Agenda for the Day

Welcome and Introductions

Stormwater Innovation Center as a local resource

Basic Hydrology

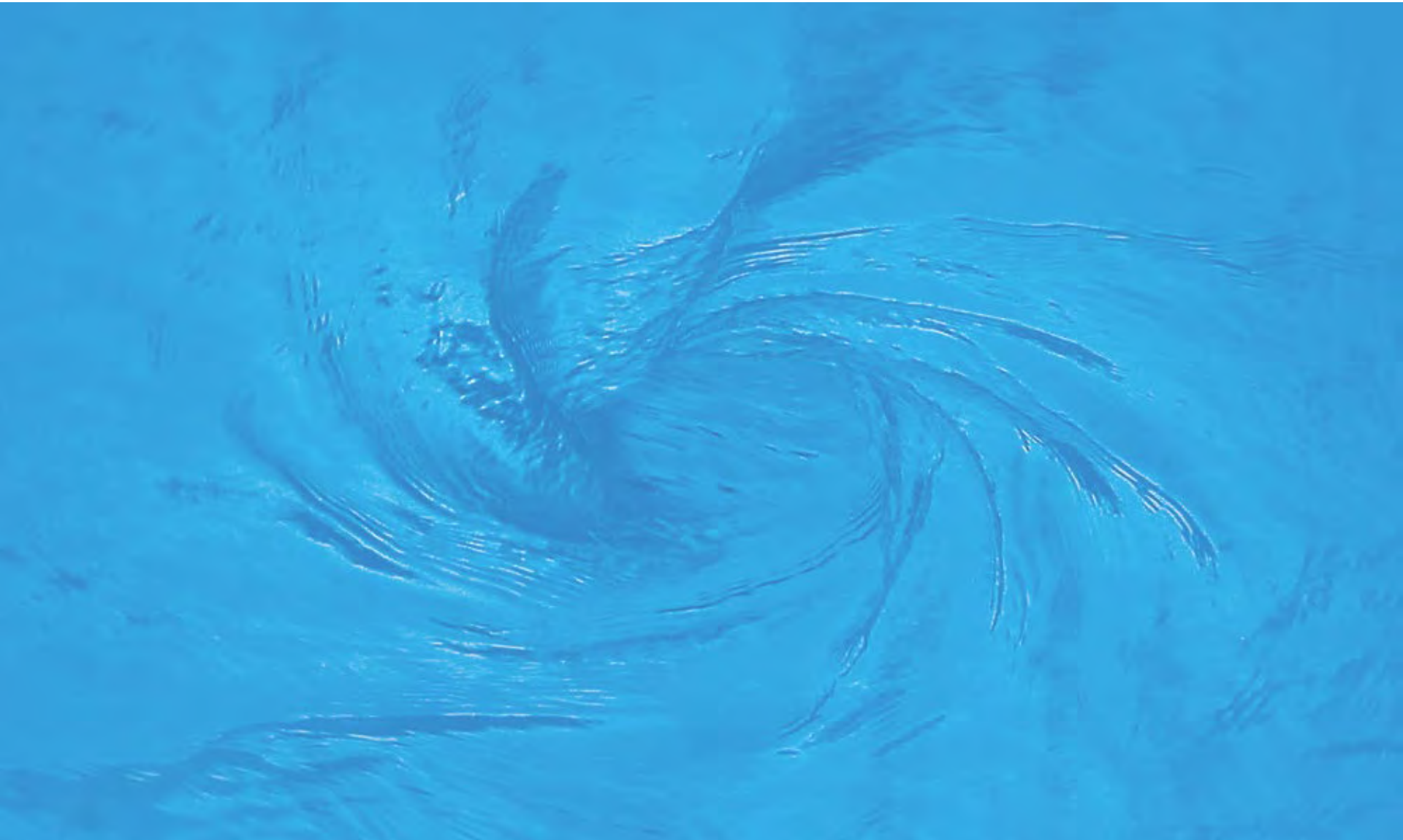
Pretreatment

Filtration BMPs

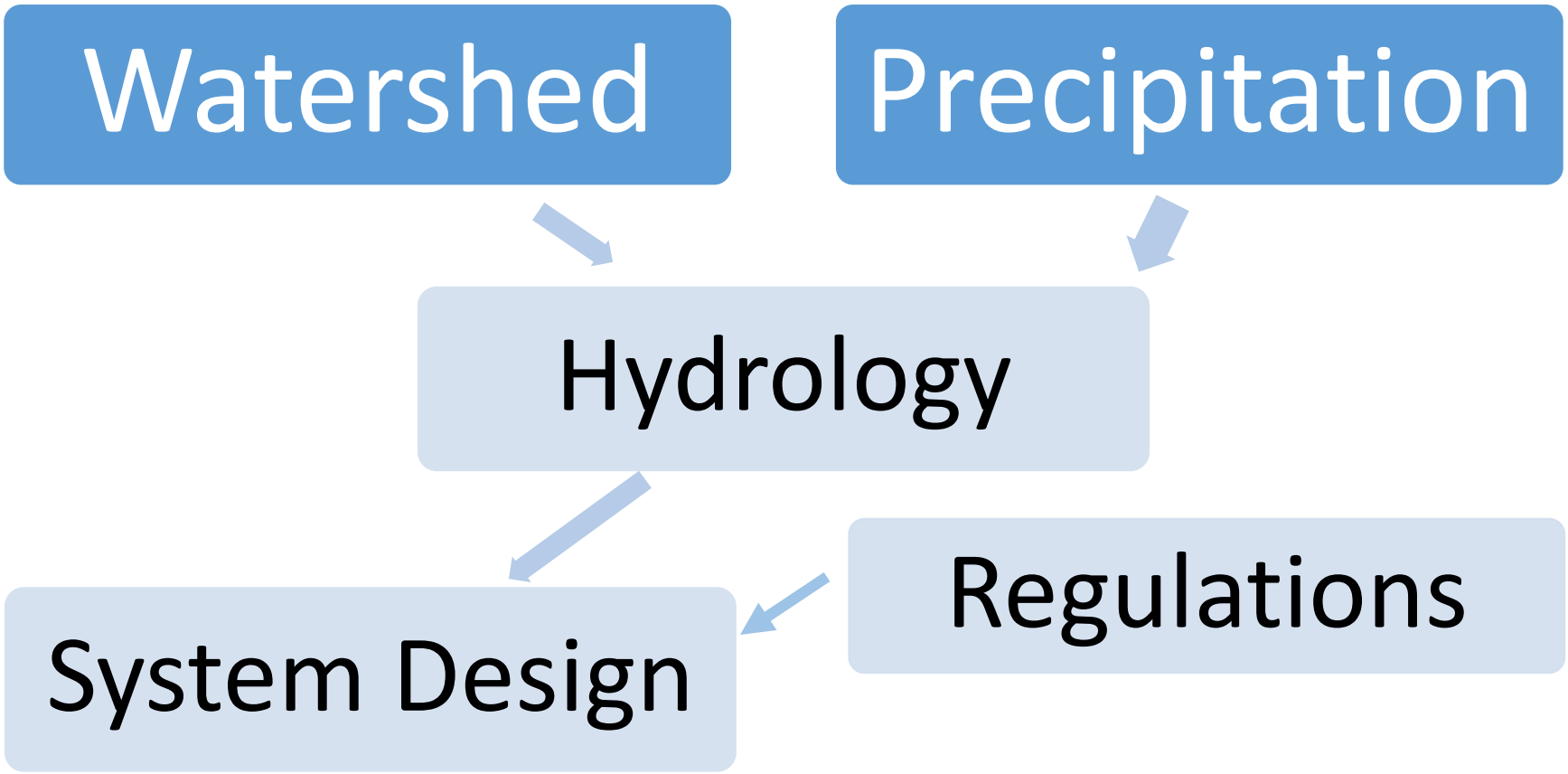
Infiltration BMPs

