounts by 49%, 52%, and 46%
- GI adds the extra storage on the urban surface, which creates comparable total storage space as the natural landscape.
- Using 80% runoff reduction rule, GI reaches overall restoration coefficients of 0.82-0.94 to approach the predevelopment condition.

Extrapolate to all campus…

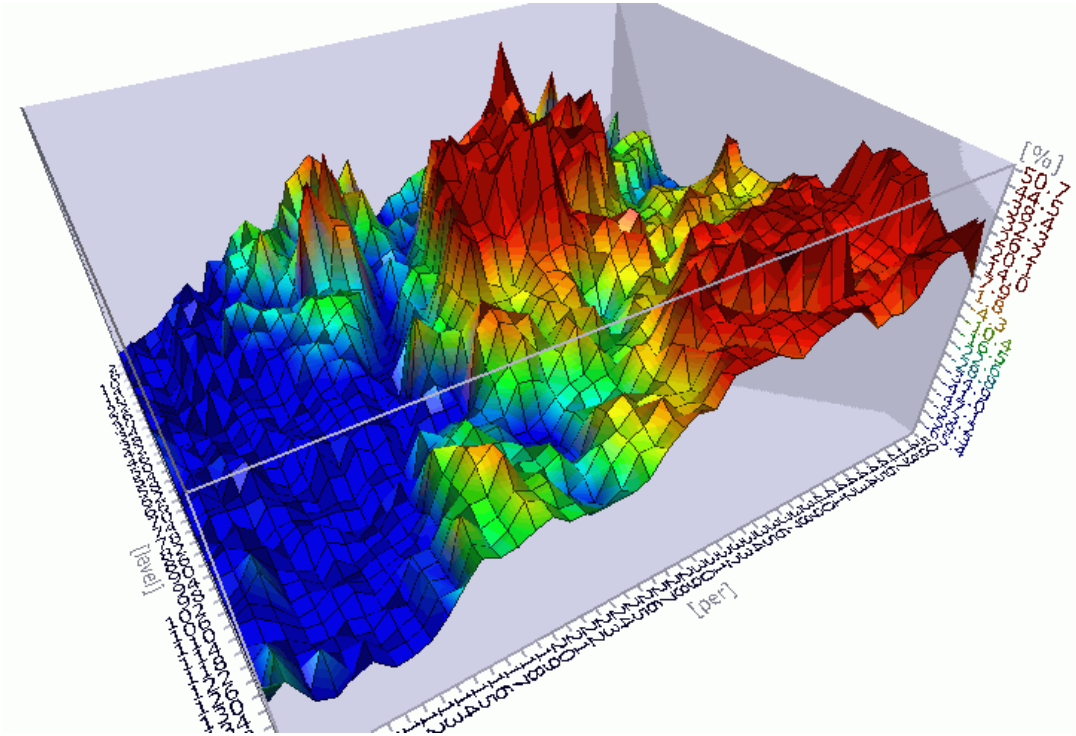
Table 5.3: Potential for of Green Infrastructure on Campus

Technology	Treatable Acres	Water Infiltrated per Acre	Total Water Infiltrated
Bioretention	384	0.48	184 MG
Pervious Pavement	538	0.48	258 MG
Total	922	-	442 MG

Research Thrust: Optimization

1. Can we optimize LID plan on performance & cost?

- Two optimization problems are setup: objectives of **WBRC** and **Runoff**
- For each optimization, **Implementation Costs** was considered as the 2nd objective
- **NGPM** (NSGA-II Program in MATLAB) has been modified to set up the optimization framework



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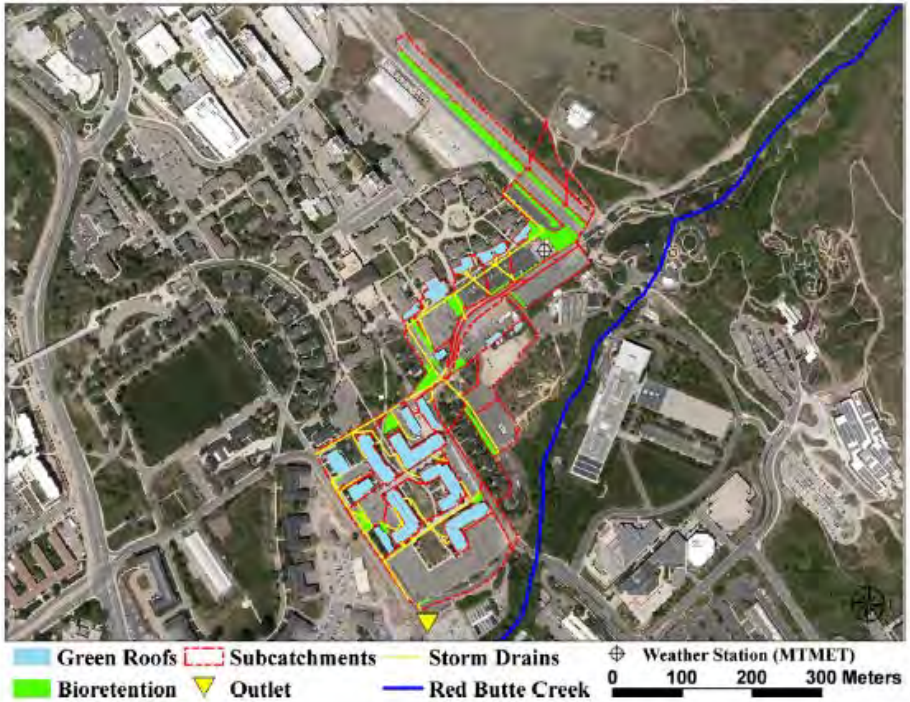
Research Thrust: Optimization

