GSI Performance Monitoring and Design Considerations for Maximizing Pollutant Removal

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Green Stormwater Infrastructure Summit

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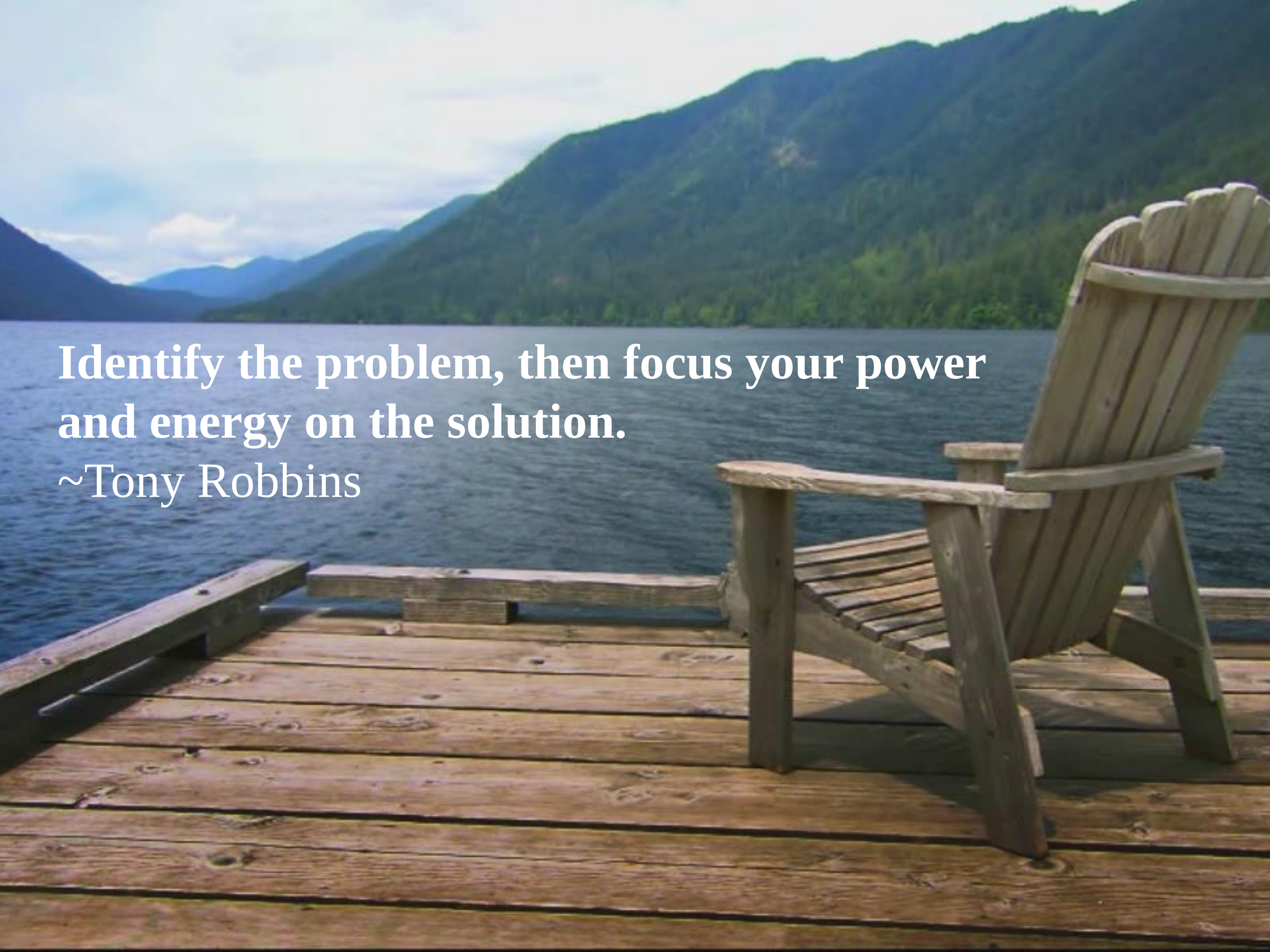

Identify the problem, then focus your power and energy on the solution.
~Tony Robbins

EPA National Green Infrastructure Strategic Agenda 2013

National Objectives:

1. Increase federal coordination
2. Expand Clean Water Act regulatory support
3. Strengthen research and information exchange
4. Distribute funding and financing
5. Build local capacity

U.S. Environmental Protection Agency. (2013). *Green Infrastructure Strategic Agenda 2013*.

Collect Data to Verify Effectiveness

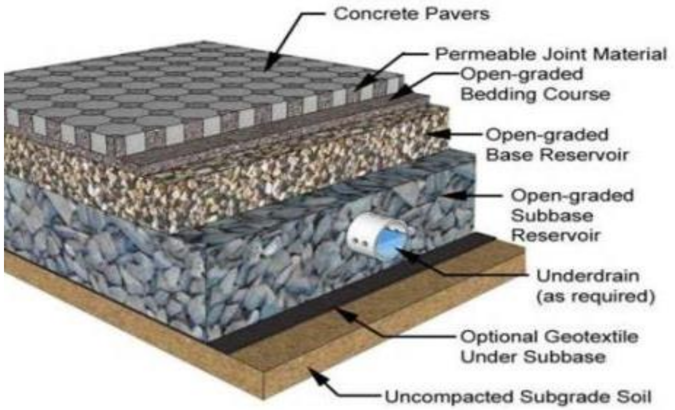
Pollutants Found in Stormwater:

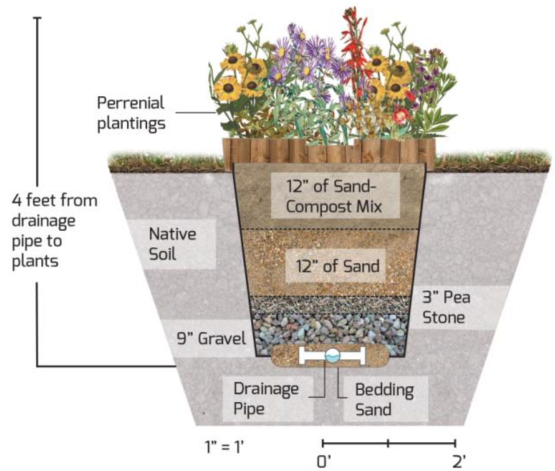
bacteria
pathogens
cadmium
chromium
copper
lead
mercury
zinc
phosphorus
nitrogen
oil and grease
total suspended solids

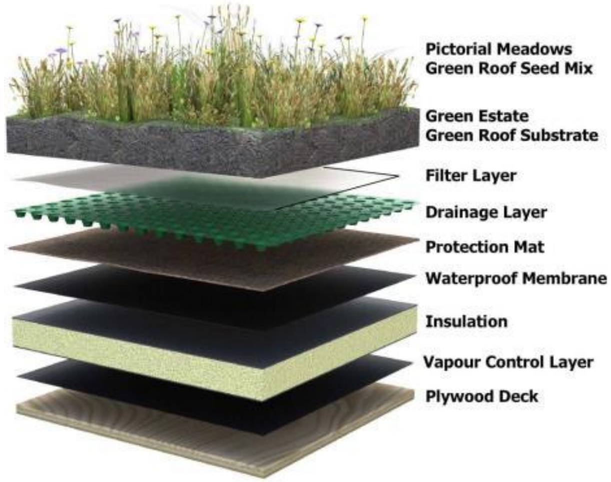
Low Impact Design & Development

LID is an approach to development (or re-development) that mimics pre-development hydrology and uses ecological design and engineering to remove pollutants in stormwater and wastewater so it can be re-used or replenish groundwater supplies.

Low Impact Design and Development (LID) includes Green Stormwater Infrastructure (GSI)





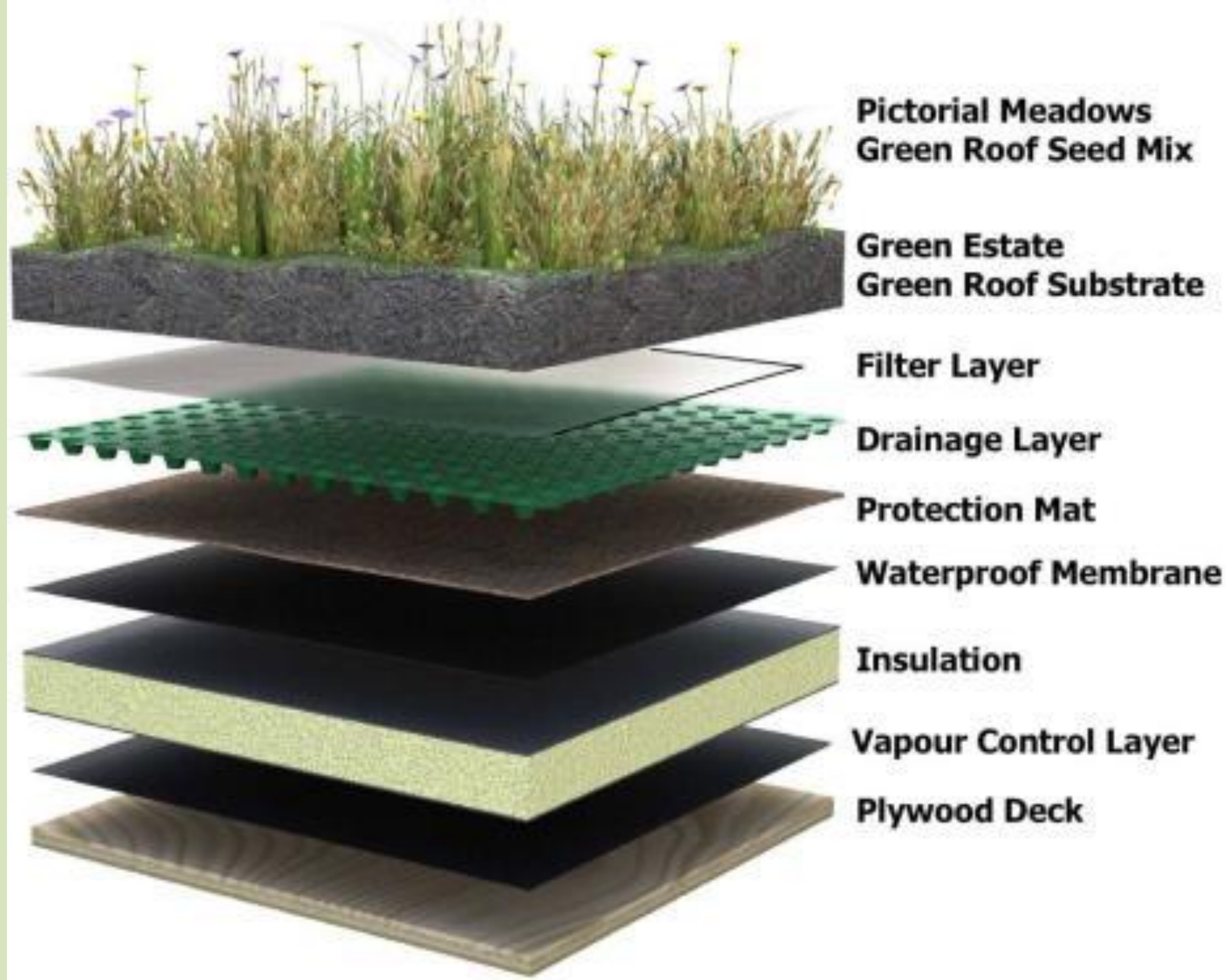


Davis 2008; Dietz and Clausen 2006; Zinger et al. 2013; Collins et al. 2010.

Green Roofs

Design Strengths:
Reduce Volume
Reduce Peak Flows
Remove Pollutants
Reduce Temperature
Heat Island
Provide Habitat
Increase Biodiversity

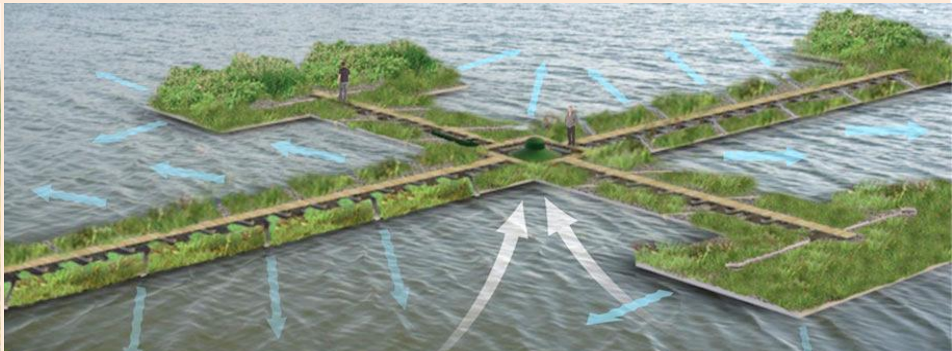
Design Challenges:
Maintenance
Plant Selection



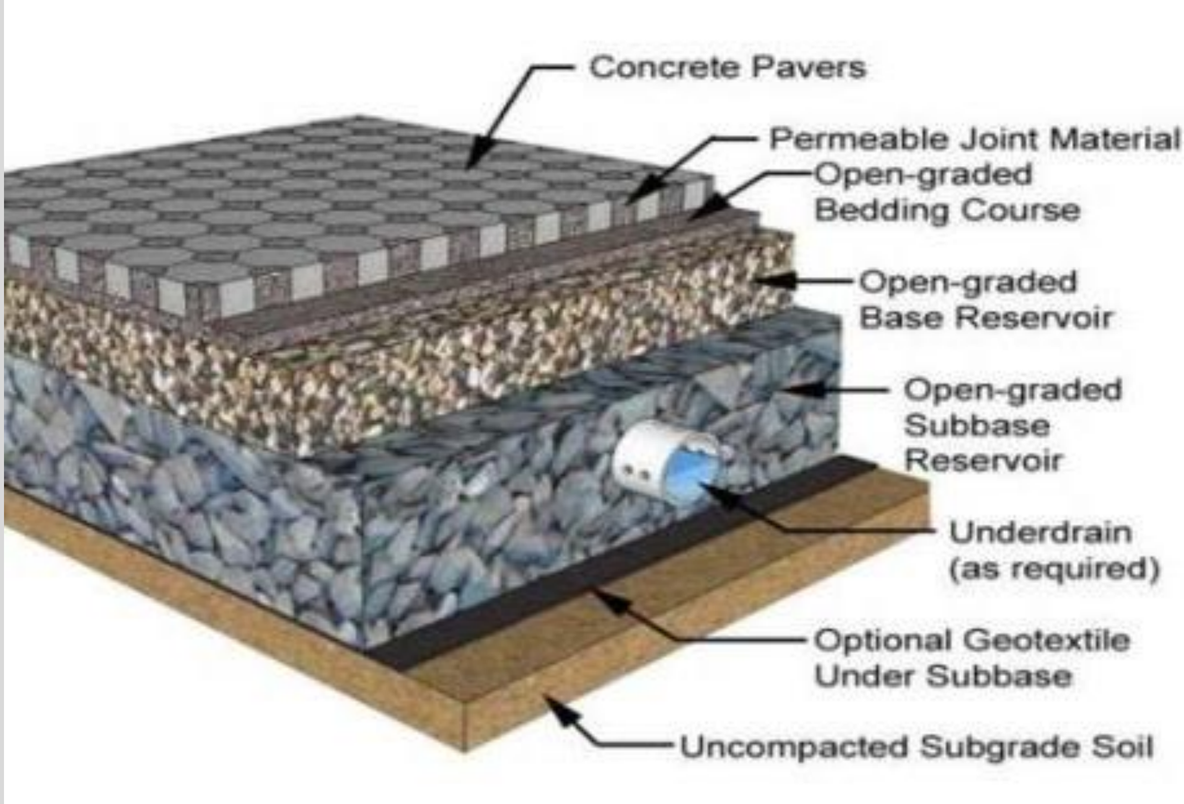
Floating Treatment Wetlands

Design Strengths:
Nutrient Removal
Provides Habitat
Increase Biodiversity
Moderates Wave Action
Reduces Shore Erosion