Other Treatment Systems

Hydrology



Players


Watershed
Precipitation
Hydrology
Regulations
System Design

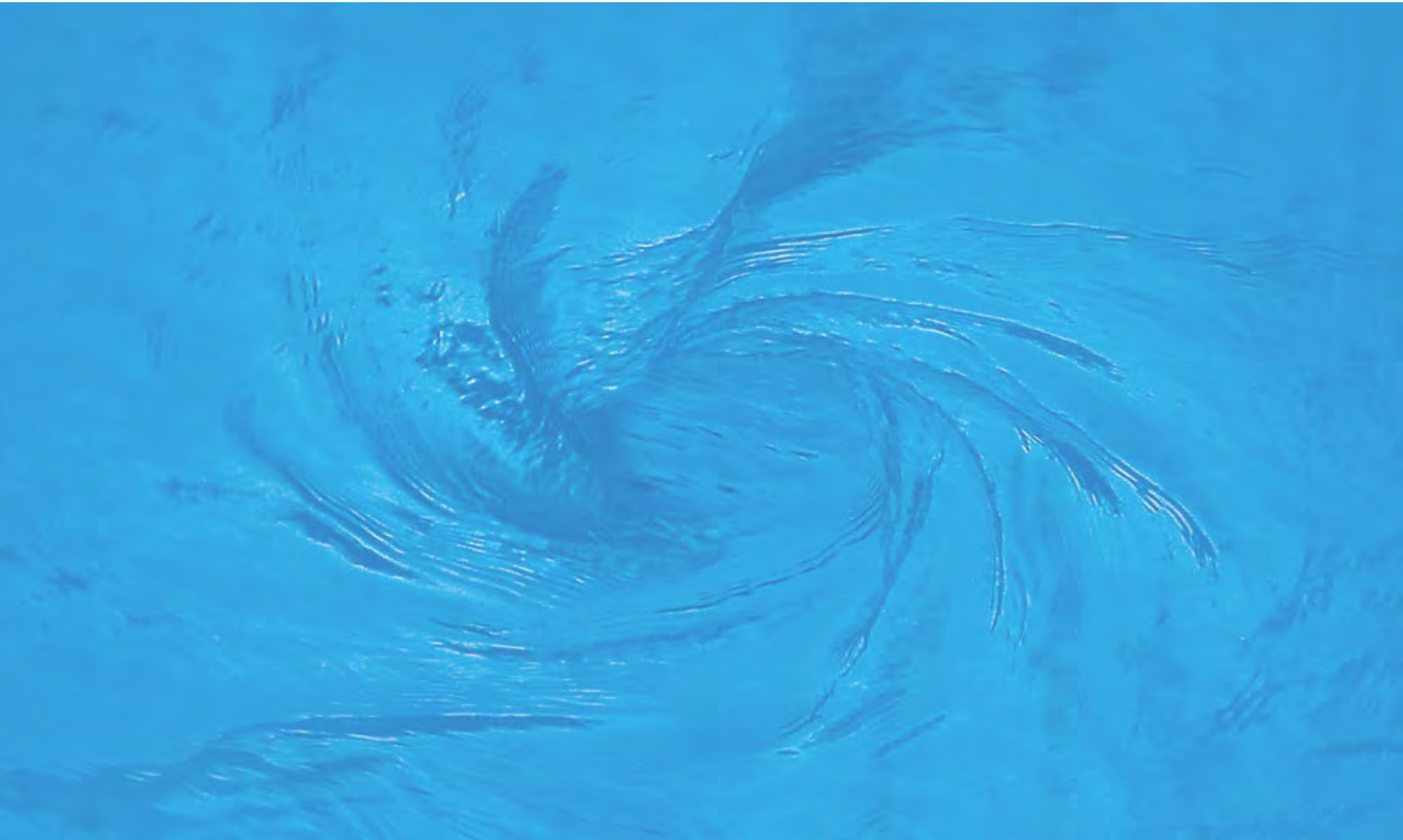
Design Fundamentals

Just like you can't design a bridge without a design load capacity you can't design a stormwater system without a design load – in this case the hydrology

Data Needs

- Slope
  - Watershed
  - Drainage network
- Flow Path
  - Longest distance
  - Longest time
- Soil Type(s)
- Land Use
- Vegetation
- Precipitation