- A 0.11 km^2 urban subcatchment in stormwater drainage network of Salt Lake City, is the focus of this study.
- A SWMM model calibrated for the studied area was used for rainfall-runoff modeling (Feng et al. 2016)
- Genetic Algorithm Optimization details:
  - No. population: 50
  - No. generation: 200
  - Variable: The area of a defined bioretention plan
  - No. Variables: 51 (subwatersheds)



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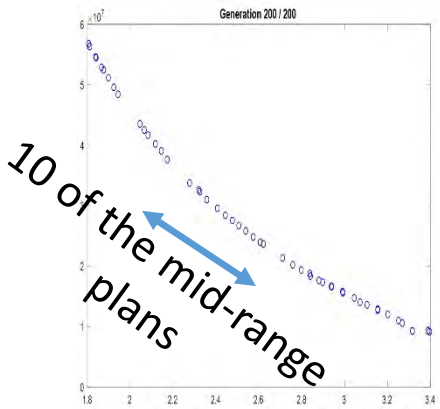
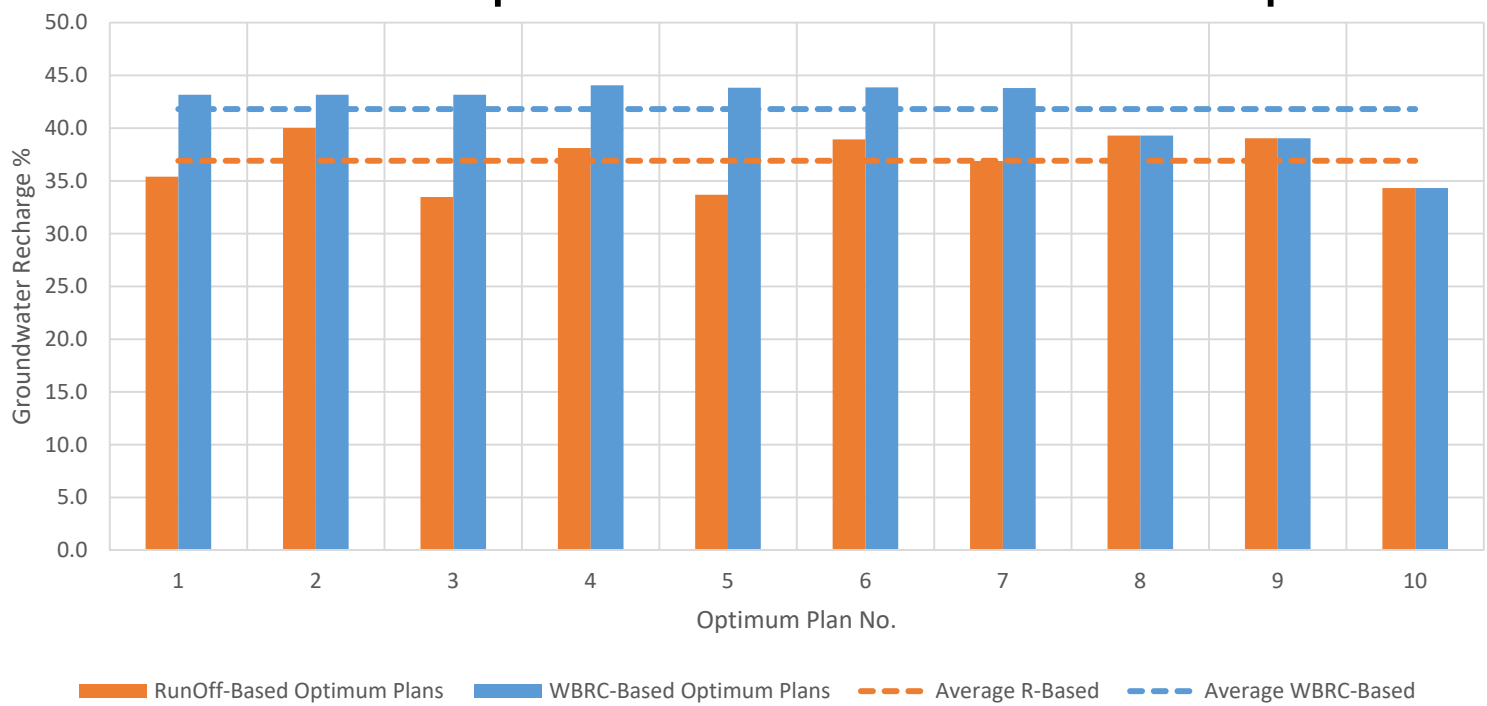
Research Thrust: Optimization



- Use of GI to meet 90th percentile control will lead to stormwater management plan that can recreate natural hydrologic cycle
- Optimization maximizing cost and WBRC will lead to, on average, 14% more infiltration when compared with runoff reduction optimization