Design Challenges:
Maintenance Logistics



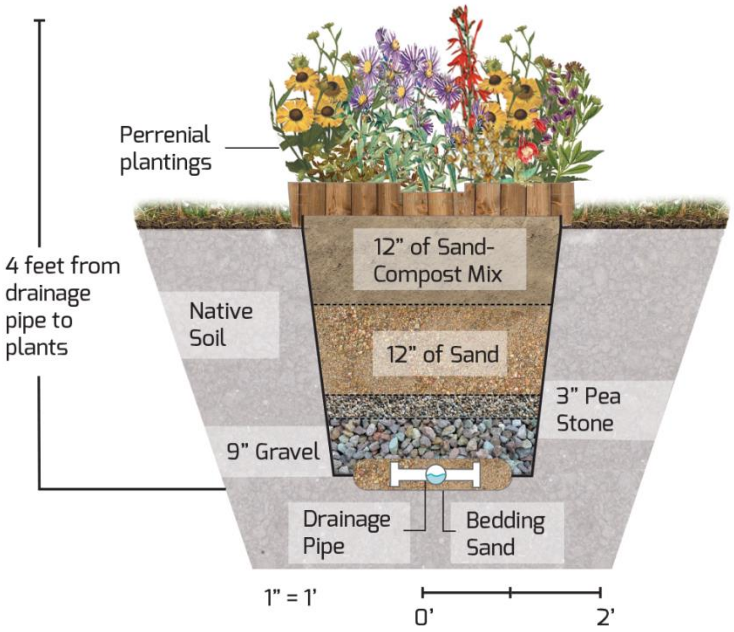
Porous Pavement



Design Strengths:
Reduces Storm Volume
Reduces Peak Flows
Particulate Pollutant Removal

Design Challenges:
Getting both strength and permeability
Protective buffer reduces siltation from offsite flows
Maintenance

Bioretention
Rain Gardens
Green Streets

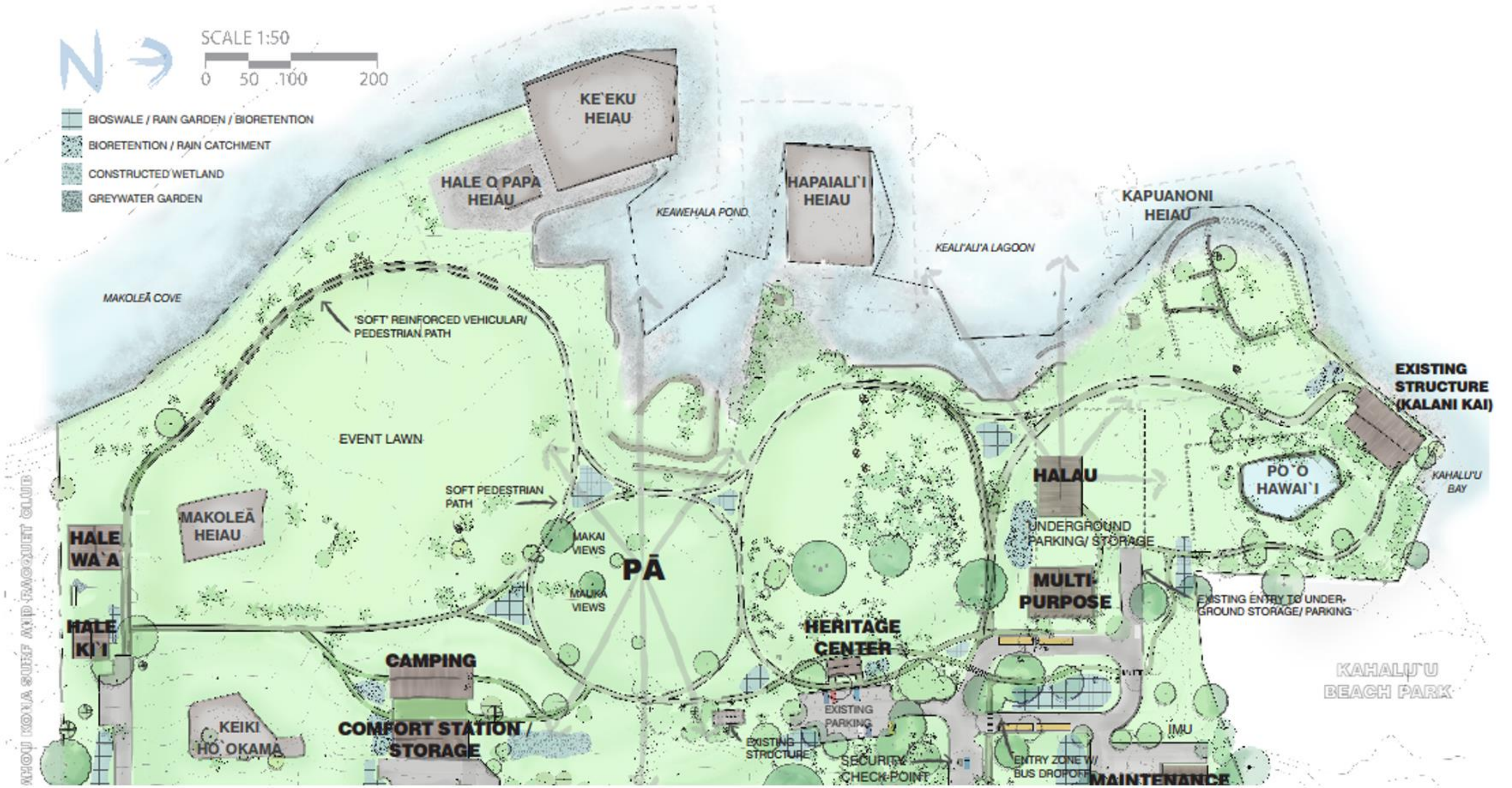


Design Strengths:
Reduces Volume & Peak Flows
Removes Total Suspended Solids
Removes Nutrients
Improved Aesthetics

Design Challenges:
Obtaining proper infiltration
Directing flow into feature
Maintenance




Low Impact Development (LID): Kahalu‘u Ma Kai



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Residential Bioretention Concept

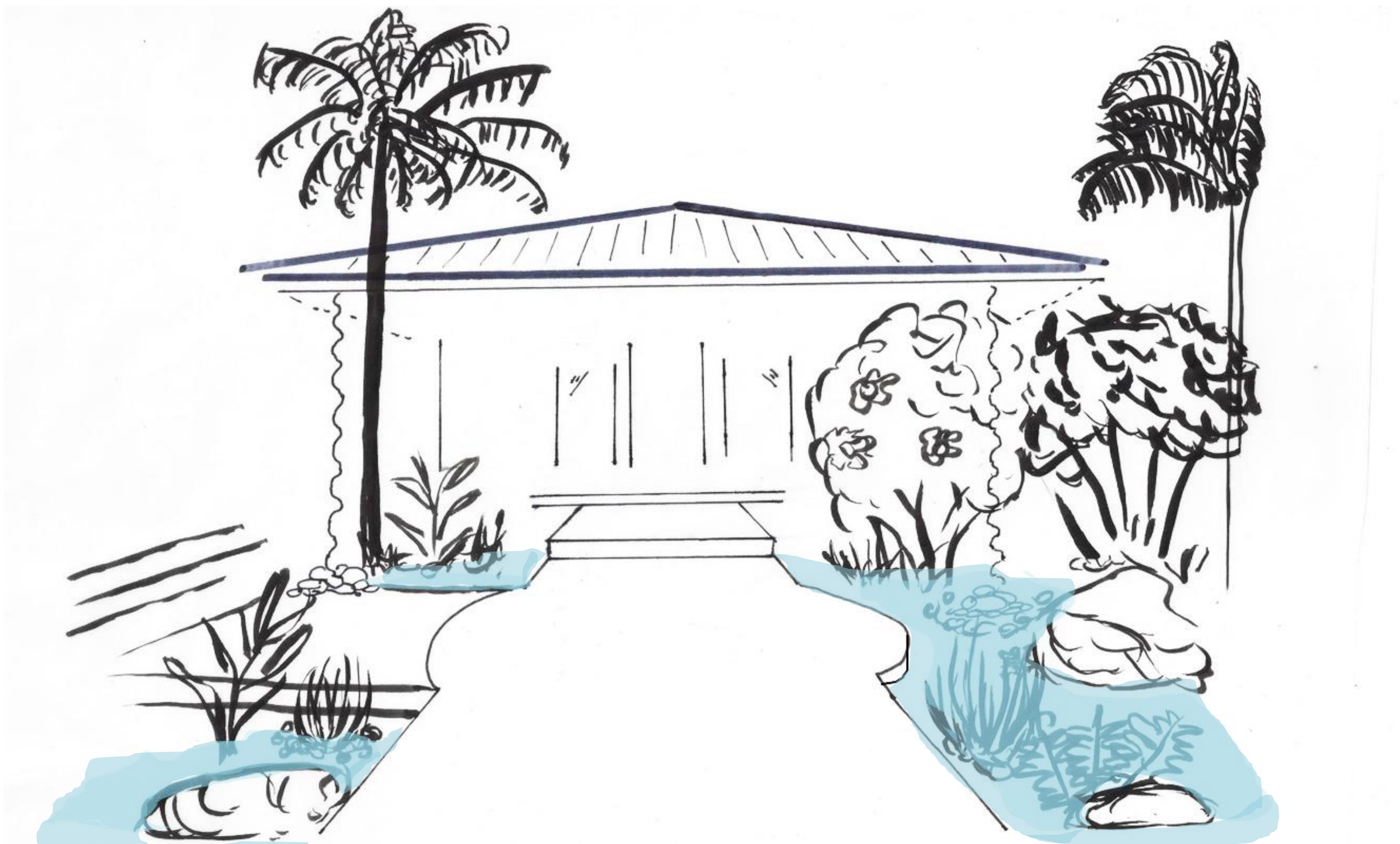


Image Source: Amanda Cording

Green Streets Concepts

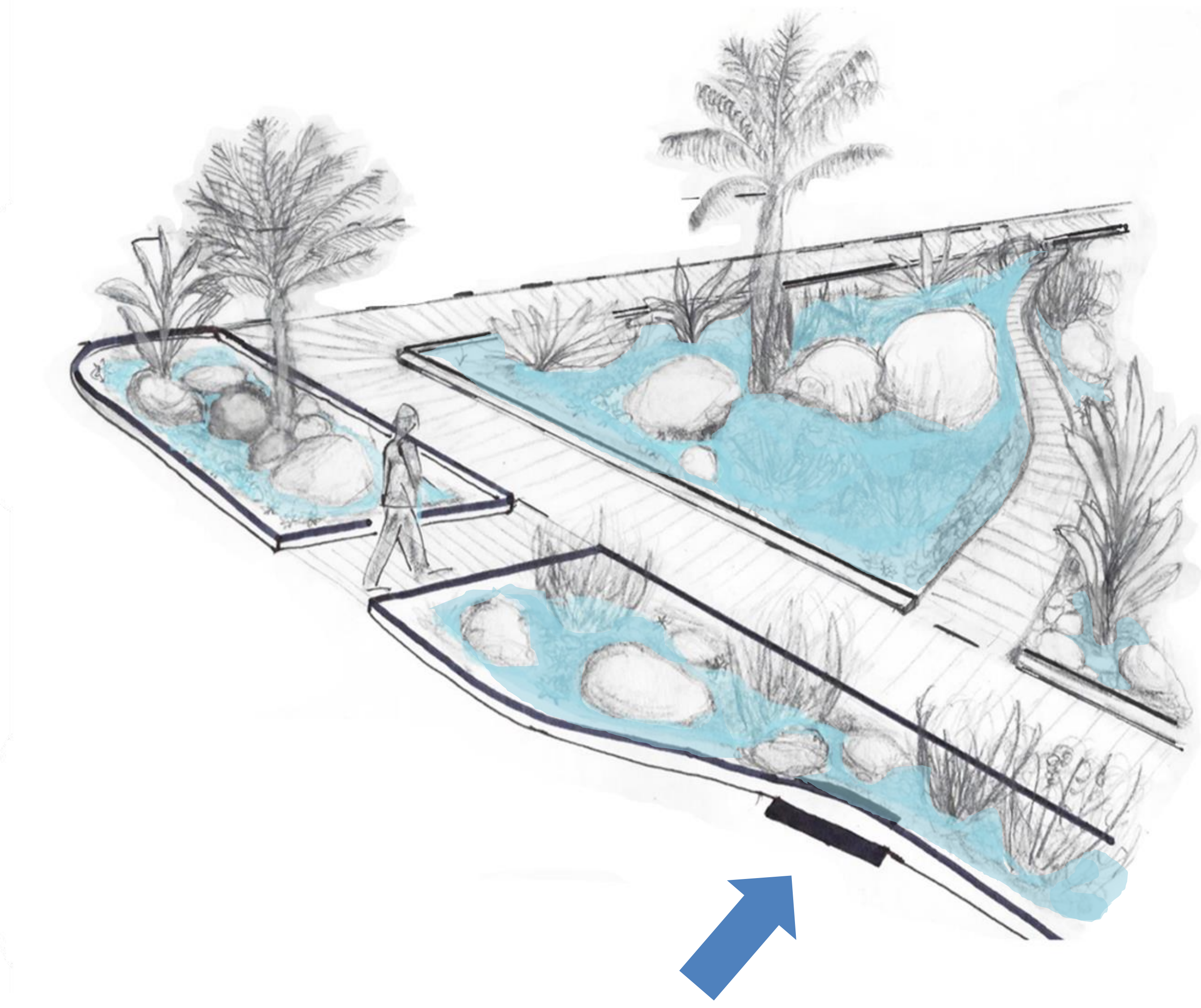


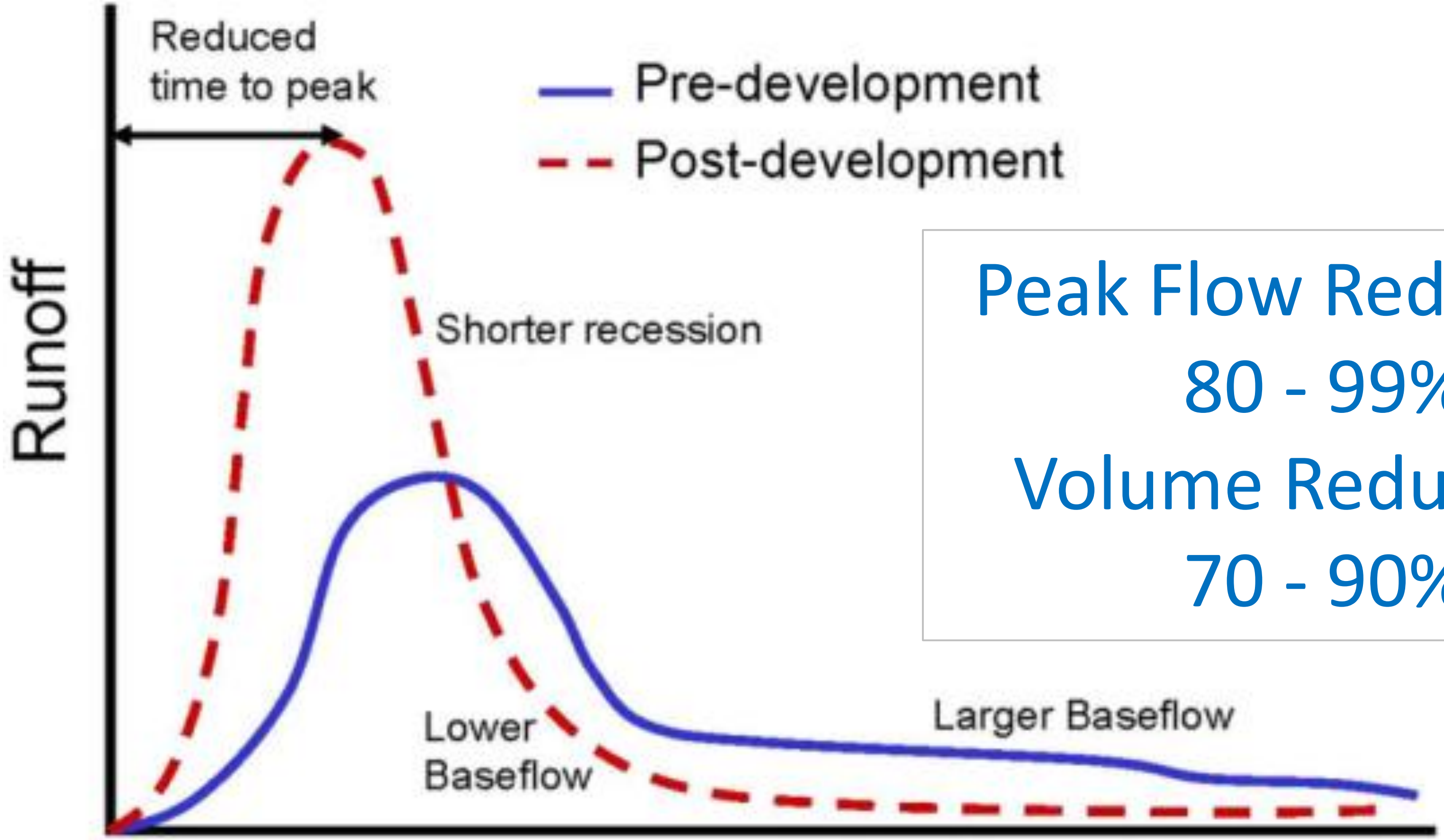
Image Source: Amanda Cording

Neighborhood Scale Bioretention

Image Source: Amanda Cording

References	What is a Bioretention System?
Claytor and Schueler (1996)	Shallow, grass filter strip, sand and loamy soils, ponding area , mulch. The total depth is 4 feet. Collected in a perforated underdrain and returned to the storm drain system.
Davis et al. (2001)	High sand content, low levels of silt and clay to promote attenuation of pollutants. Wood mulch to prevent erosion/ excessive drying.
Vermont Agency of Natural Resources (2002)	Shallow depression, soil matrix, returned to storm drain system.
Kim et al. (2003)	Simple, plant and soil based infiltration facility
Dietz & Clausen (2005)	Shallow, planted with trees and/or shrubs, bark mulch layer or ground cover.
Dietz et al. (2007)	Depressed, planted with shrubs, perennials or trees, shredded hardwood bark mulch.
Hunt et al. (2007)	Excavated basin, underdrains, gravel envelope. Between 0.7 and 1.2 m (2.3 to 4 ft) of fill soil. Plants and mulch.
Hatt et al. (2008)	Gravel-, sand-, or soil-based filter media. Flexible in design (ranging from large basins to small garden beds) and are particularly advantageous for urban areas where there are space constraints.
Collins et al. (2010)	Bioretention systems (also referred to as rain gardens or bioswales) are shallow, vegetated depressions, soil filter media