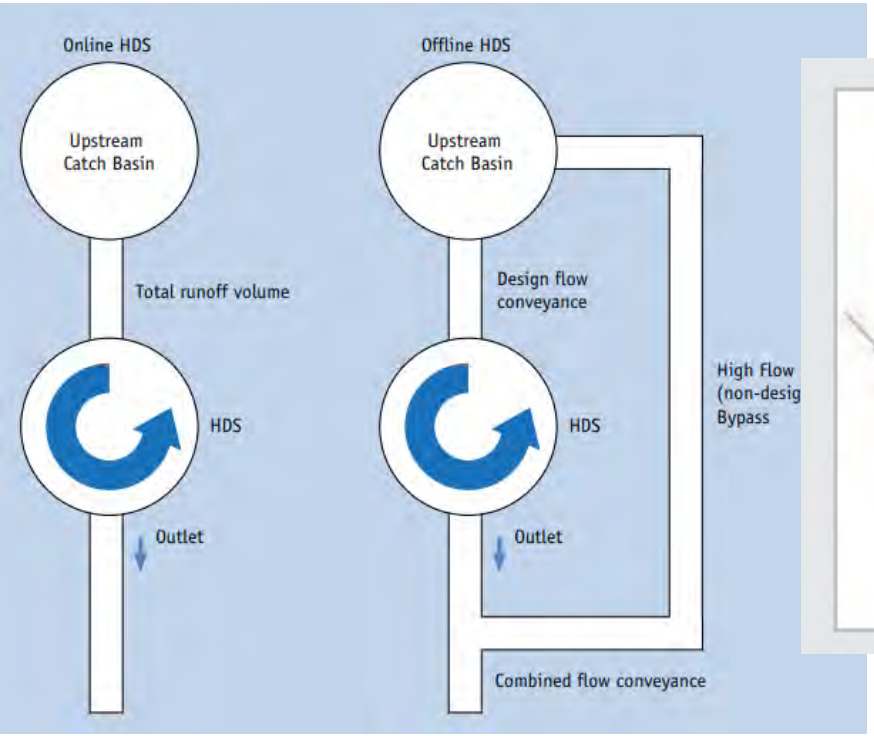
A Note about pretreatment

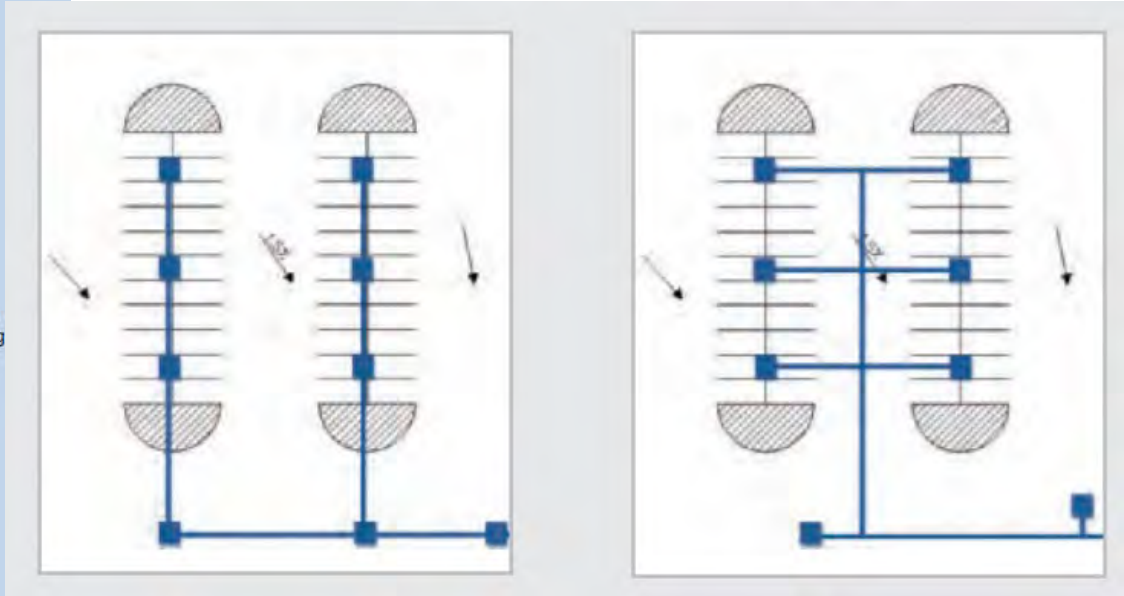


Pretreatment is good

- Pretreatment is intended to enhance operation and maintenance.
- Design should target enhanced O&M

Online vs Offline Configuration





Pretreatment Objective

The goal is that we have a viable and maintainable pretreatment access point.