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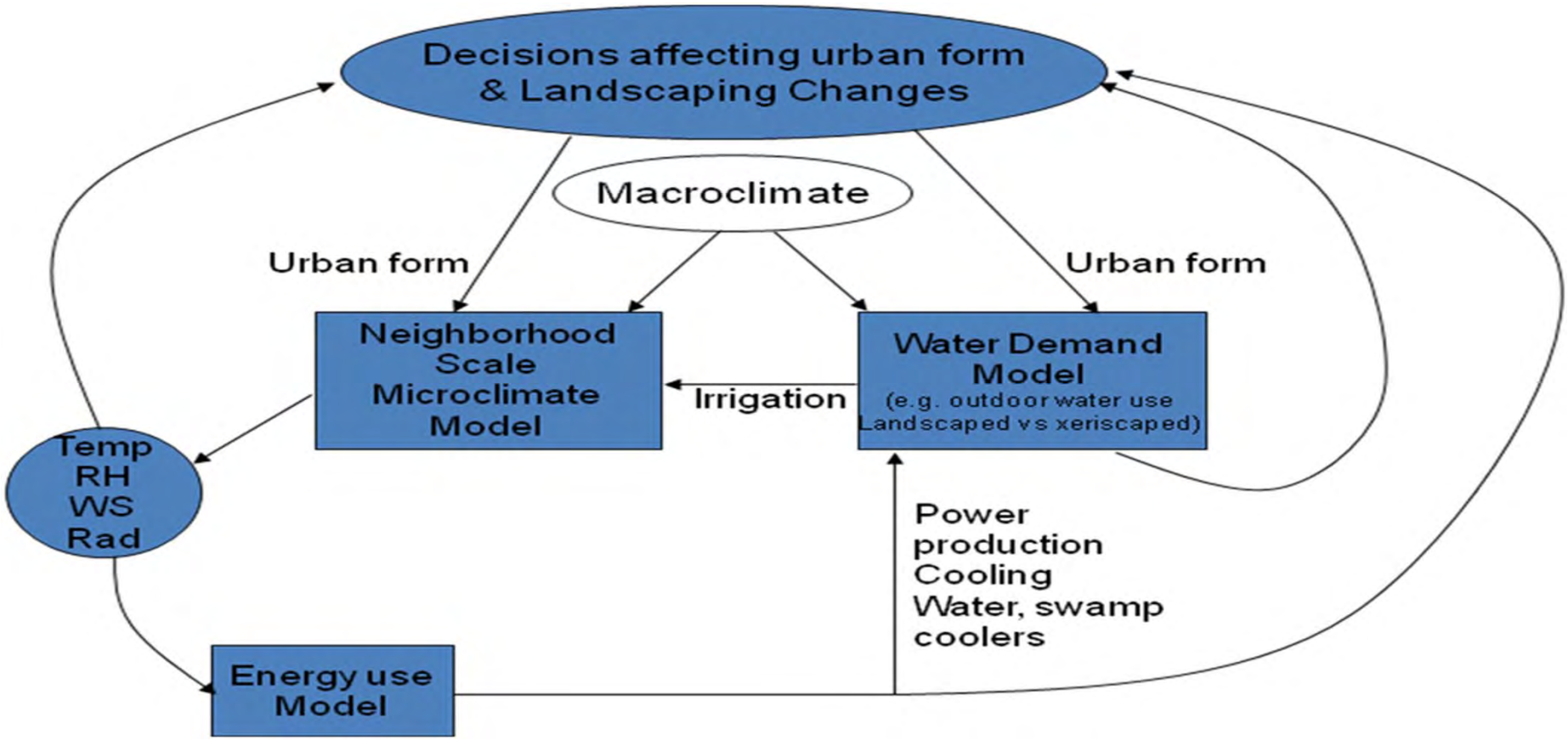
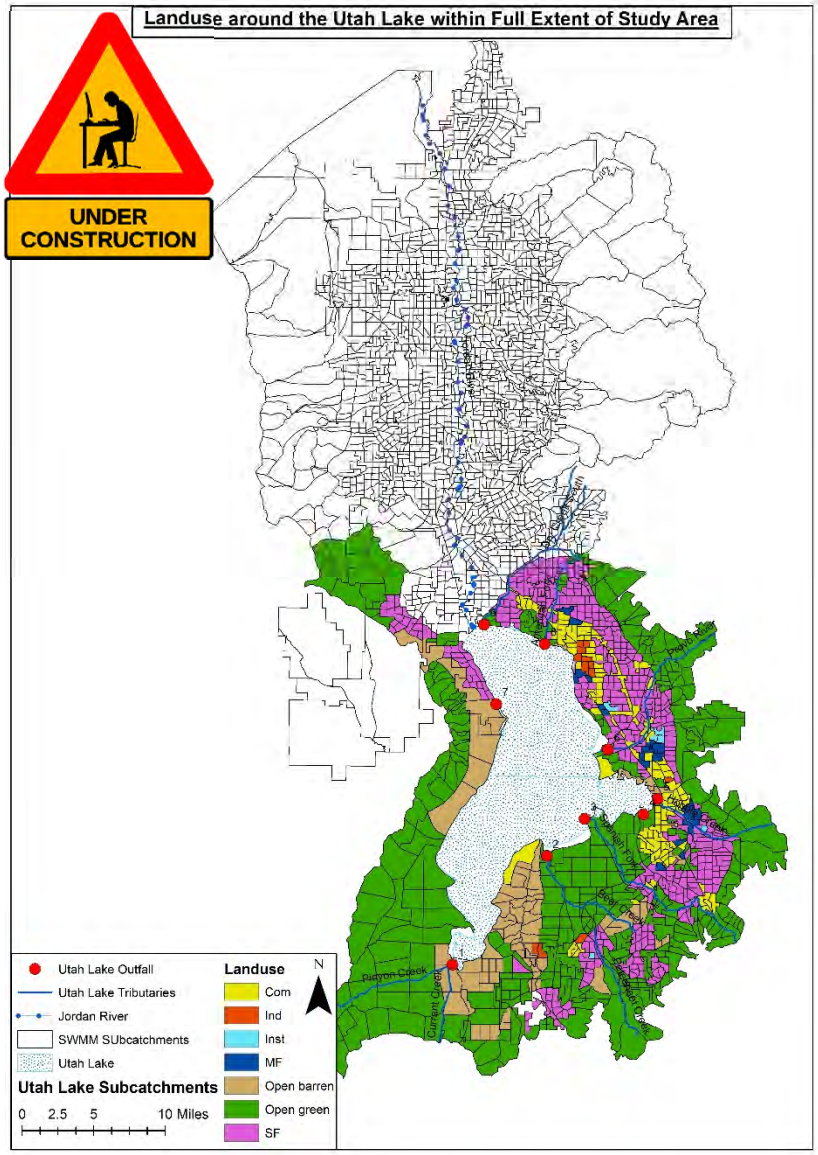
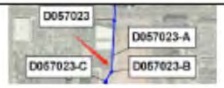
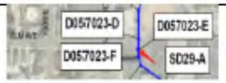
(Tavakol-Davani and Burian, 2018)