Bioretention: Hydrologic Performance

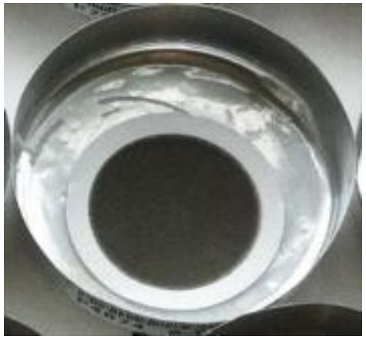


Peak Flow Reduction:
80 - 99%
Volume Reduction:
70 - 90%

Hunt et al. (2008); Debusk et al. (2011); Image Source: Liu et al. (2014)

Bioretention: Sediment Removal

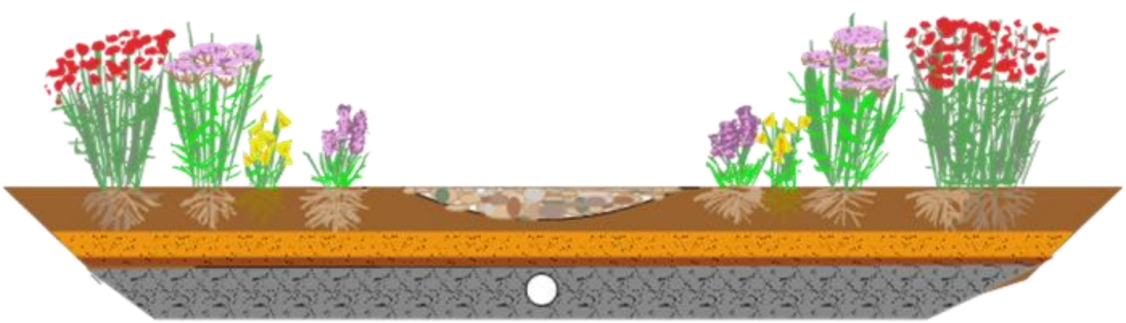
Removal of
Total Suspended Solids:
70% - 99%



Brown and Hunt (2011); Bratieres et al. (2008); Hatt et al. (2008)

Average Outflow Concentrations within the Literature

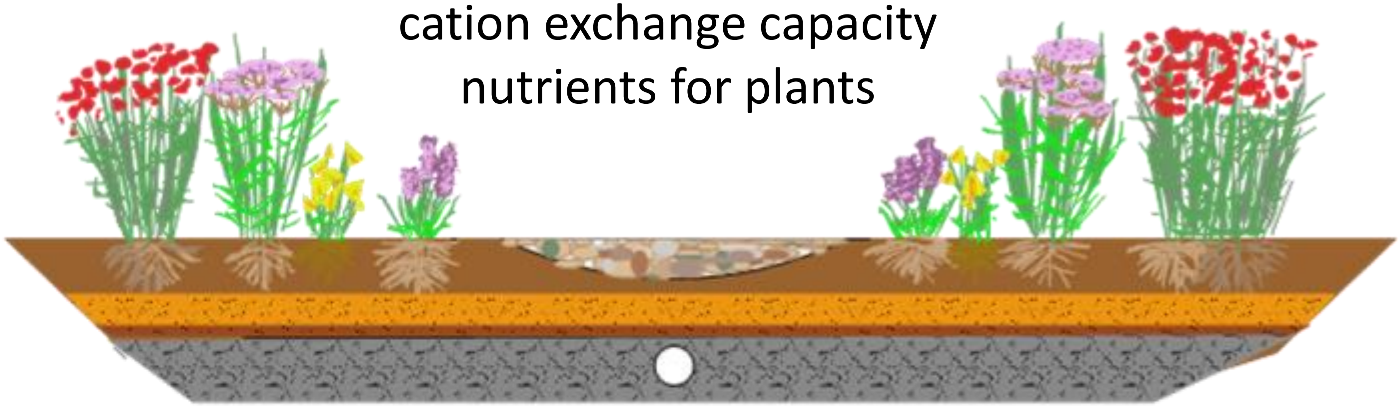
Parameter	Literature	Reference
NLP	40 – 800 µg L^{-1}	Hunt et al. (2006)
SRP	210 – 670 µg L^{-1}	Geosyntec (2008)
SRP	140 µg L^{-1}	Chardon et al. (2005) (Iron Coated Sand)
	< 10 µg L^{-1}	O'Neill and Davis (2011) (WW Residual)
NO_3^-	300 – 400 µg L^{-1}	Dietz and Clausen (2006)
TKN	1,240 – 1,780 µg L^{-1}	Geosyntec (2008)
TSS	15 – 33 mg L^{-1}	Geosyntec (2008)



Inconsistent Nutrient Removal

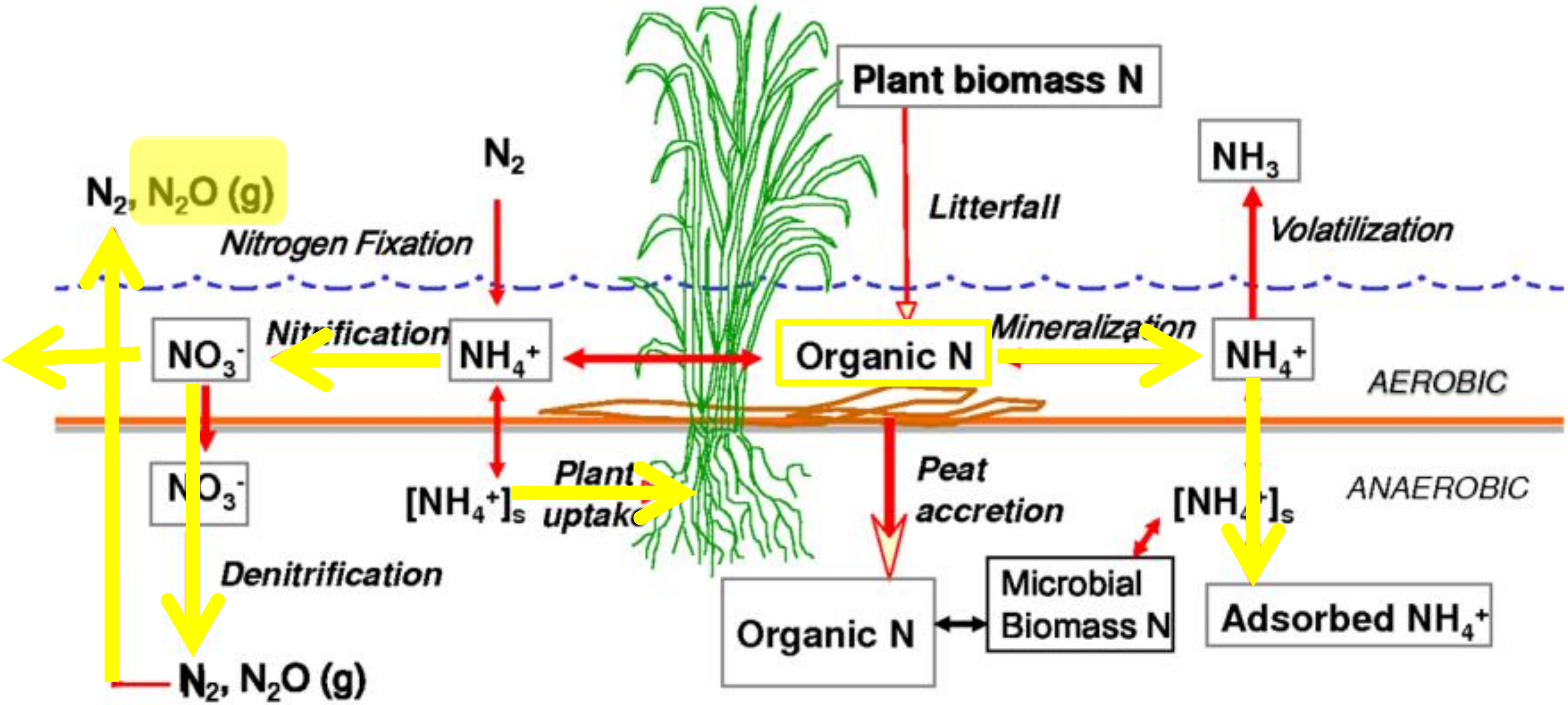
- Some of the variability could be attributed to <u>soil media selected</u>
- Sand based bioretention soil designs are common
- Organic amendments (<u>compost</u>, mulch) are recommended for:

metals removal
soil moisture retention
cation exchange capacity
nutrients for plants



Bratieres et al. 2008; DeBusk and Wynn 2011; Michigan Department of Environmental Quality 2008; Thompson et al. 2008; Vermont Agency of Natural Resources 2002; Washington State University Pierce County Extension 2012.

Nitrogen Removal Mechanisms



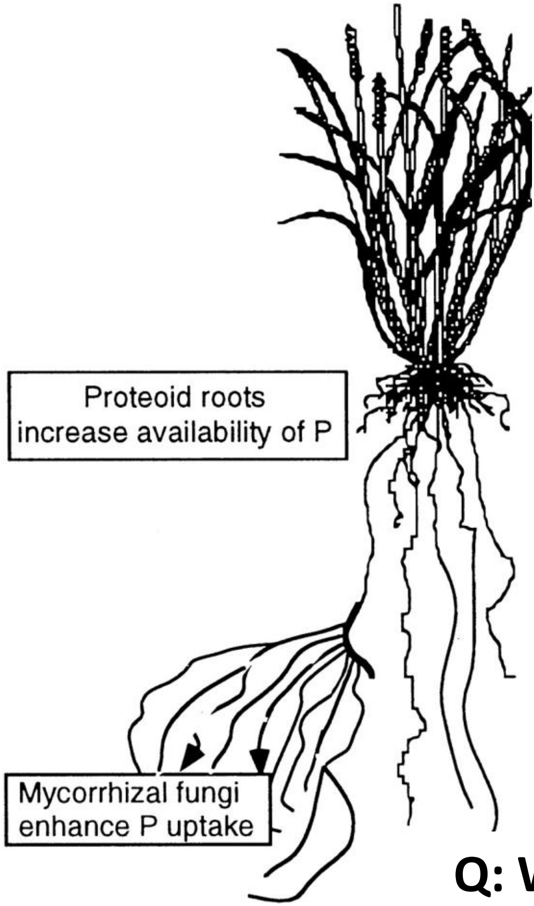
***Mn (II) may also reduce NO_3^- via chemo-denitrification**

Q: Which mechanisms are dominant in bioretention?

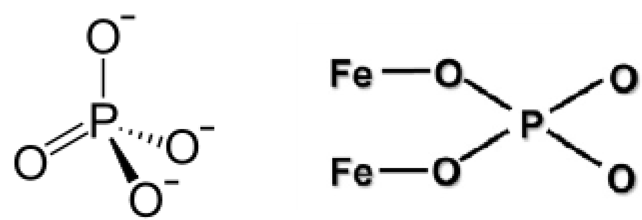
Q: How can we maximize removal through design?

Davis et al. (2006); Bratieres et al. (2008); Kim et al. (2003); Charpuis-Lardy et al. (2007)

Phosphorus Removal Mechanisms



1. Physical Filtration: Non-labile P
2. Sorption of SRP: Fe, Ca, and Al in Soil



$$2{\equiv}FeOH^{-0.5} + PO_4^{3-} + 2H^+ = ({\equiv}FeO)_2PO_2^{2-} + 2H_2O$$

3. Plant Uptake: SRP

Q: Which mechanisms are dominant in bioretention?

Q: How can we maximize removal mechanisms through design?

Tanner (1996); Arias et al. (2001); Lucas and Greenway (2011); Liping et al. (2012)

Soil Media Designed to Remove P

Reference	Media	Composition	Ca	Fe	Al	SRP	TP Removal (%)
Liu et al. (2014)	TerraSolve	15% coir/peat mix, 9% hardwood mulch, 12% WTR, 58% sand	-	1,979	7,541	196	90– 99
	Virginia Institute of Technology Mixture	3% WTR, 15% saprolite, 25% compost, 57% sand	-	6,613	3,367	138	58 – 95
Stoner et al. (2012)	Industrial byproducts	Geothite, gypsum, calcite, quartz, portlandite	90 – 6,500	600 – 40,000	60 – 58,000	-	10 – 60
Arias et al. (2001)	Denmark Sands	Quartz sand	600	1,210	320	40	-
Chardon et al. (2005)	Iron-coated Sand	Iron-coated sand	6,100	198,000	620	3,400	94

* All Constituents are in mg kg^{-1}

Research Objectives:

1. How does one monitor bioretention effectiveness?
2. What is the stormwater pollutant load from paved road?
3. What design parameters dominate pollutant removal?