This is the design parameter

The regulations should not redesign

The regulations should ensure maintainability of the pretreatment approach

Tree Pod pretreatment study





Event Date	Sediment			Total Petroleum Hydrocarbons - Diesel				Total Zinc			
	Total Mass (g)	Influent Load* (g)	Removed by Pre-Filter (%)	Conc (µg/g)	Total Mass (g)	Influent Load* (g)	Removed by Pre-Filter (%)	Conc (µg/g)	Total Mass (g)	Influent Load* (g)	Removed by Pre-Filter (%)
6/22/2012	2,458			950	2.33	21.2	11%	48	0.12	1.47	8%
8/5/2012	67	152	44%	3,400	0.23			89	0.01	0.05	13%
8/10/2012	1,097	76,206	1%	610	0.67	61.7	1%	40	0.04	2.77	2%
8/28/2012	1,974	2,560	77%	1,800	3.55			47	0.09	2.67	3%
9/8/2012	392	13,964	3%	2,700	1.06	5.2	20%	45	0.02	0.25	7%
9/18/2012	927	2,471	38%	1,900	1.76	24.4	7%	52	0.05	1.03	5%
9/28/2012	158	1,625	10%	6,900	1.09			140	0.02	1.02	2%
10/6/2012	78	398	20%	9,700	0.76	10.9	7%	240	0.02	0.37	5%
10/19/2012	1,675	11,986	14%	750	1.26	45.4	3%	36	0.06	0.63	10%
10/29/2012	1,033	9,292	11%	6,300	6.51	79.9	8%	150	0.15	3.26	5%
12/8/2012	176	400	44%	7,400	1.30	9.3	14%	110	0.02	0.17	12%
Average			26%				9%				6%

Event Date	Total Phosphorus				Total Nitrogen			
	Conc (µg/g)	Total Mass (g)	Influent Load* (g)	Removed by Pre-Filter (%)	Conc (µg/g)	Total Mass (g)	Influent Load* (g)	Removed by Pre-Filter (%)
6/22/2012	280	0.69	3.75	18%	910	2.24	32.6	6.9%
8/5/2012	760	0.05	0.43	12%	2,900	0.19		
8/10/2012	310	0.34	4.85	7%	220	0.24	110.8	0.2%
8/28/2012	160	0.32	11.20	3%	1,100	2.17	80.0	2.7%
9/8/2012	230	0.09	0.82	11%	500	0.20	11.5	1.7%
9/18/2012	250	0.23	2.75	8%	680	0.63	20.6	3.1%
9/28/2012	300	0.05	2.54	2%	2,900	0.46	45.7	1.0%
10/6/2012	590	0.05	0.37	12%	6,800	0.53	17.4	3.1%
10/19/2012	190	0.32	1.26	25%	260	0.44	50.5	0.9%
10/29/2012	490	0.51			5,800	5.99	146.7	4.1%
12/8/2012	380	0.07	0.50	13%	1,200	0.21	23.3	0.9%
Average				11%				2%

*Influent Load is the Aqueous Phase Pollutant Mass Load (APPM)

Questions



Providence Stormwater Innovation Center

PROVIDENCE PARKS & RECREATION play · relax · explore

THE UNIVERSITY OF RHODE ISLAND

Audubon Society of Rhode Island

RESTORE AMERICA'S ESTUARIES

University of New Hampshire

The Nature Conservancy

SNEP

Stormwater BMPs

Filtration BMPs

Infiltration BMPs

Basic Stormwater Controls

- **Retention and Detention ponds**
- **Swales**

Conventional BMPs

- **Bioretention systems/tree filters**
- **Sand Filters**
- **Subsurface gravel wetland**