Other Benefits: Systems Research



Current Research



Locations / Nodes	Location Information	Nodes in Map via(Hydraulic Analysis Tech Memo Draft)	3D Junction View via (Google Earth Model)	Node In-site View via(Hydraulic Analysis Tech Memo Draft)
240	Grate in Hidden Hollow			
D56007	Wilson Avenue and 1100 E			
D057023	2100 South and McClelland Street			
D057023-B	SH parking lot and McClelland Street			
D057023-E	Element Avenue and McClelland Street			

Note: The sensor locations are pointed out by the red arrow in the column of '3D junction view'

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Your Take Home

1. Use bioretention configuration and vegetation specs
2. Apply optimized catchment scale LID control guidance
3. Plan for multiple benefits of LID controls
4. Link installations to research:
   - winter performance
   - long-term durability (and O&M strategies/costs)
   - asset management planning
   - modifications for climate change
   - Etc.

Steve Burian

Professor, Civil & Environmental Engineering
Director, Water Center
Project Director, U.S.-Pakistan Center for Advanced Studies in Water
Associate Director, Global Change and Sustainability Center
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THE GREY TO GREEN INFRASTRUCTURE TRANSITION

Dr. R. Ryan Dupont, CEE, UWRL, USU

WHAT WE'LL DISCUSS THIS MORNING

- "Future" of Stormwater Management
- The What's
- The How Well's
- Concluding Remarks

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“FUTURE” STORMWATER MANAGEMENT – GREEN INFRASTRUCTURE & LID

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GI/LID DESIGN PRINCIPLES

- Move from Historical Centralized Stormwater Collection and Rapid Conveyance
- TO **Distributed** Management
- Design to **Minimize** Impact TO
  - Receiving Ecosystem
  - Water Supplies
  - Livability of Your Own & Downstream Communities

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THE WHAT'S

GREEN INFRASTRUCTURE & LOW IMPACT DEVELOPMENT OPTIONS

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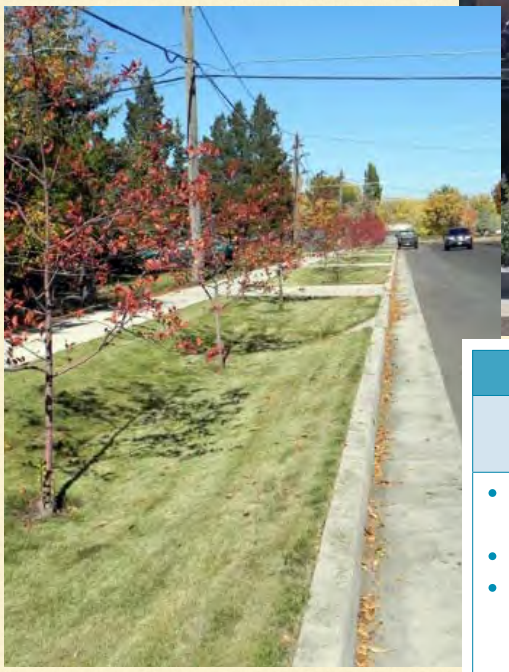
CURB CUTS & SWALES



Green spaces	
Water management benefits	**Co-benefits**
• Flood mitigation (stormwater runoff control) • Water purification • Water supply regulation (improved groundwater recharge) • Temperature control (shading of water ways)	• Biodiversity benefits • Aesthetic value • Improved air quality • Energy savings for water treatment • Carbon sequestration • Reduced urban heat island effect • Reduced noise pollution

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THE HOW WELL'S - ISSUES REMAIN

- What is Feasible in Arid Regions?
- How Well Do these Systems Perform?
- What is Appropriate Approach for New & Retrofitted Systems?
- How Do We Make them Sustainable?