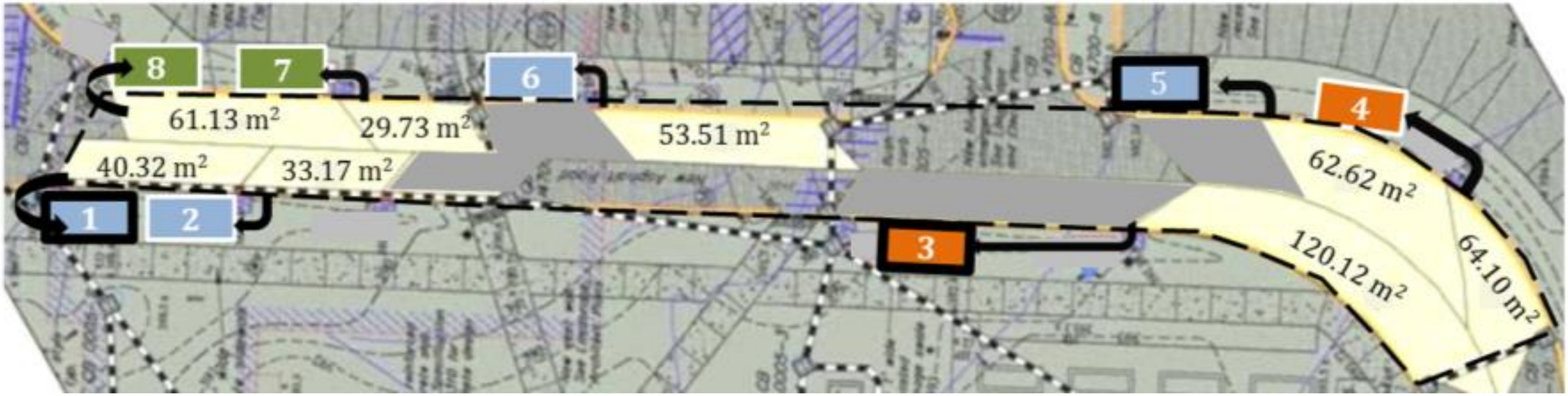
Welcome to the University of Vermont Bioretention Laboratory

The Research Site

Site Description:

- The University of Vermont Outdoor Bioretention Laboratory was constructed in November of 2012
- Total area: approx. 5,000 ft^2 or 0.1 acres
- Eight small paved road sub-watersheds
- Bioretention Surface Areas: 29.73 m^2 to 120.12 m^2

The Research Site



Numerous Design Factors that Affect Pollutant Removal Performance

Factor	Authors
1. Residence time	(Collins et al. 2010; Hurley and Forman 2011; Kadlec et al. 2010; Rosenquist et al. 2010)
2. Media depth	(Brown and Hunt 2011)
3. Vegetation type, root depth, root architecture	(Claassen and Young 2010; Collins et al. 2010; Davis et al. 2009; Kadlec et al. 2010; Lucas and Greenway 2008)
4. Soil organic matter content, use of mulch	(DeBusk and Wynn 2011; Fassman et al. 2013)
5. % sand, silt, and clay	(Liu et al. 2014)
6. Chemical characteristics of soil media (Fe, Ca, Al)	(Groenenberg et al. 2013; Vance et al. 2003)
7. Ponding depth, hydraulic conductivity, infiltration rate	(Thompson et al. 2008)
8. Inclusion of internal water storage (IWS) zones	(Chen et al. 2013; Dietz and Clausen 2006; Hunt et al. 2006)
9. Careful construction, maintenance	(Brown and Hunt 2011; Dietz and Clausen 2006)

Step 1: Monitoring Bioretention

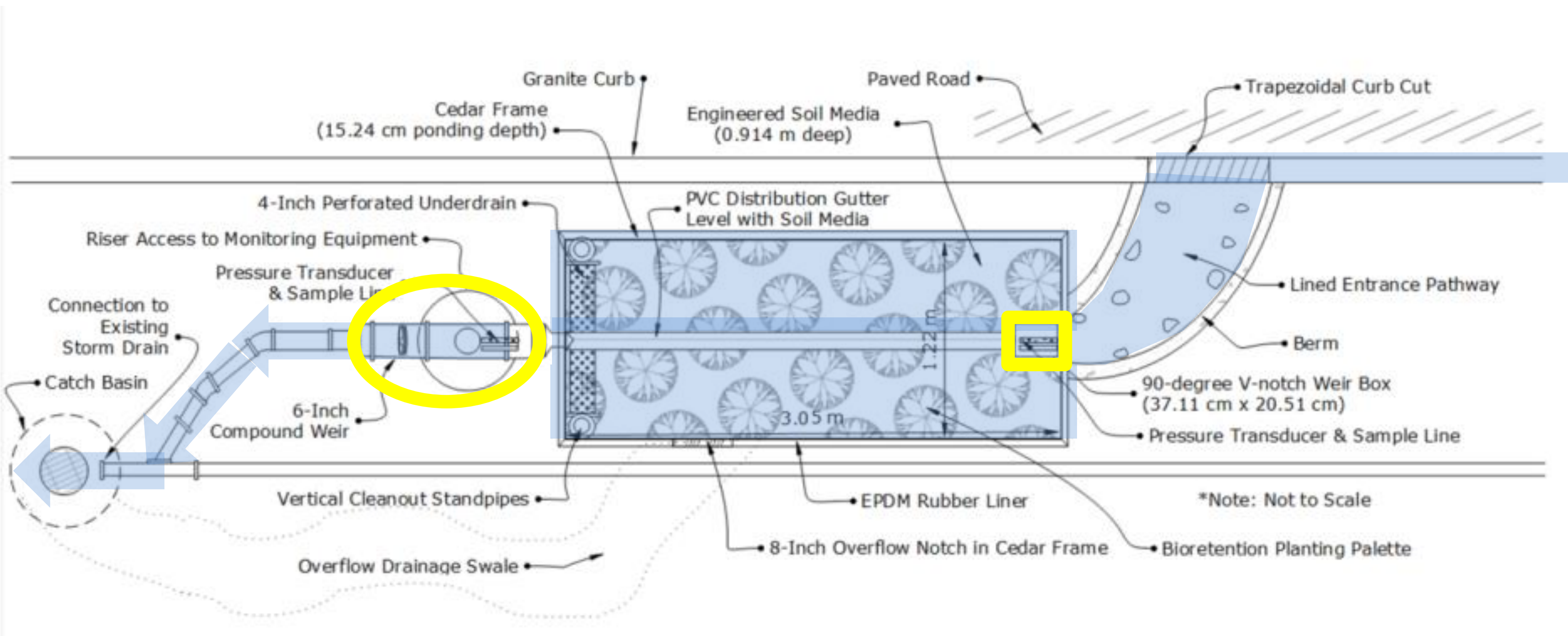


Image Credit: Amanda Cording

Converting Concentration to Mass with Numeric Integration

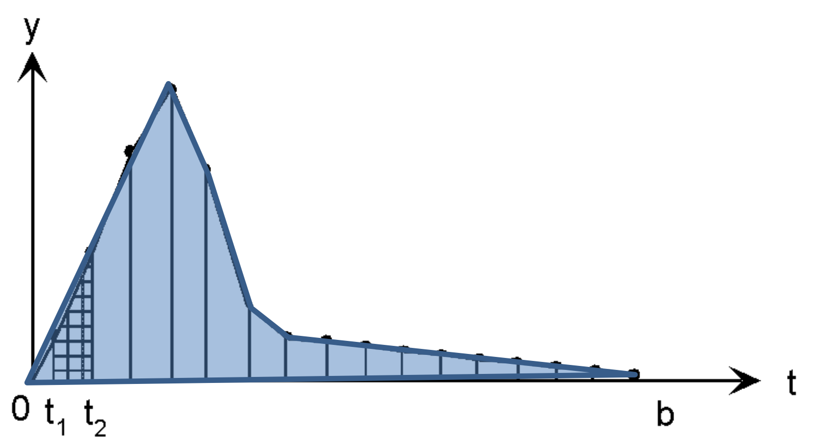
$$V = \int_{t0}^{tn} Q(t)\, dt$$

Where,
V = volume delivered during storm event (L)
Q = flow rate as a function of time (Ls^{-1})

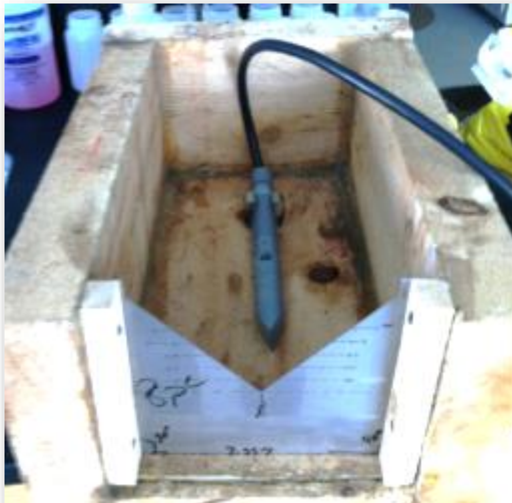
$$M = \int_{t0}^{tn} C(t) dt\, Q(t)\, dt$$

Where,
M = mass delivered during storm event (µg or mg)
C = concentration as a function of time (µg L^{-1})
Q = flow rate as a function of time (Ls^{-1})

$$Area = (t_2 - t_1)\left[\frac{f(t_1) + f(t_2)}{2}\right]$$



How do you measure flow rate entering and exiting bioretention?



Inflow 90º Weir Box

Outflow Thel-Mar™ Weir

$$Q=CH^n$$

Where:

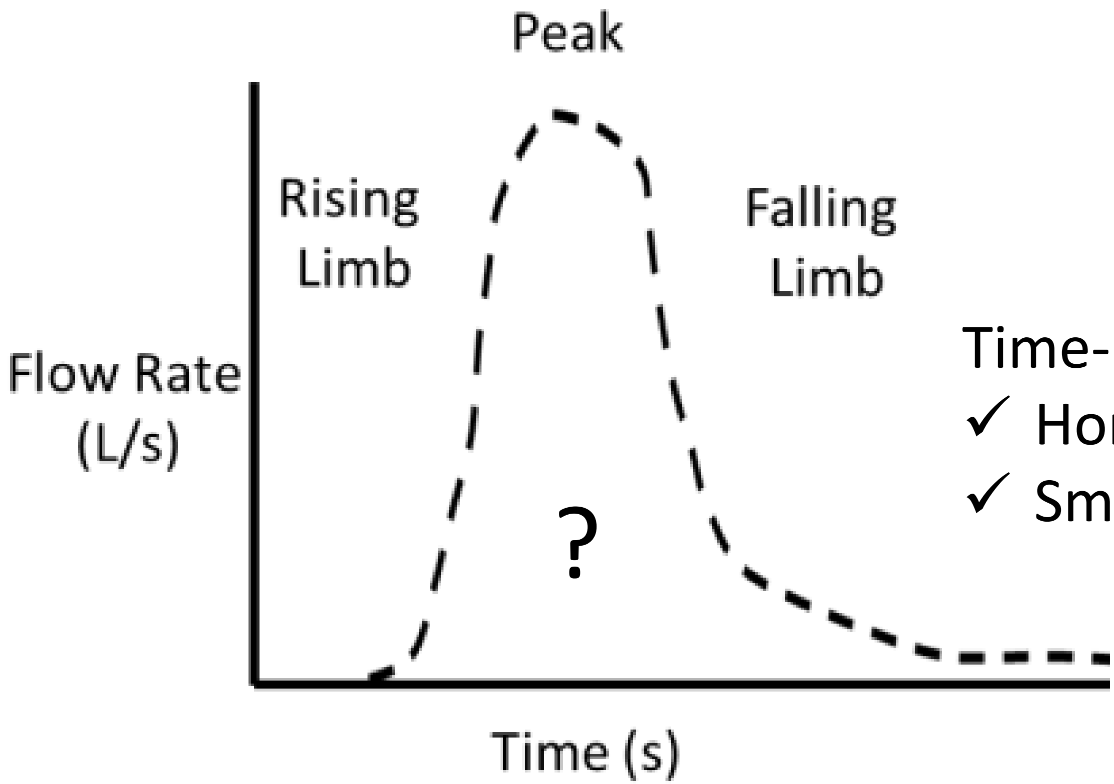
Q = flow rate over the weir (cfs, L s^{-1})

C= coefficient of discharge, or weir coefficient

H= height of water behind the weir (pressure transducer)

n = an empirical exponent (dimensionless)

How to Capture the Inflow Hydrograph?



Time-Based Sampling:

- ✓ Homogeneous paved surface
- ✓ Small watersheds

Harmel et al. 2003; Sansalone and Cristina 2004

Capturing the Inflow Hydrograph: Estimate Time of Concentration

$$Tc = \frac{G\,(1.1 - C)L^{0.5}}{(100\,S)^{1/3}}$$

Where,
T_c is the time of concentration (min)
G is equal to 1.8 (FAA method, constant)
C is the runoff coefficient using the rational method (dimensionless)
L is the longest distance from the fixed location within the watershed (ft)
S is the slope of the watershed (ft ft^{-1} or m m^{-1})

Estimate Peak Flow Rate with the Rational Method

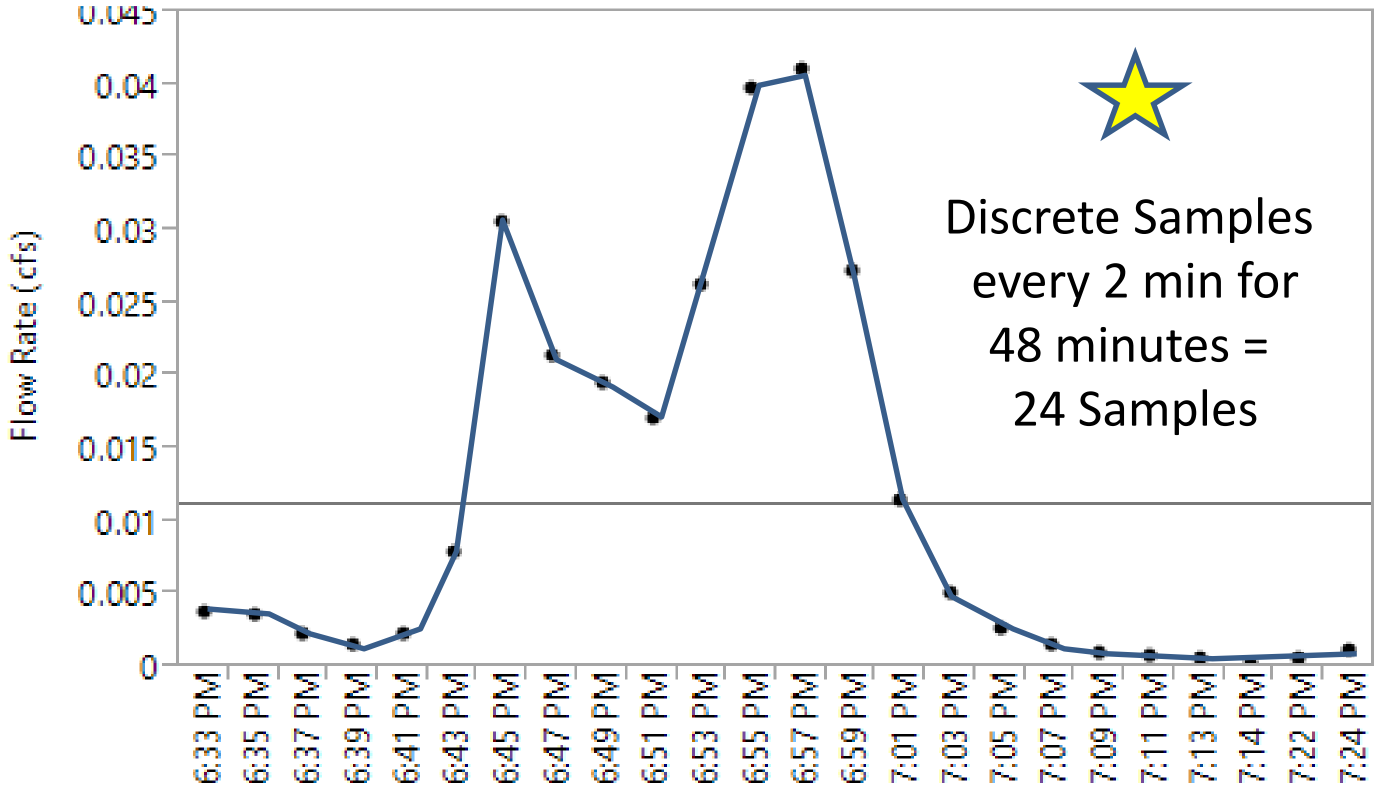
$$Q = C_f * C_i * A$$

Where,
Q is the peak discharge, or flow rate ($ft^3\ s^{-1}$, $m^3\ s^{-1}$, $L\ s^1$)
C_f is the runoff coefficient (dimensionless)
C_i is the rainfall intensity ($ft\ s^{-1}$ or $m\ s^{-1}$)
A is the drainage area (ft^2 or m^2)