Conventional BMPs

- **Manufactured Treatment Devices**

(filters, chamber systems, subsurface i

- **Porous pavements**

Conventional BMPs

Bioretention and Similar Systems





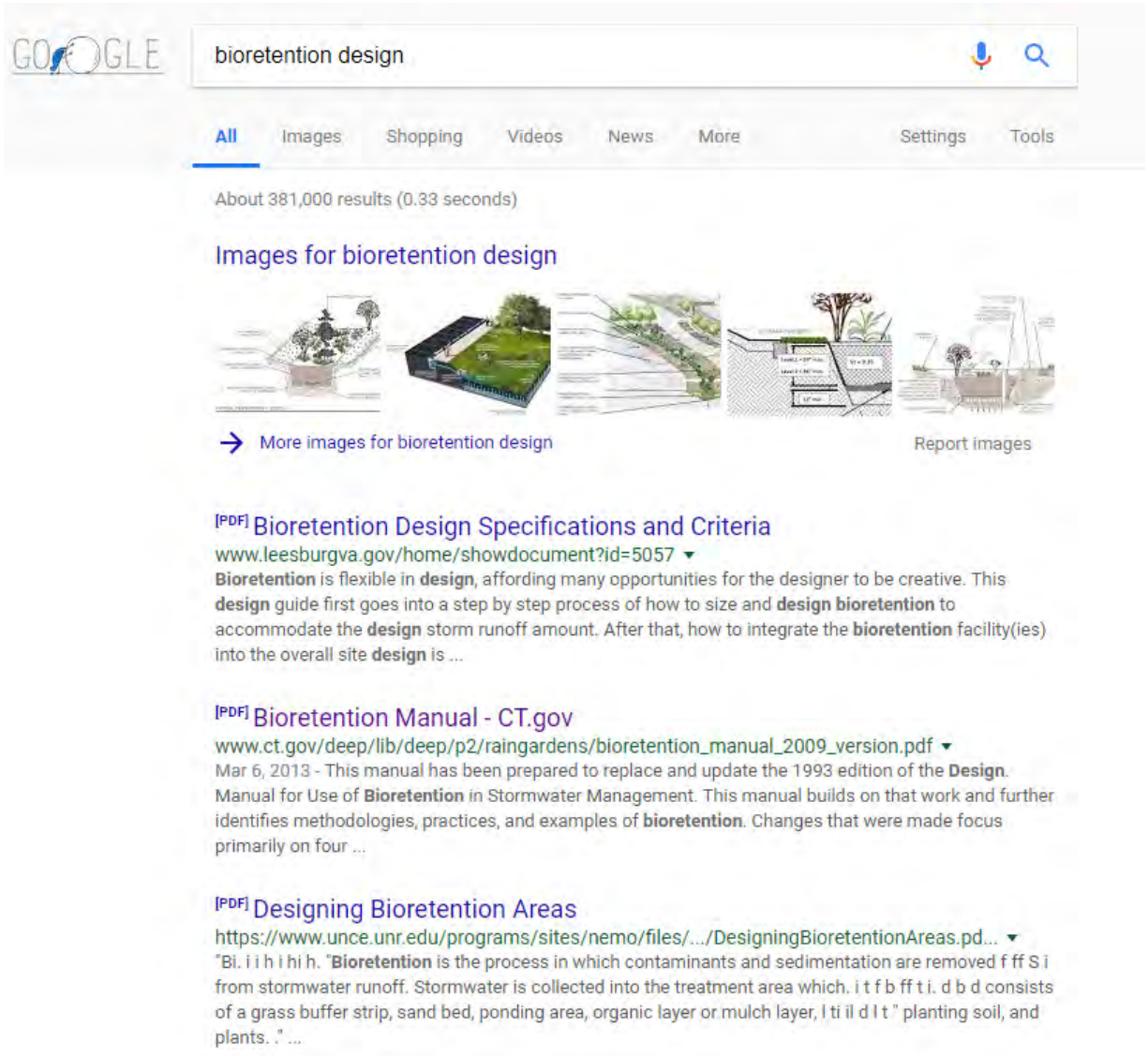


Terminology

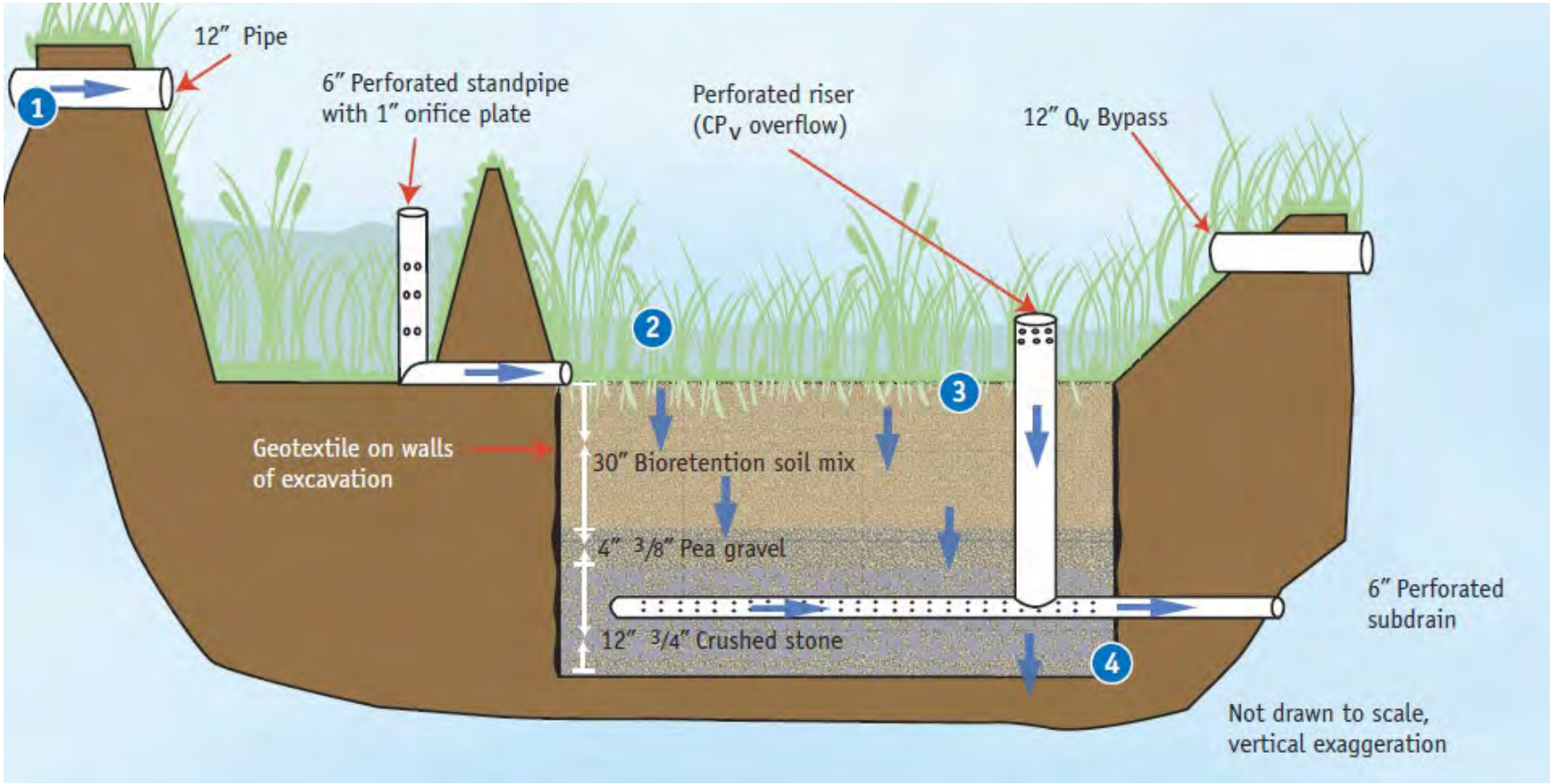
- Bioretention – Holds WQV. Typically has underdrain, high flow bypass, and hydraulic design
- Rain garden – Holds WQV or less. Commonly for very small watersheds (residential), often do not have an underdrain
- Tree filter – Very little storage. Urban installations include high rate media designed on WQF. For Very small drainage areas, underdrain to storm sewer

“Bioretention Design”

- 381,000 results!