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SERIES OF STUDIES OVER LAST 10 YEARS TO ASSESS PERFORMANCE OF BMPS & GI SYSTEMS IN NORTHERN UTAH

- Field Evaluation of Three BMPs in Logan
- Greenhouse Study of BMP Performance f(Plant Species & Metals & Nutrient Loading)
- Field Study of Performance f(Plant Species & Harvesting)
- Field Studies of GI Systems Cache & Salt Lake County

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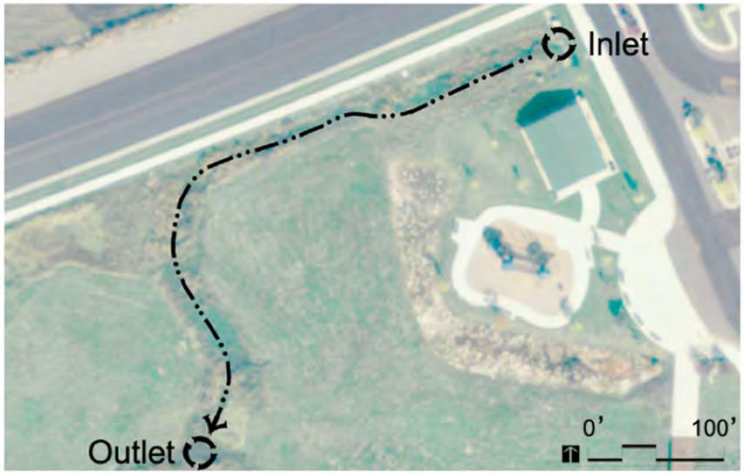
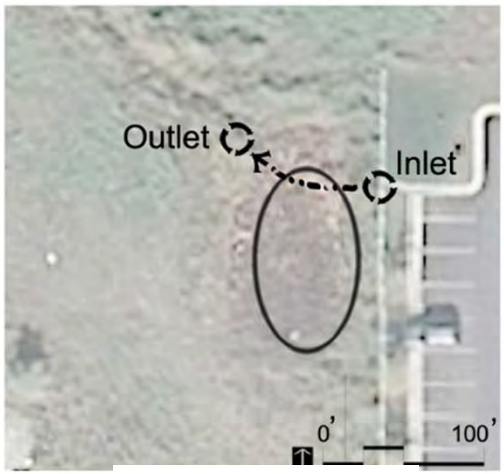
FIELD EVALUATION OF BMPs



Riparian Corridor

Detention Basin



Retention Pond

- Evaluation of Three Typical Post-Construction, Vegetated BMPs
- Three Natural Rainfall Events
- Flow and Pollutant Reduction Assessment

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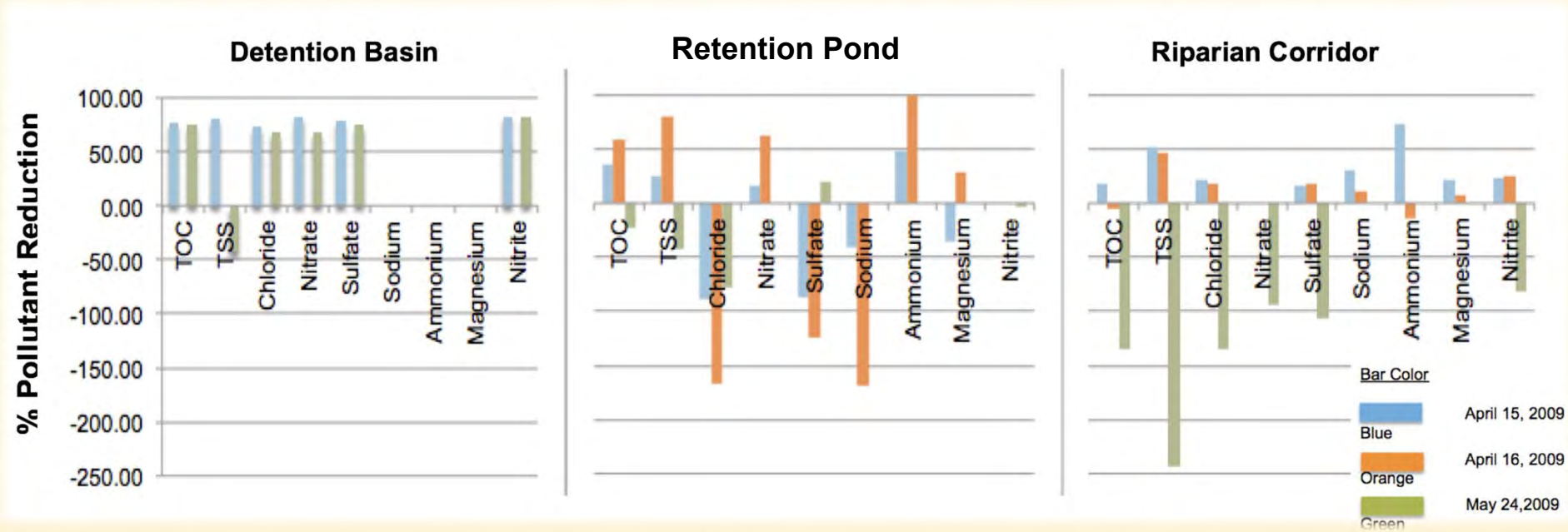
RESULTS