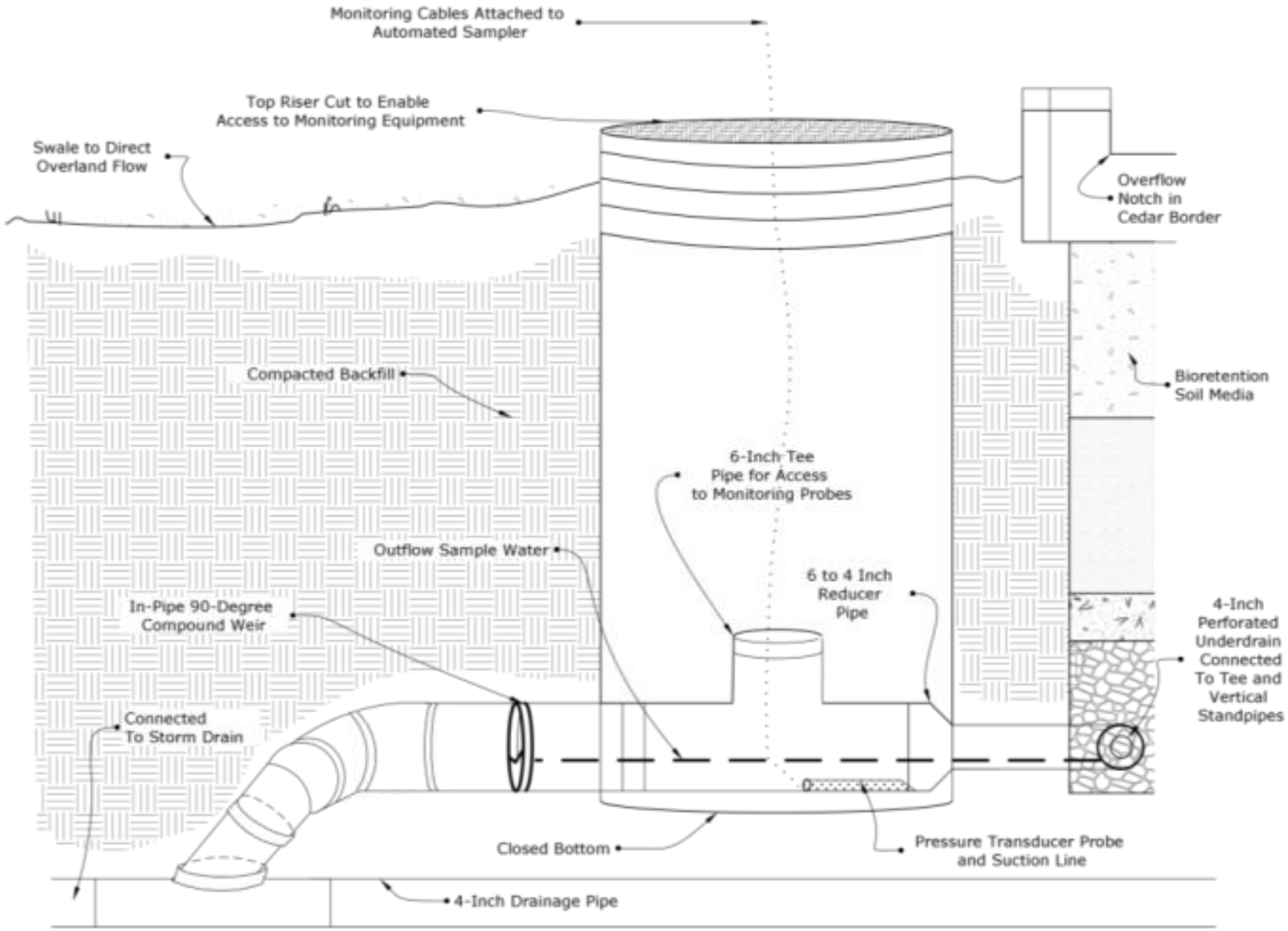
Natural Resources Conservation Service (1986)

Take Multiple Samples within the Inflow Hydrograph

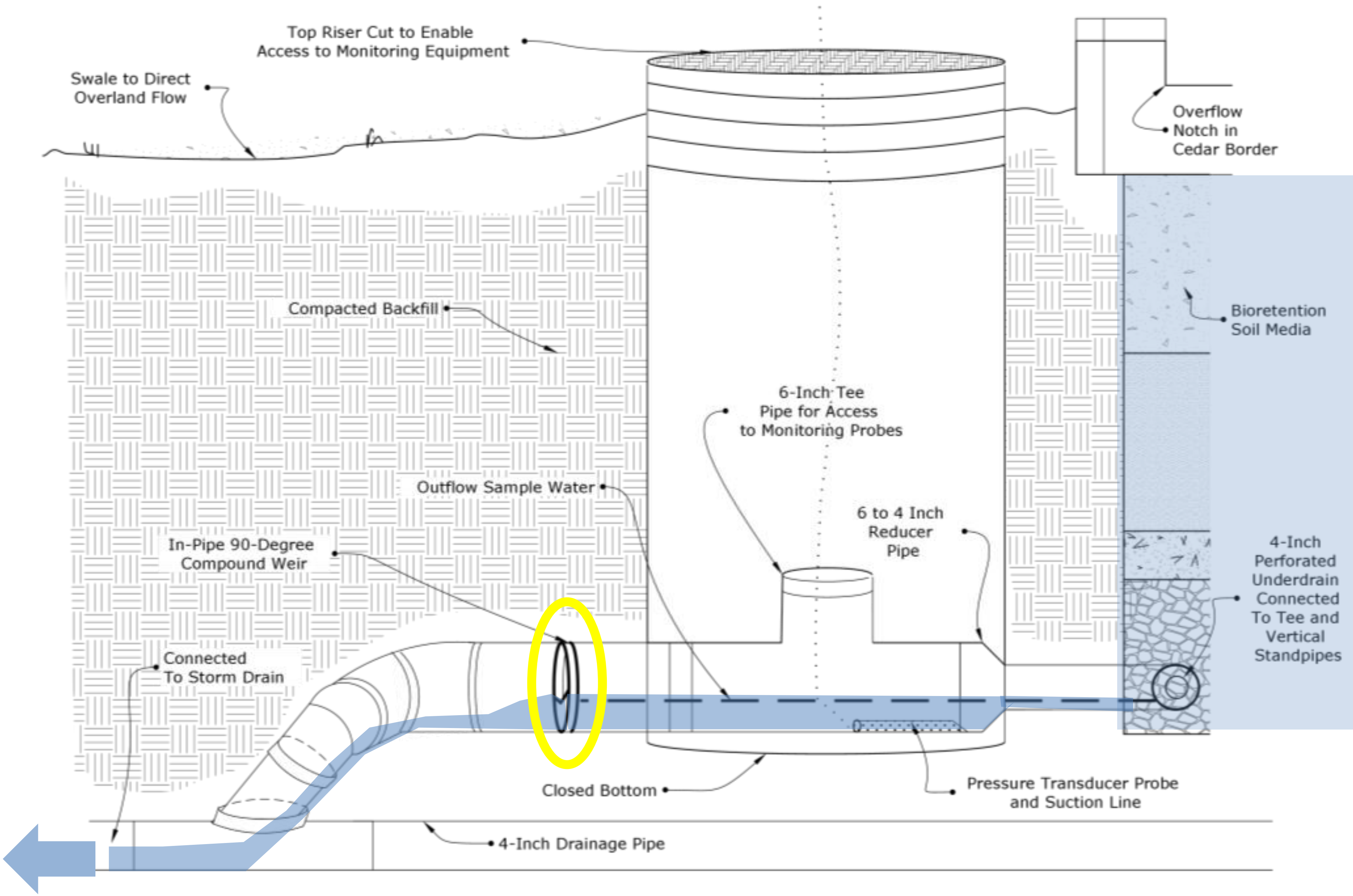
$$Time = \frac{watershed\ area\ x\ rainfall\ depth}{peak\ flow\ rate}$$



What infrastructure could one use to measure the outflow from bioretention?



Outflow Monitoring: In-Pipe Thel-Mar™ Weir



Capturing the Outflow Hydrograph: Estimate Hydraulic Conductivity

$$K_z = \frac{D}{\sum_{i=1}^{n} \frac{d_i}{k_i}}$$

Where,

K_z is the vertical hydraulic conductivity for the layered system (m s^{-1})

D is the total cumulative depth of the layers (m)

d_i is the depth of a given layer (m)

k_i is the hydraulic conductivity of a given layer (m s^{-1})

$$K_x = \sum_{i=1}^{n} \frac{K_i d_i}{d}$$

Where,

K_x is the horizontal hydraulic conductivity (m s^{-1})

d_i is the depth of a given layer (m)

K_i is the hydraulic conductivity of a given layer (m s^{-1})

d is the horizontal distance of the given layer (m)

Capturing the Outflow Hydrograph: Estimate Hydraulic Conductivity

Bioretention Media	Depth (m)	Hydraulic Conductivity ($m\ s^{-1}$)	d_i/k_i
Sand/Compost Mixture	0.3048	1.50E-04	2.03E+03
Medium Sand	0.3048	6.90E-04	4.42E+02
Pea Gravel	0.0762	6.40E-03	1.19E+01
Gravel	0.2286	9.14E-03	2.50E+01
			Total d_i/k_i = 2.51E+03
			Total Depth = 0.9144 m
			K_z ($m\ s^{-1}$) = 3.64E-04

K_z = 131.04 $cm\ hr^{-1}$ or 51.59 $in\ hr^{-1}$

Estimate Hydraulic Conductivity

$$T = \frac{A_w D}{K_z A_{BR(z)}} + \frac{A_w D}{K_x A_{BR(\mathbf{x})}}$$

Where,

T is the time for the outflow peak to reach monitoring equipment (s)

A_w is the watershed area (m^2)

D is the selected rainfall depth (m)

K_z is the cumulative vertical hydraulic conductivity ($m\ s^{-1}$)

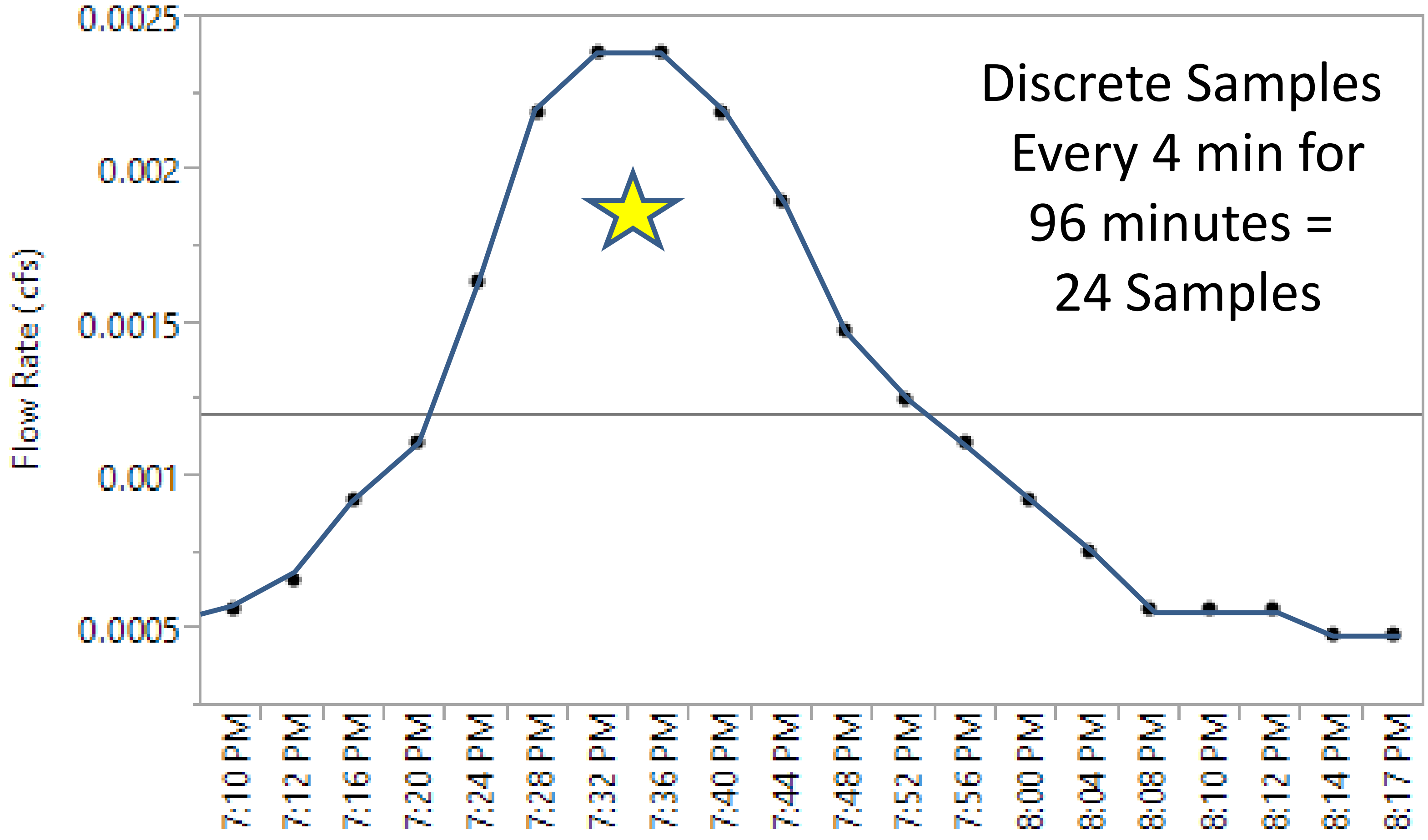
K_x is the horizontal hydraulic conductivity ($m\ s^{-1}$)

A_{BR} (z) is the vertical cross-sectional area along the Y-plane (m^2)

A_{BR} (x) is the vertical cross-sectional area of the layer directly above the flow impeding layer along the X-plane (m^2)

Sampling the Outflow Hydrograph

Time Needed to Monitor Outflow Hydrograph = 90 minutes

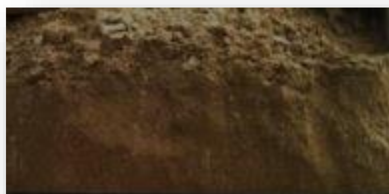


Installing Outflow Monitoring Equipment

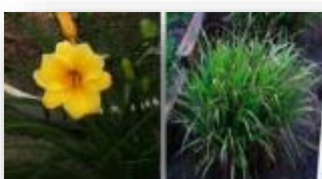
Photo Credit: Amanda Cording, Paliza Shrestha

Step 2: Testing Bioretention Designs

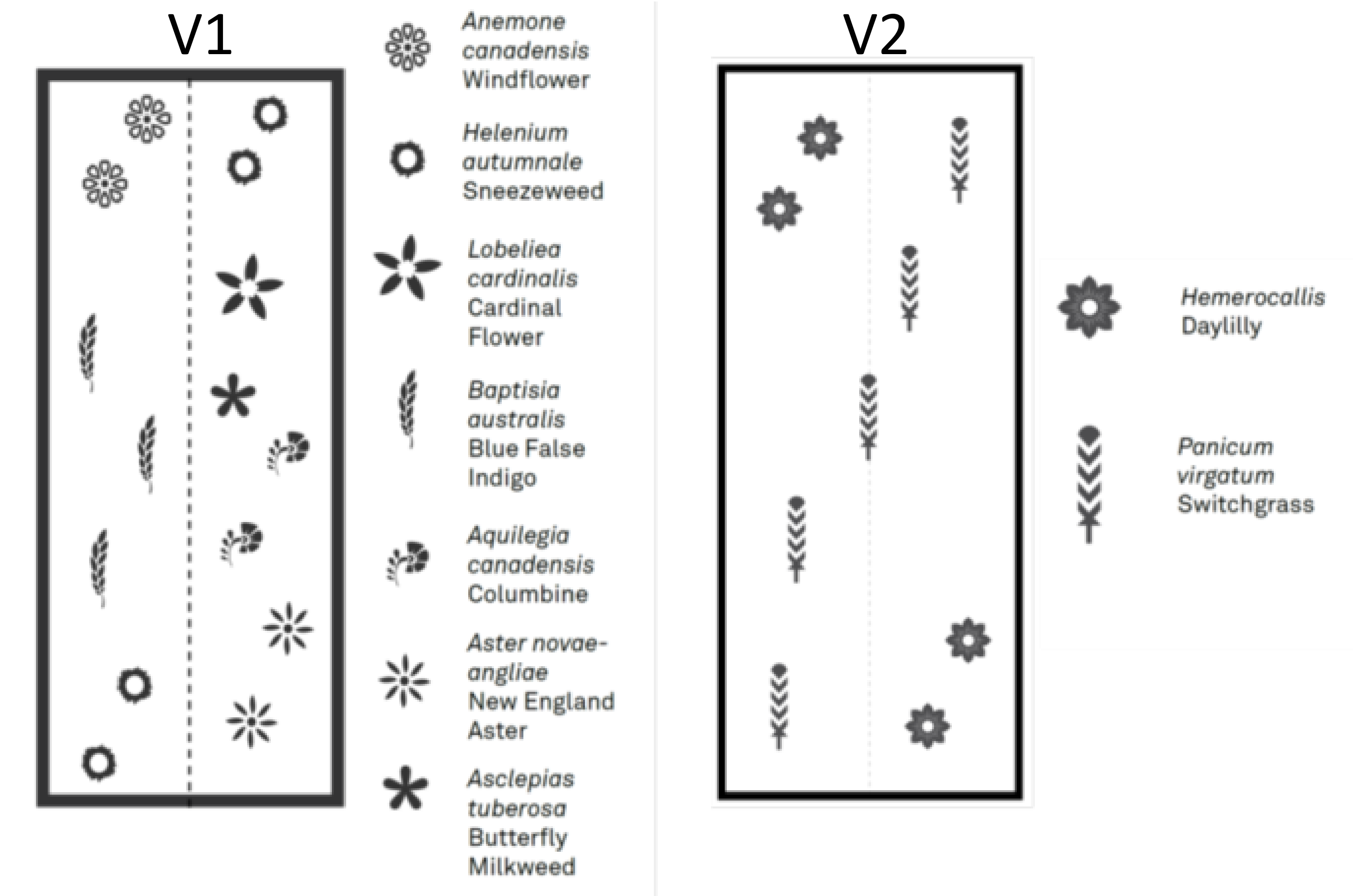
1. Soil Media: Conventional vs. Sorbtive Media™