- **Wet Detention Basin Only BMP Providing Consistent Pollutant Removal & Peak Flow Reduction**
  - 78 to 83% Reduction of Flow
  - 66 to 83% Reduction of Pollutant Mass Loading
- From Hydrographs – **Water Retention w/In BMPs Vital to Reducing Pollutant Loads in BMPs**

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VEGETATIVE IMPACTS ON STORMWATER QUALITY IMPROVEMENTS

- Greenhouse Study
  - Six Plant Species
  - N, P & Metals Removal Performance
- Field Demonstration Study
  - Three Plant Species & Controls
  - N, P & Metal Uptake
  - Growth & Harvesting in Northern Utah Climate

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Six BMP Species Evaluated in Greenhouse Study

Common%Reed%

Ca_ail%

So` ?stem%Bulrush%

Hard?stem%Bulrush%

Clustered%ield%Sedge%

Smallwing%Sedge%

+)

Unplanted%Controls%

FINDINGS OF GREENHOUSE STUDY

- **Any Planted System Maintains Long-Term Infiltration Rates**
- >80% Retention of Cu, Pb, Zn by Soil
- Roots & Shoots Actively Take Up TN
- **Significant Plant Variability in Pollutant Uptake**
  - **Sedge** Had Consistently Higher Removal of All Pollutants than Other Species, Concentrated in **Above Ground Tissue**

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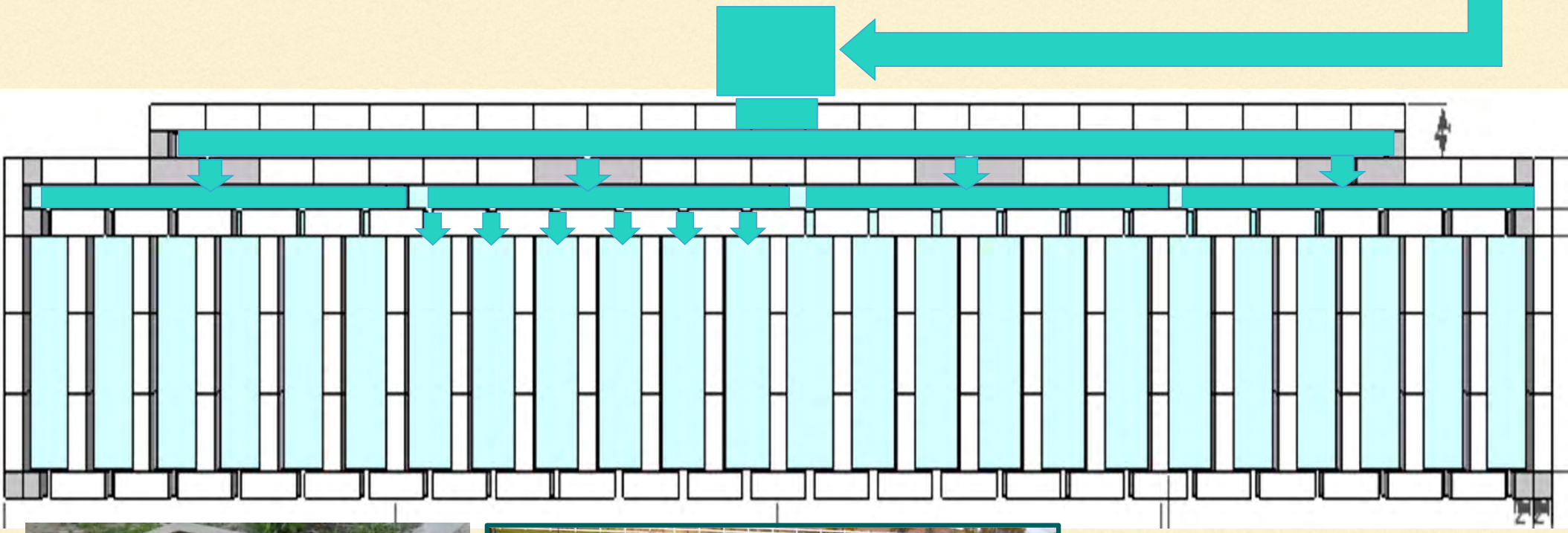
FIELD DEMONSTRATION SITE – GREEN MEADOWS SUBDIVISION, LOGAN



FIELD DEMONSTRATION SITE

Treatment Areas Planted with One of Three Species or Allowed to Naturally Seed

Small Wing Sedge

Maximilian Sunflower
(*Helianthus maximillian*)

Cattail (*Typha latifolia*)

Naturally Seeded

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FIELD DEMONSTRATION SITE FINDINGS

- Plant Growth Stabilizes Over 3 Yr Period
  - **No Benefit to More than Annual Harvesting for Metals**
  - N & P Recovery Increase w/2x Year Harvesting
- **Plant Species Selection has Significant Impact on Pollutant Uptake**
  - Sedges > Uptake Cu, Zn than Sunflower or Cattails
  - Sedges > Uptake Total-N, and Total-P than Sunflower
- **Sedges** Store Pollutants Preferentially in Above Ground Tissue for **"Easy" Harvesting**