2. Vegetation: Plant Palette 1 vs. Plant Palette 2



Comparing Vegetation Treatments



Vegetation Palette 1 (left) and Vegetation Palette 2 (right)

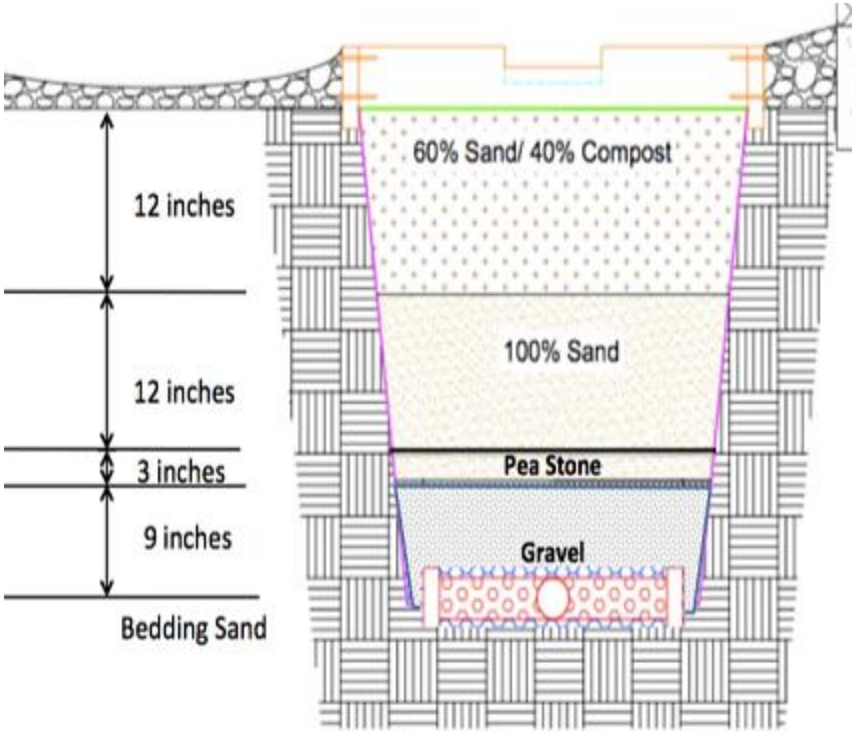
(Diagram created by S. Hurley and A. Zeitz, unpublished).

Vegetation 1 (V1)

Vegetation 2 (V2)

Comparing Soil Media Treatments

Conventional Media (CM)



Sorbtive Media ™ (SM)

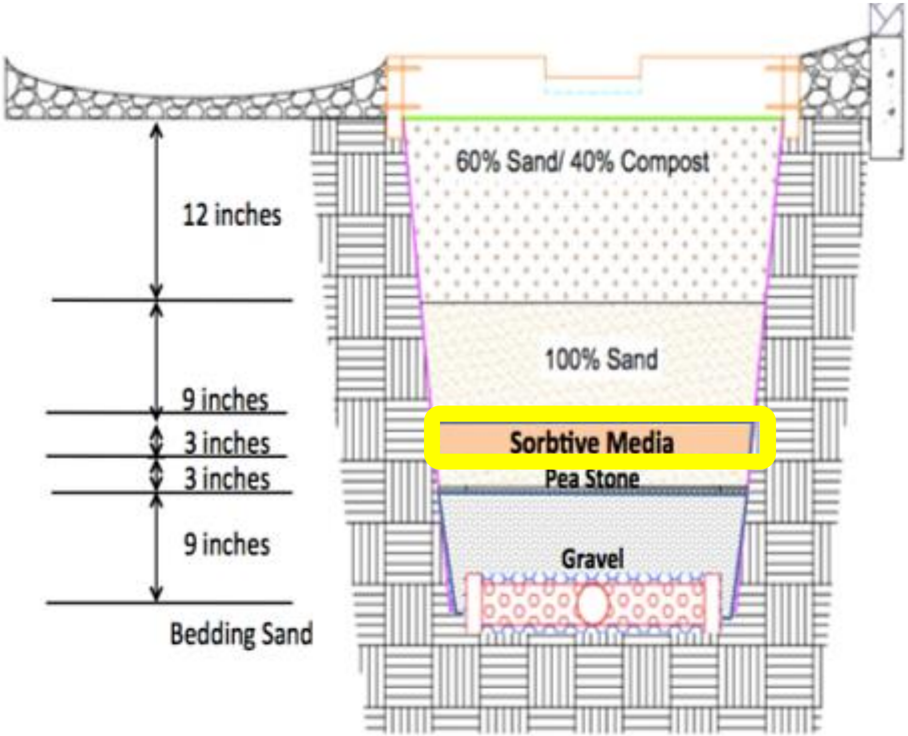


Image Credit: J. Schultz, C. Brackett, J. Nummy, O. Lapierre (unpublished).

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Methods: Measuring Stormwater Quality

Equipment	Parameter	Sampling and Analysis Methods
6700 Series Automatic Samplers (Teledyne™) Model 720 Differential Pressure Transducer	1. TP 2. NLP 3. SRP 4. TN 5. TKN 6. NO_3^- 7. TSS 8. Flow Rate	• Time Based • Discrete Samples • Based on the Hydrograph • Inflow = Every 2 min for 48 min (950 mL) • Outflow = Every 4 min for 96 min (500 mL) • Inflow to Outflow, 20-L increments (n = 6) • Outflow to Outflow, 20-L increments (n = 6) • Partial Event Mean Concentration (PEMC)




Methods: Measuring Bioretention Soil Media Characteristics

Equipment	Parameter	Sampling Method
Soil auger Soil core cylinder Trowel Decagon soil probes	1. NH_4^+ (n = 13) and NO_3^- (n = 13) 2. SRP (n = 7) 3. Bulk Density (n = 11) 4. Ca, K, Mg, Na, S, Mn, Al, Fe, Zn, Cu (n = 7) 5. Cation exchange capacity (CEC) 6. Organic matter content (n = 7) 7. Volumetric water content 8. Electrical conductivity 9. Soil temperature	1. 2 M KCl extraction 2. Modified Morgan 3. Change in mass /volume 4. Inductively coupled plasma spectroscopy 5. Ammonium acetate 6. Loss on ignition (375^oC) 7. Soil probe (Every 5 min) **3 composited sub-samples per bioretention cell**




Step 2: Testing Bioretention Designs

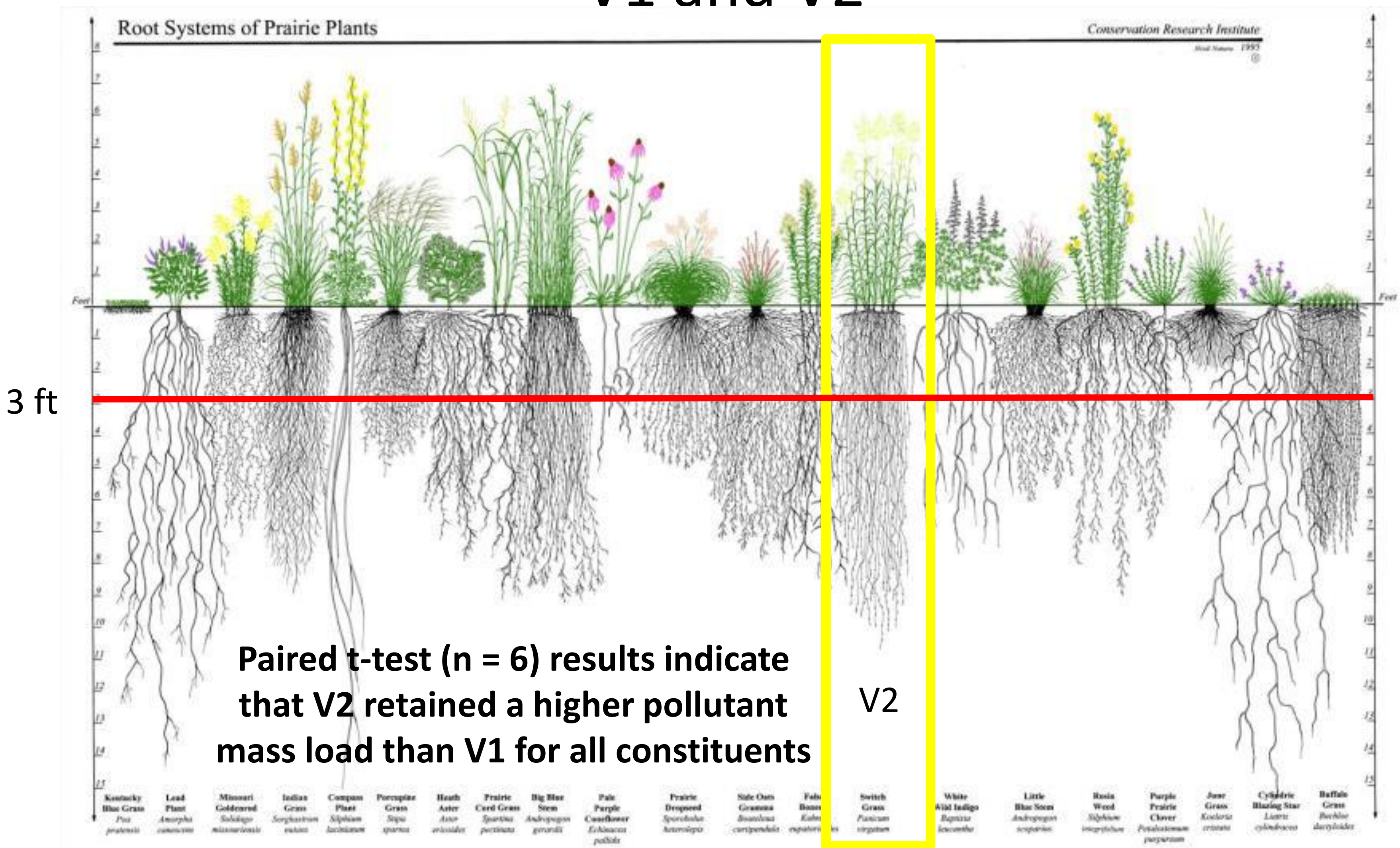
1. Vegetation: Plant Palette 1 vs. Plant Palette 2

2. Soil Media: Conventional vs. Sorbtive Media™

Vegetation 1 (V1)

Vegetation 2 (V2)

Nutrient and Sediment Retention Results: V1 and V2

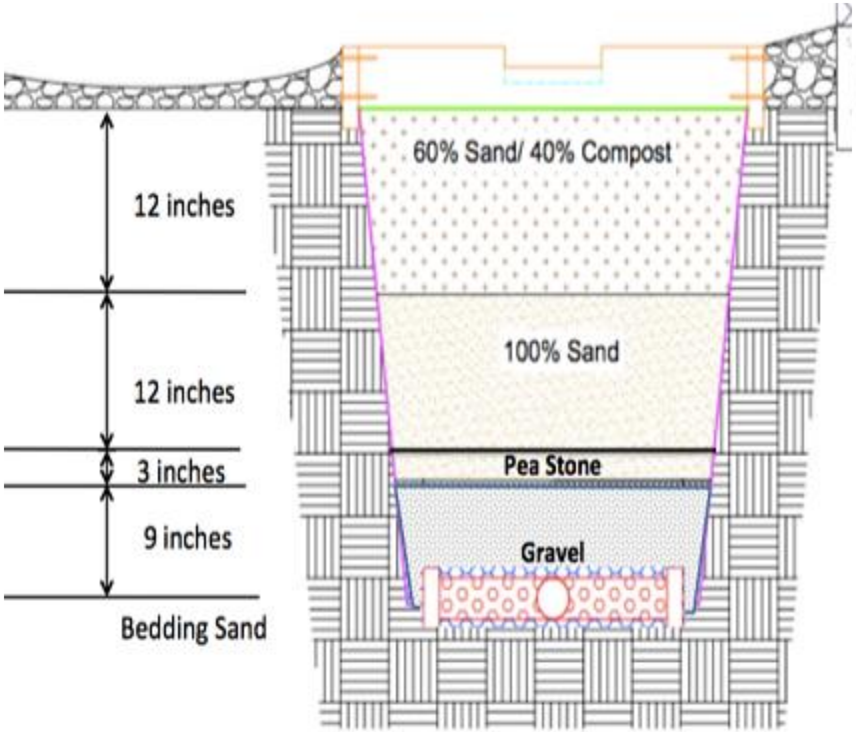


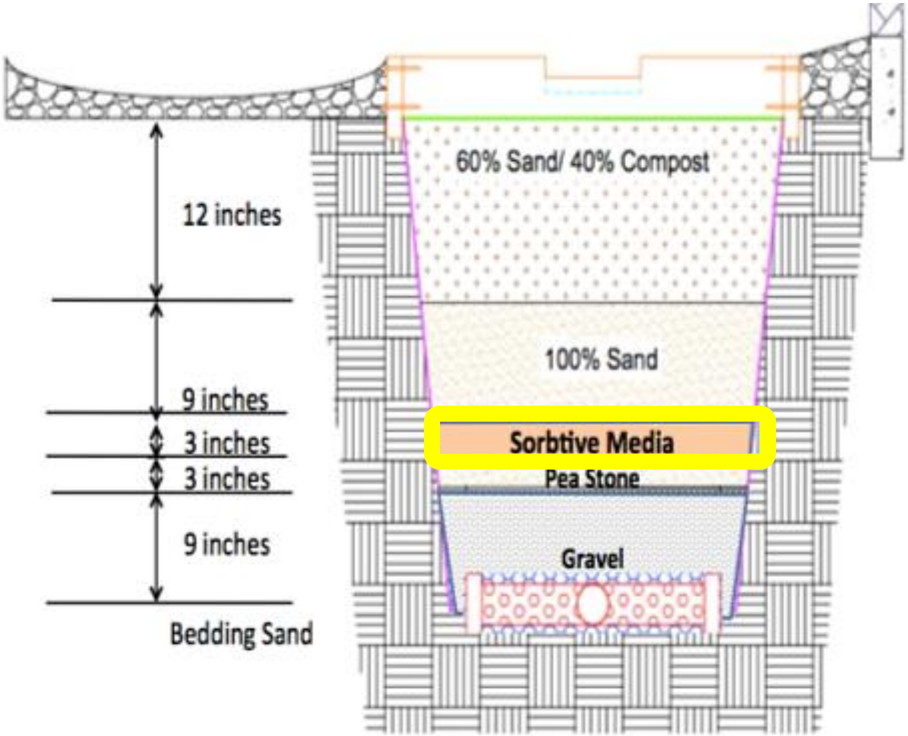
Paired t-test (n = 6) results indicate that V2 retained a higher pollutant mass load than V1 for all constituents

Image Source: Conservation Research Institute; Mann et al. (2013)

Comparing Soil Media Treatments

Conventional Media (CM) | Sorbtive Media ™ (SM)