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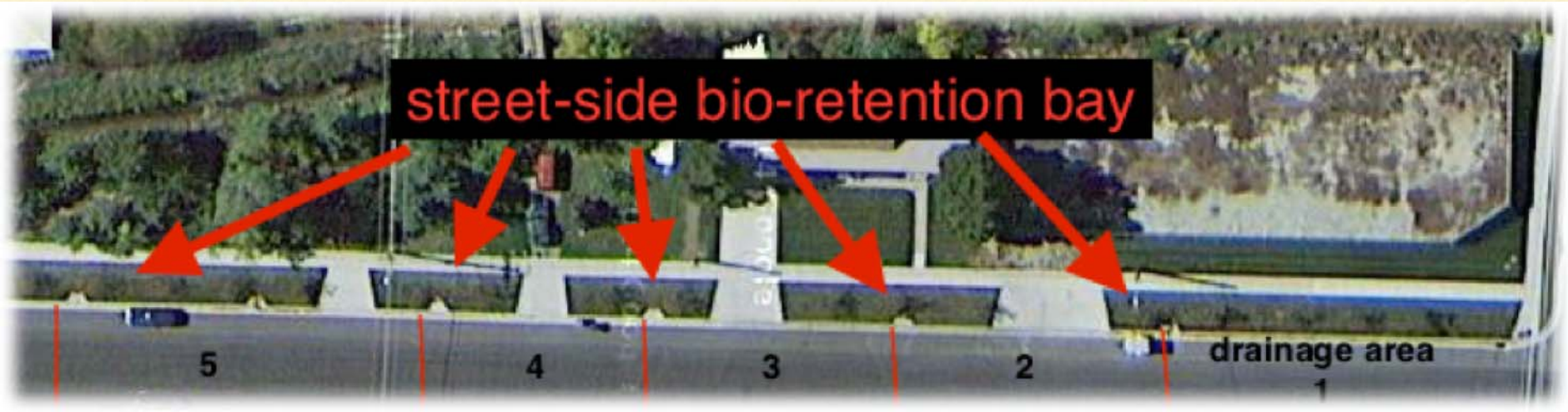
GI STUDY AREA

- **300 East Logan, UT – Curb-Cut Bioswale**



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300 EAST LOGAN

- Curb Cut Bioswale
- Planted with Turf Grass & Pear Trees
- Sample
  - Influent to Bays
  - Pore Water @ Two Depths – N&P & Metals

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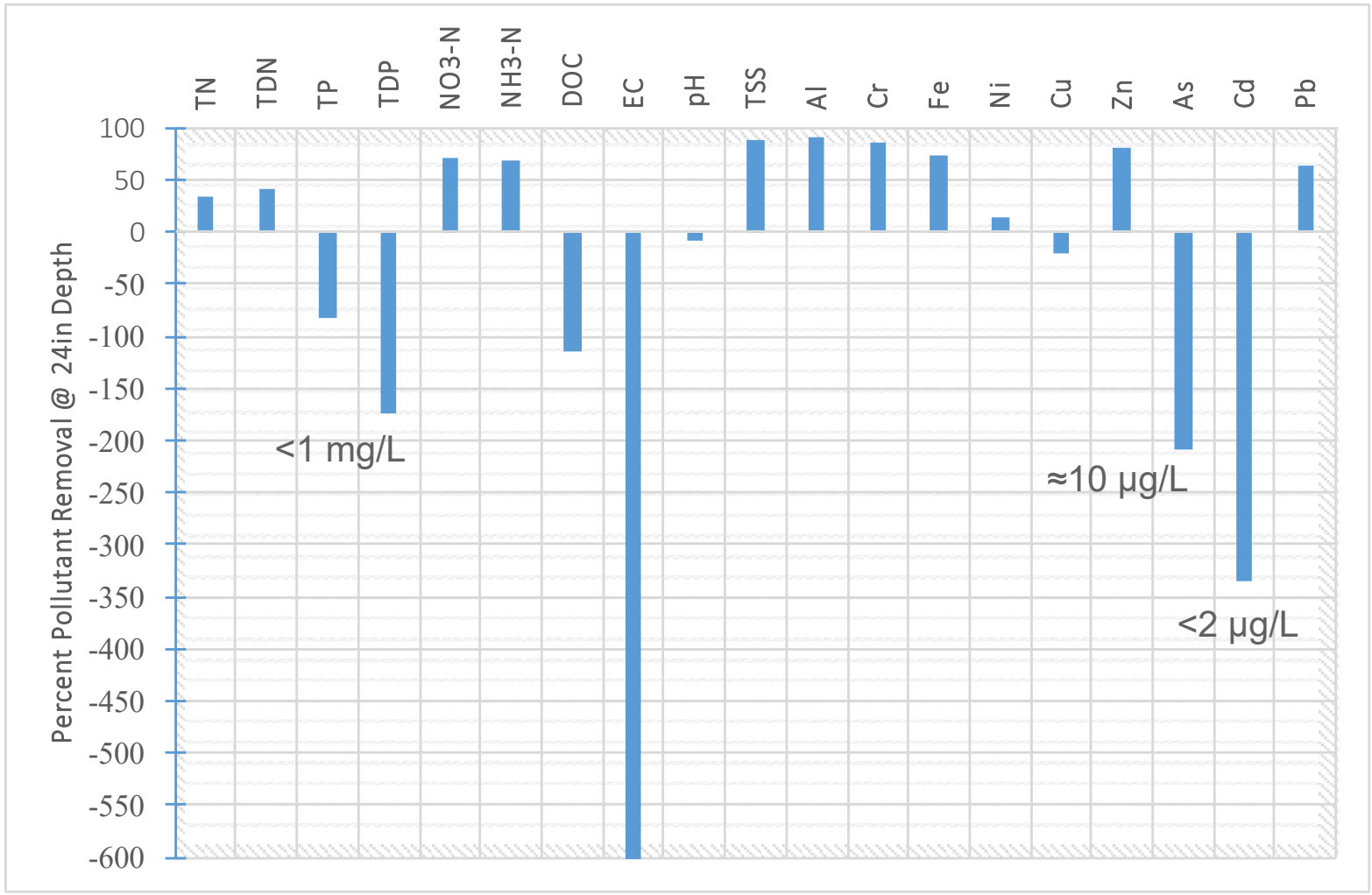
300 EAST POLLUTANT REMOVAL (INFLOW/INFILTRATION) – GLOBAL AVERAGE SEVEN EVENTS