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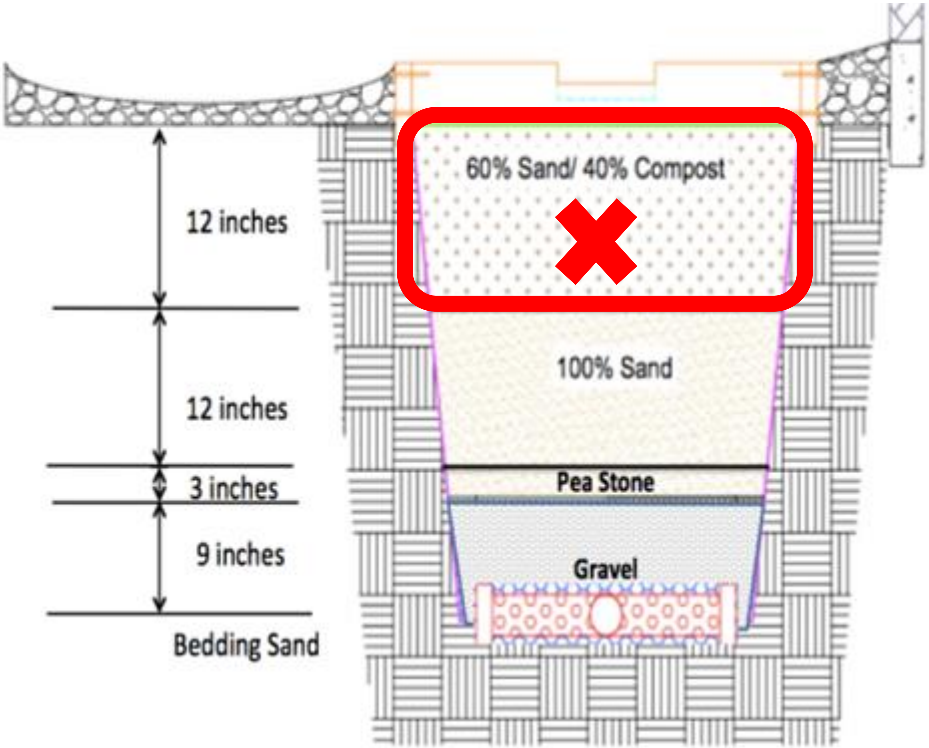
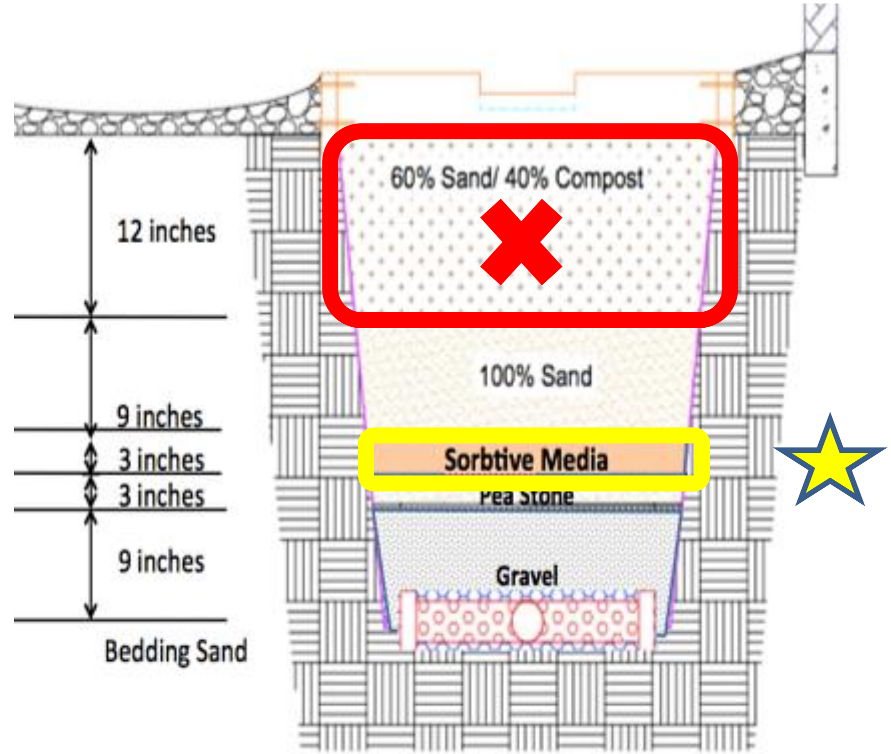
Conventional Media Design

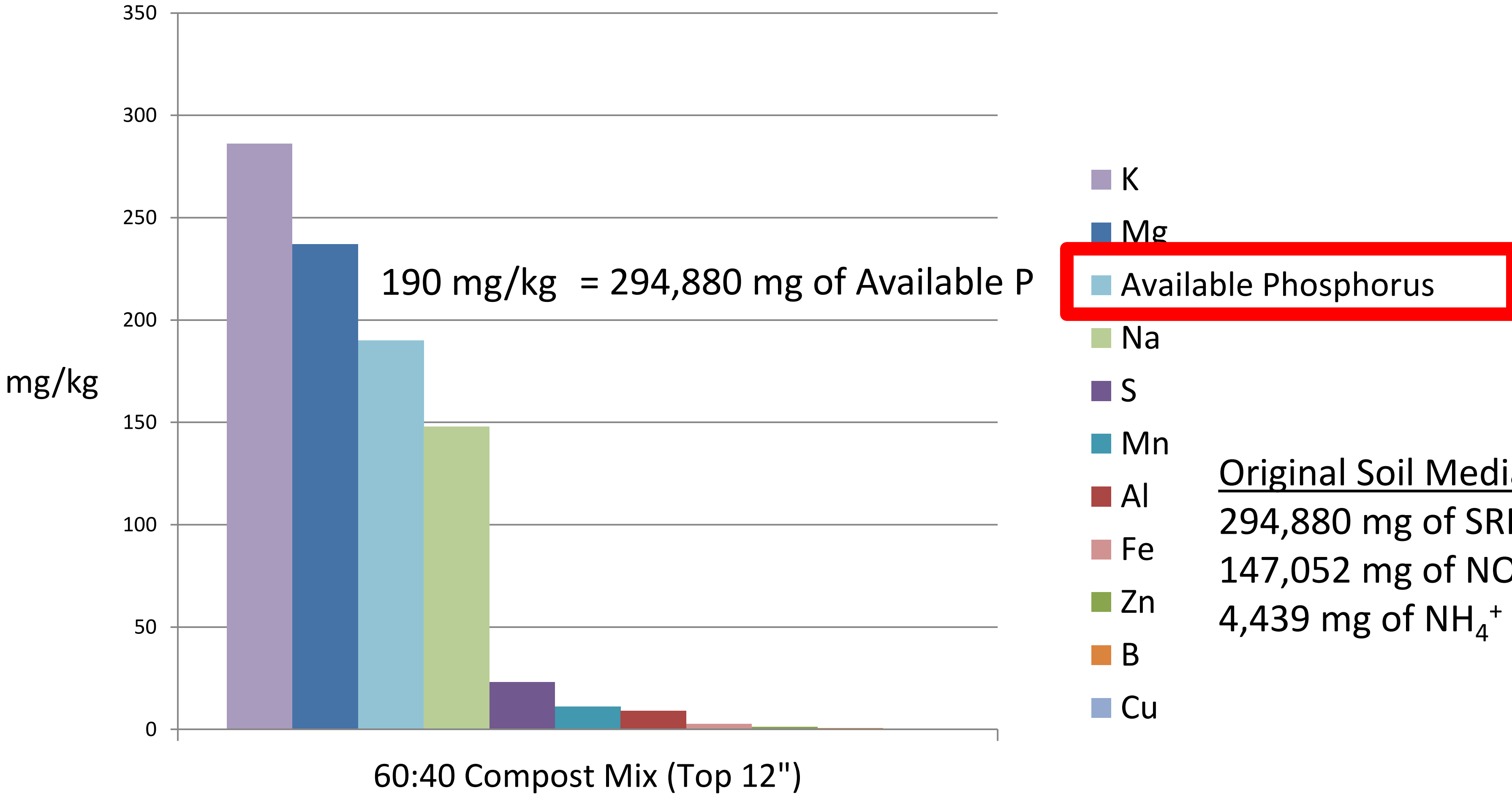


Sorbtive Media Design



1. Sorbtive Media (SM) retained more pollutant mass than Conventional Media (CM) for all constituents except NLP and TKN.
2. Conventional Media (CM) exported SRP and NO_3^-
3. Stormwater runoff contributed less than 5% of the total SRP load from the cells, with the remainder coming from the compost in the soil media
4. NO_3^- mass from stormwater contributed between approximately 10% and 20% of the total load.

Conventional Bioretention Design: 60:40 Sand Compost Mix



<u>Original Soil Media:</u>

294,880 mg of SRP

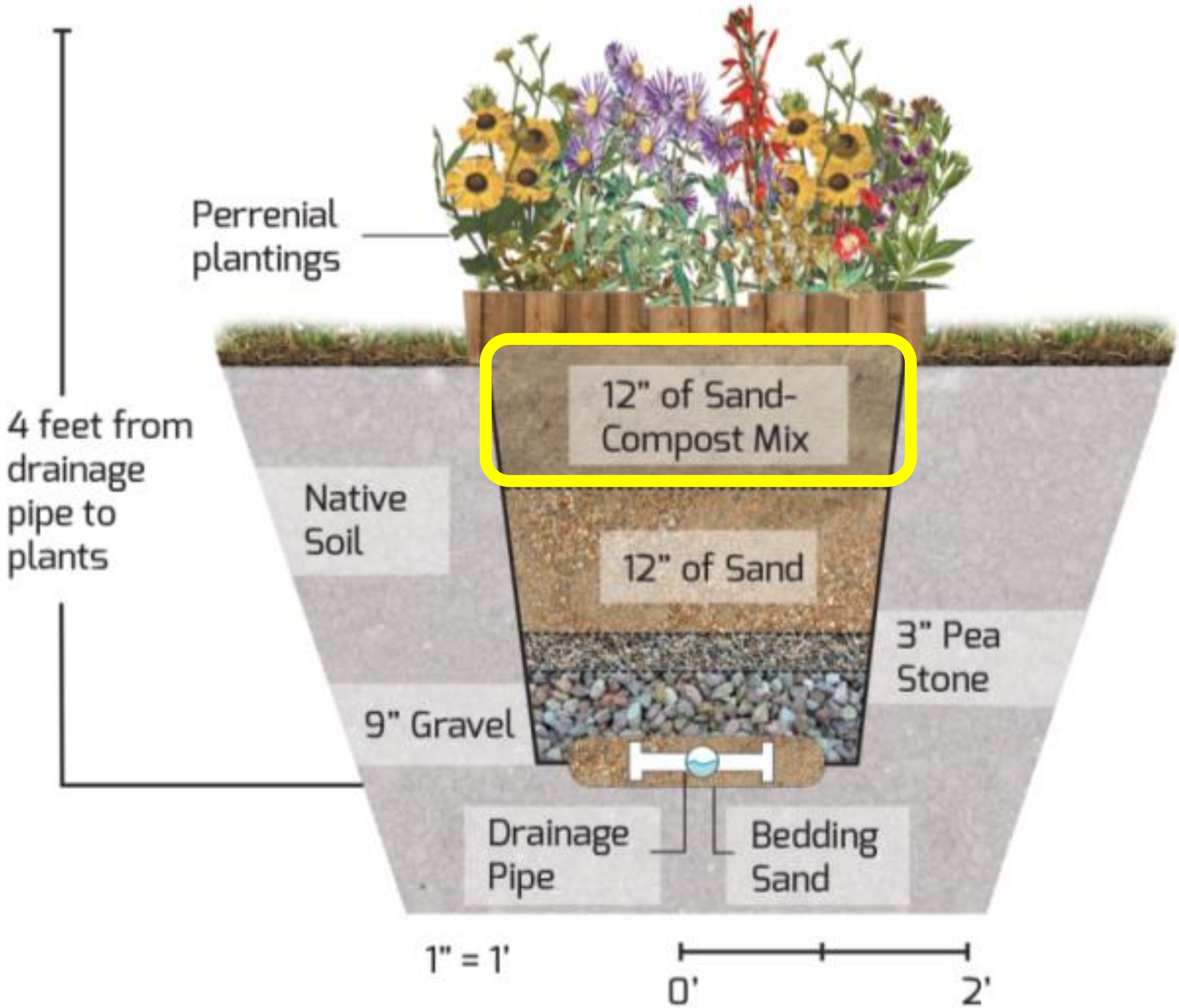
147,052 mg of NO_x

4,439 mg of NH_4^+

Average Outflow Concentrations Compared to the Literature

Parameter	This Study	Literature	Reference
NLP	53 µg L^{-1} (CM)	40 – 800 µg L^{-1} ★	Hunt et al. (2006)
SRP	568 µg L^{-1} (CM)	210 – 670 µg L^{-1} ✓	Geosyntec (2008)
SRP	24 µg L^{-1} (SM)	140 µg L^{-1} ★	Chardon et al. (2005) (Iron Coated Sand)
		< 10 µg L^{-1} ✓	O’Neill and Davis (2011) (WW Treat. Residual)
TKN	376 µg L^{-1} (SM)	1,240 – 1,780 µg L^{-1} ★	Geosyntec (2008)
NO_3^-	227 µg L^{-1} (V2) , 547 µg L^{-1} (V1)	300 – 400 µg L^{-1} ✓	Dietz and Clausen (2006)
TSS	10.20 mg L^{-1} (CM)	15 – 33 mg L^{-1} ★	Geosyntec (2008)

Conventional Bioretention Media Design



Recommended By:

1. Vermont Agency of Natural Resources (2002)

2. Washington State University Pierce County Extension (2012)

3. Center for Watershed Protection

Image Credit: Hurley, S., Zeitz, G.,(unpublished)

Effective Bioretention Requires the Right Soils

<u>Considerations</u>
Textural Class
Infiltration Rate
CEC/AEC
Fe, Ca, or Al
pH

Availability
Cost

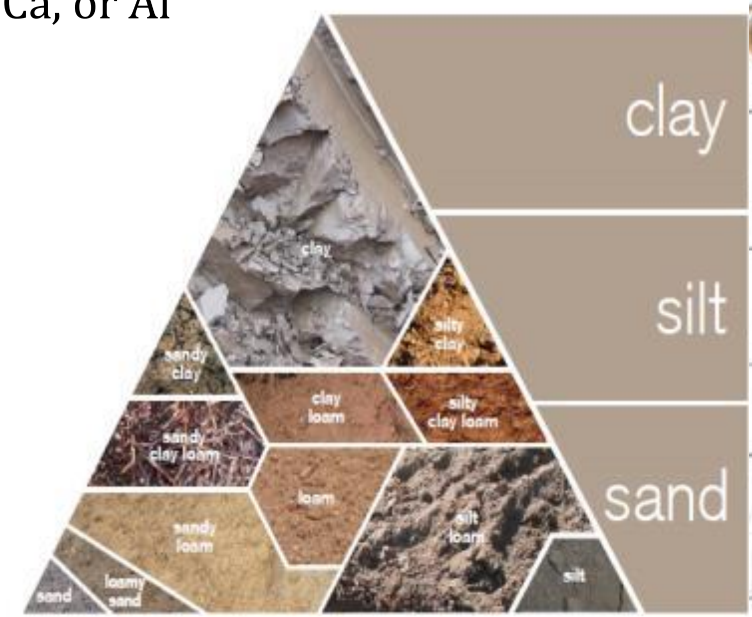


FIGURE 2.2 - SOIL TEXTURE TRIANGLE

Source: University of Arkansas Community Design Center. Image Credit: A. Cording

Media Infiltration Rates

Reference	Infiltration Rate
This study	Modelled Rate at Installation: 131 cm hr^{-1}
Arias et al (2001)	Actual Rate: 463 cm hr^{-1}
Brix et al. (2001)	Actual Rate: 92 cm hr^{-1}
Chen et al (2013)	Actual Rate: 1.3 cm hr^{-1}
Davis et al. (2009)	Recommends > 2.5 cm hr^{-1}
Debusk et al. (2011)	Actual Rate: 11.8 cm hr^{-1}
Dietz and Clausen (2005)	Design Rate: 10 – 13 cm hr^{-1}. Actual Rate: 3.5 cm hr^{-1}
Hatt et al. (2008)	Actual Rate: 26.028 cm hr^{-1} to 232.92 cm hr^{-1} in different treatments
Hunt et al. (2006)	Actual Rate: 7.62 cm hr^{-1} to 38.1 cm hr^{-1}
Li and Davis (2008)	Actual Rate: Reduction from 43 – 164 cm hr^{-1} to 3-11 cm hr^{-1}
Lucas and Greenway (2011)	Vegetated: 27.7 cm hr^{-1} to 59.6 cm hr^{-1}
Thompson et al. (2008)	Actual Rate: 150 to 178 cm hr^{-1} (sand/compost mix)
Washington State University Pierce County Extension (2012)	Recommends > 2.54 cm hr^{-1}

Soil Orders In Hawaii

Prepared by Hue, Ikawa & Yost
Graphics was prepared by Miles Hakoda

Andisol

Kula Series, Maui — Hilo Series, Hawaii

Andisols are soils derived from volcanic ash. The less weathered Kula soil on Maui is quite productive, while the Hilo soil on the Big Island is highly weathered and requires lots of fertilizers for crop production.

Aridisol

Kawaihae Series, Hawaii

Aridisols are soils of the arid areas or soils with high salt content. The Kawaihae soil of the Big Island has features of an arid area of light color, low organic matter, and shallow depth.

Entisol

Jaucas Series, Maui

Entisols are least-developed soils showing only a weak surface development. The calareous Jaucas soil on Maui is an example with sandy texture, and excessive drainage.

Histosol

Papai Series, Hawaii — Alakai Series, Oahu

Histosols are organic soils with a high organic matter content in the surface horizon. The Papai soil on the Big Island has lost almost all of the surface organic matter (OM), but the Alakai soil atop Mt. Kaala on Oahu is high in OM.

Inceptisol

Kolekole Series, Oahu

Inceptisols are soils showing minimal development of soil horizons. The Kolekole soil on Oahu is an example.

Mollisol

Kawaihapai Series, Oahu — Makawele Series, Kauai

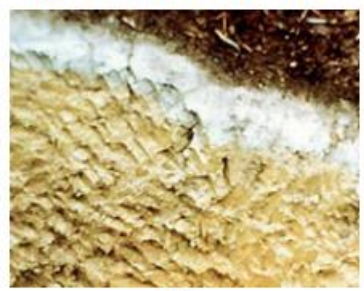
Mollisols are fertile soils with high organic C and high base saturation. Although the Kawaihapai soil on Oahu is dark, the Makawele soil on Kauai is red because of Fe oxides.

Oxisol

Halii Series, Kauai

Oxisols are the most weathered soils of the tropics with low nutrient holding capacity and high Fe and Al oxides. The Halii soil on Kauai is an example.

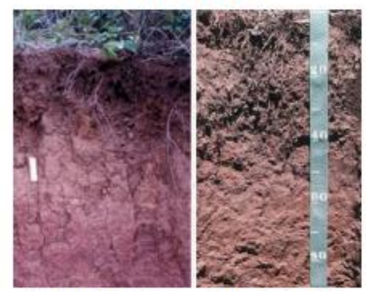
Spodosol-like soil



Oahu

Spodosols are soils with leached Al, Fe, and organic materials in the subsoil, showing a distinct layer.

Ultisol



Alaeloa Series, Oahu — Haiku Series, Maui

Ultisols are highly weathered infertile soils with clay accumulation in the subsoils. Examples are Alaeloa soil on Oahu and Haiku soil on Maui.

Vertisol

Lualualei Series, Oahu

Vertisols are soils that shrink when dry and swell when wet. They usually occur in valleys with poor drainage. They are fertile, but pose severe limitations for roads, housing, and related uses. The Lualualei soil on Oahu is an example.


Fossil fuel
Emission
Protein

Conclusions

1. The majority of nutrient mass in runoff from the paved road surface was found to be largely particulate N and P, as opposed to the soluble component.

2. The first flush (0.5 inches) was not found to mobilize the majority of pollutant mass from the paved road surface, for particulate or soluble N and P, or TSS.

3. Bioretention consistently reduce peak stormwater flow rates and volumes.

4. Non-labile nutrient and sediment removal by bioretention is considerable as a result of physical filtration within the soil media.

5. Deep rooted, fine textured roots (*Panicum Virgatum*) provided greater soil stability and access to soil nutrients throughout the profile.

6. Organic amendments (compost) added labile nutrient mass loads which far exceed loads from stormwater from a medium traffic paved road surface, and need to be limited.

7. Sorbtive Media™ was extremely effective at removing SRP, and may have influenced nitrate removal, although mechanisms are not fully understood.

8. Nitrate reduction through extended retention time in an anaerobic zone can provide significant denitrification but optimal conditions necessary are yet to be determined.

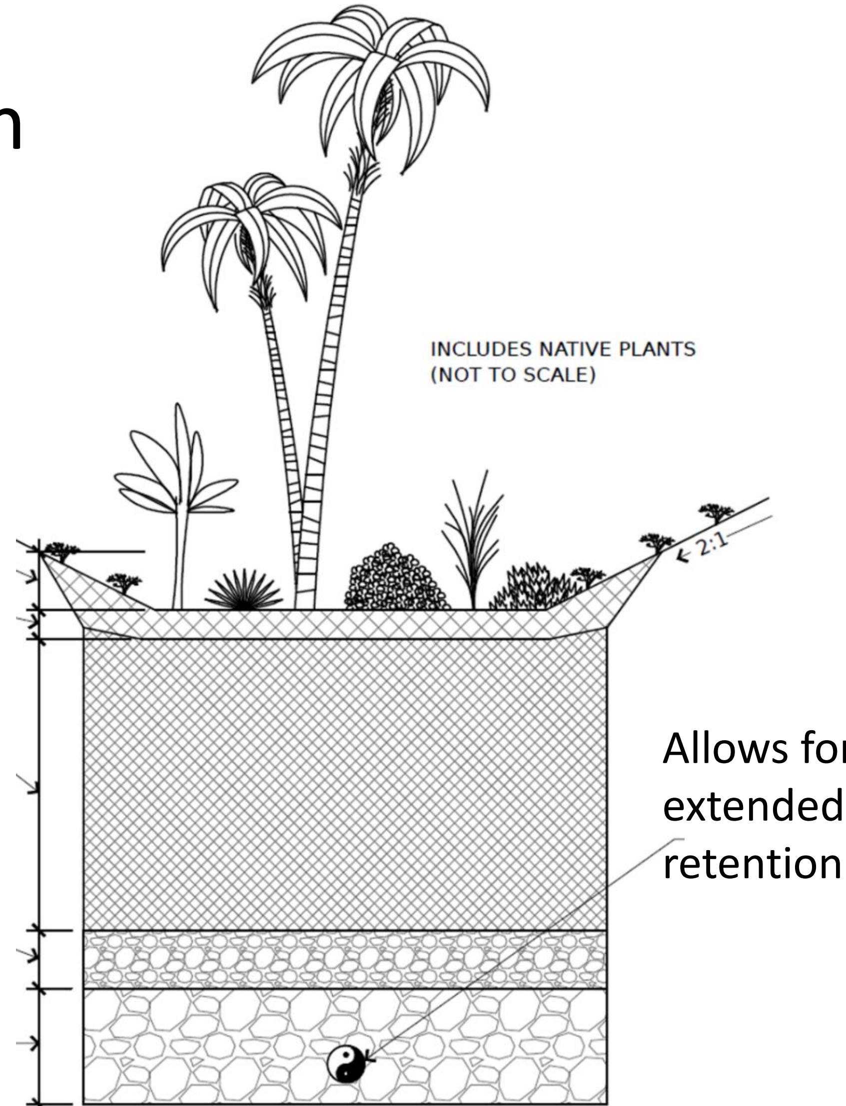
Effective
Bioretention (LID) Design

Native Soil Blend:
Target Infiltration Rate 2.5 - 100 cm/hr
High Mineral Contents (Ca, Fe)

Extended Retention, NO_3^- Removal:
Target Retention Time > 6hrs

Native Plants:
Target >75% Cover
Target Root Depths 1 to 4 ft

- <u>No Compost</u>
- Mulch or Stone Top Dressing



Future Research

1. Retention time and labile carbon needed for efficient nitrate (NO_3^-) removal

2. Soil blends – getting the right mix of minerals and permeability

3. Planting pallets – maximizing pollutant removal, root depth, surface area, survivability and aesthetics

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Mahalo nui!

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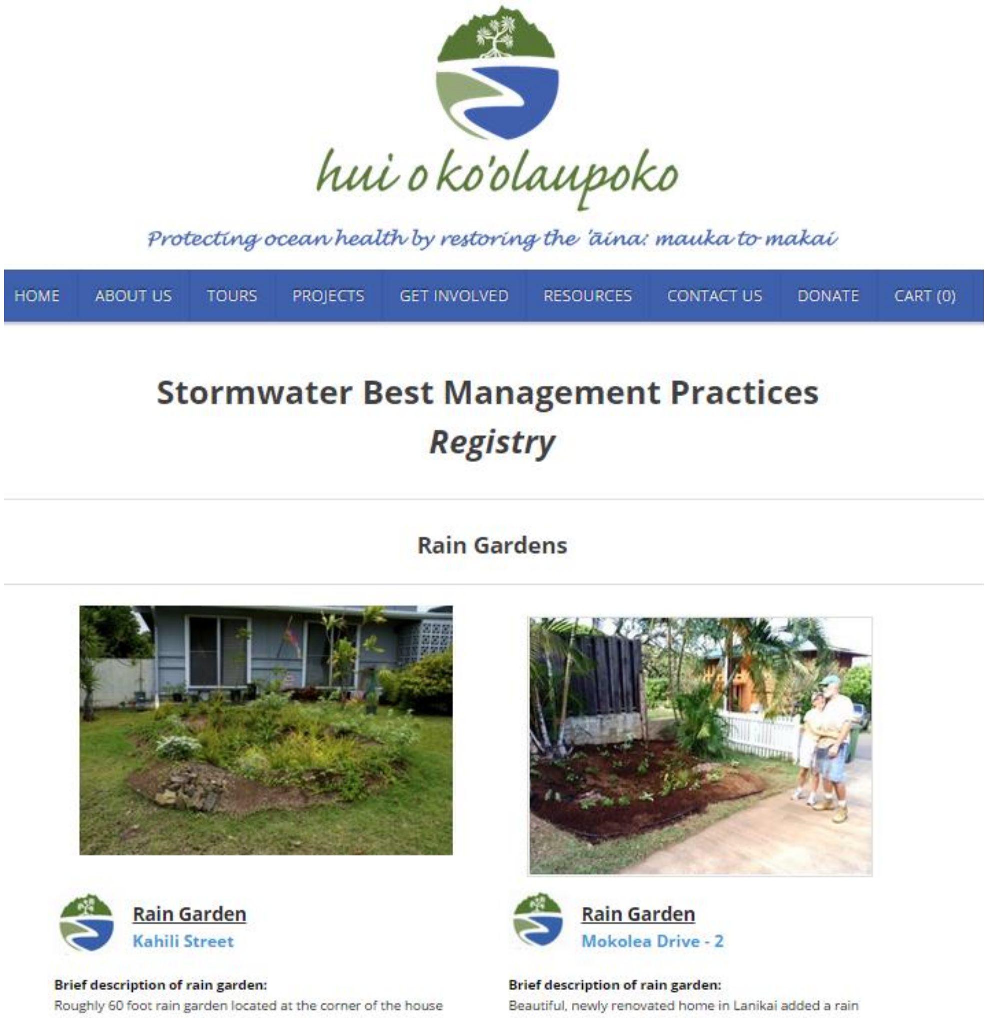
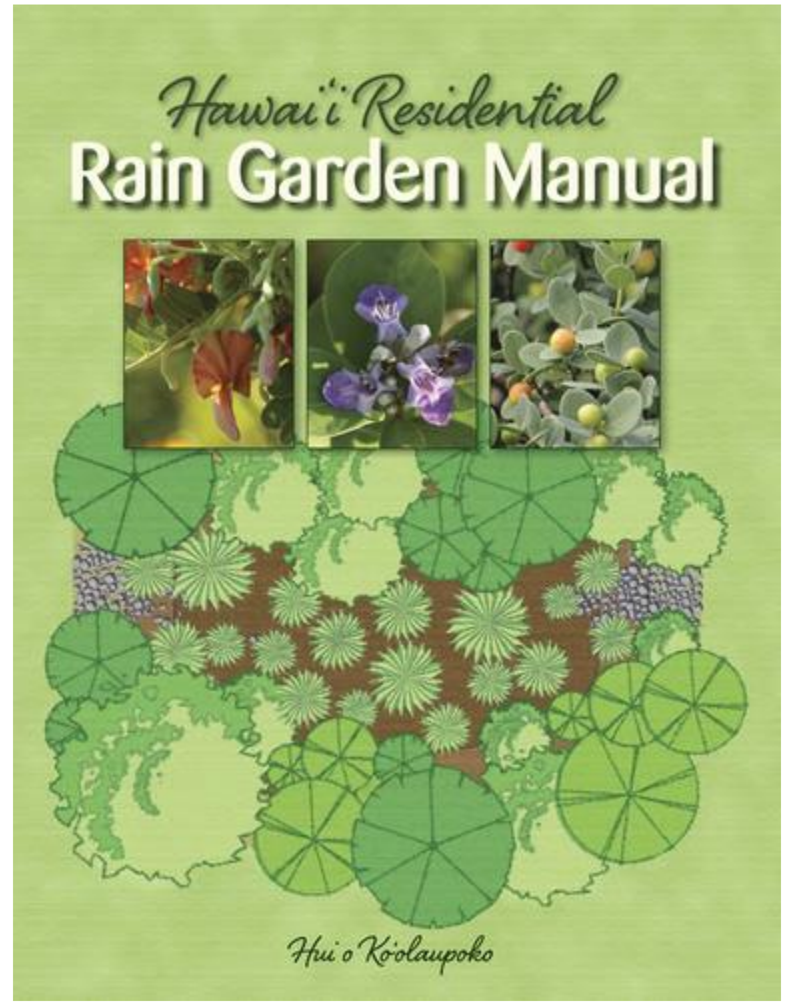
Local Resources





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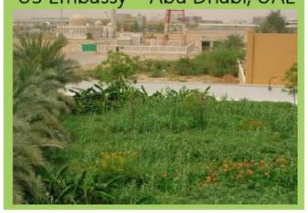

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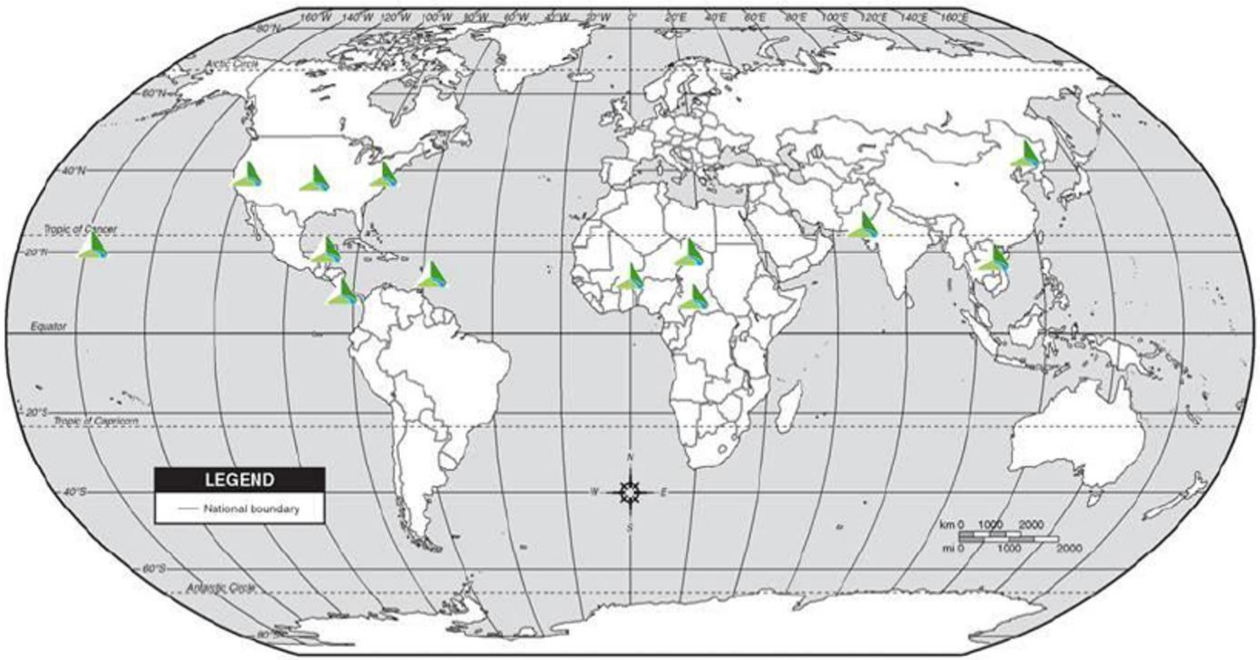

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