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DO THESE SYSTEMS WORK?

ABSOLUTELY… SORT OF

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RAINFALL EVENTS COMPLETELY CONTAINED

- Over Last 27 Mo @ Field Sites
  - Multiple 25 Year Storms ≈ 3 in
  - Multiple 10 Year Storms ≈ 2 in
- **No Overflow/Discharge to Surface Water**
- **100% Pollutant Load Reduction to Surface Water**
- Groundwater Loading On-Going Concern

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WHERE DO WE NEED TO GO?

- Focus on Distributed Treatment & Multifunctional Solutions
  - Integration of GI Into Local Landscapes
  - Generate More System Performance Data
  - Generate Groundwater Impact Data

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QUESTIONS?

Local Examples

Questions?

Overview of Permit Requirements
Low Impact Development
Storm Water Integration
BMP Overview
The 90th Percentile Volume
Group Exercise #1

Break

Land Use Examples
Local Examples
Storm Water Quality Report
Group Exercise #2
Final Q&A

Storm Water Quality Report Template

"If meeting this retention standard is technically infeasible, a **rationale shall be provided** on a **case by case basis** for the use of alternative design criteria. The project must document and quantify that infiltration, evapotranspiration and rainwater harvesting **have been used to the maximum extent technically feasible** and that full employment of these controls are infeasible due to site constraints."

Small MS4 Permit - Section 4.2.5.3.4

Storm Water Quality Report Template

Project Information (p. 1)	Site Characteristics (p. 2)	Water Quality Calculations (p. 3)
Project Information (General)	Project Information – Calculation of V_{goal}	LID Drainage Areas
Watershed/TMDL Information	Subsurface Information	LID BMP Design
Signatures	Soil Information	Description of Technical Infeasibilities (if any)
	Drinking Water	Additional Storm Water Quality Measures Used on Project (if any)
	Additional Relevant Site Information	

Storm Water Quality Report Template

Project Information
(p. 1)

Date: 9/1/2019

Project Name: Garden Valley Condominiums

Project ID: 999999

Design Engineer: John Doe, PE

Is the project within a watershed that is 303(d) listed? Yes

If yes:

Name of receiving water(s): Little Cottonwood Creek-2

Listed Impairment(s): pH; Cadmium, Dissolved; C

Does the watershed that has an approved TMDL? Yes

If yes:

Approved TMDL(s): Zinc

I have reviewed the storm water quality design and find this report to be complete, accurate, and current.

[stamp required at final design phase]

Project Manager

[name], Project Manager

Storm Water Coordinator

[name], Designate Storm Water Coordinator

Maintenance

[name], Head of Maintenance

Landscaping

[name], Landscape Architect or Equivalent

Storm Water Quality Report Template

Site Characteristics (p. 2)

Project Information

Type of Project (New Development,

Area of Land Disturbance (ac): 3.7

Project Impervious Area (ac): 2.0

Projec

Projec

90th St

Projec

Subsurface Information

Groundwater

Depth to Groundwater (ft): 17 ft

Historical High Depth to Groundwater if known (ft): 9 ft

Source: Project groundwater monitoring

Additional Relevant Site Information

Source: Project geotechnical report

Soil Contamination at Site: None

Drinking Water

Within Drinking Water Source Area Protection: No

UTAH DEPARTMENT of ENVIRONMENTAL QUALITY WATER QUALITY

Michael Baker INTERNATIONAL

Storm Water Quality Report Template

Water Quality Calculations (p. 3)

If 100% of V_{goal} is not captured, document and provide narrative of technical infeasibilities and/or alternate compliance measures below:

Describe additional storm water quality measures incorporated into the site:

Storm Water Quality Report Template

Questions?

Overview of Permit Requirements
Low Impact Development
Storm Water Integration
BMP Overview
The 90th Percentile Volume
Group Exercise #1

Break

Land Use Examples
Local Examples
Storm Water Quality Report
Group Exercise #2
Final Q&A

Group Exercise

Complete a Storm Water Quality Report

Page 1

Create project information representative of your developments.

Page 2

Create site characteristics based on previous group exercise and information representative of your developments.

Page 3

Complete tables and additional narration if needed. List typical infeasibilities that may be encountered at your developments.

Review of Group Exercise

Final Q&A

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