Bioretention Cross Section



Main Cell



Forebay



Bioretention Retrofit



Retrofit in A Soil



Bump-out Internal Weir and Overflow



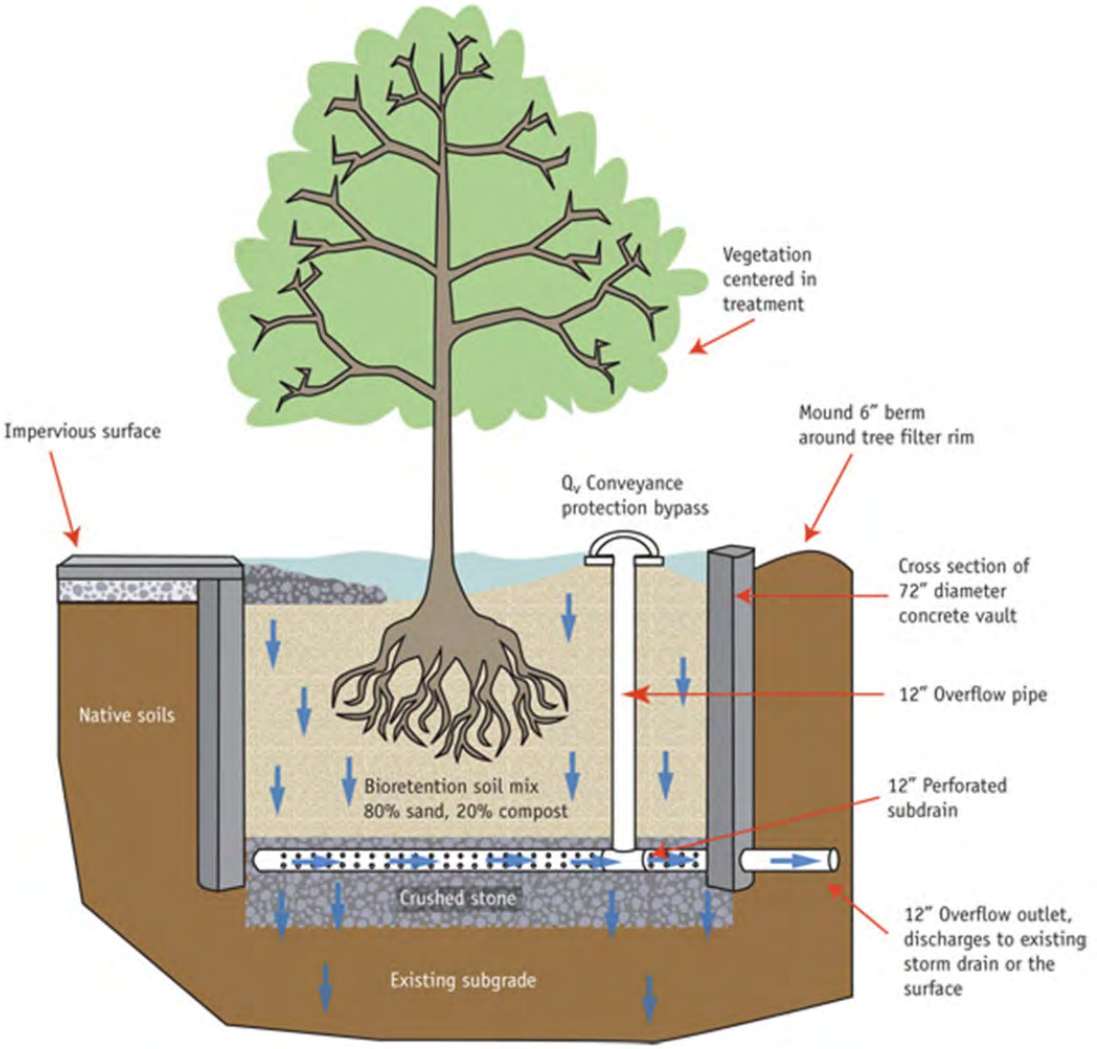
Bump-out Secondary Spillway



Bump-out Plumbed to Existing Drainage



The Street Tree



Street Tree New Construction



Street Tree Design Storm



Street Tree Retrofit – Coakley Road Portsmouth, NH

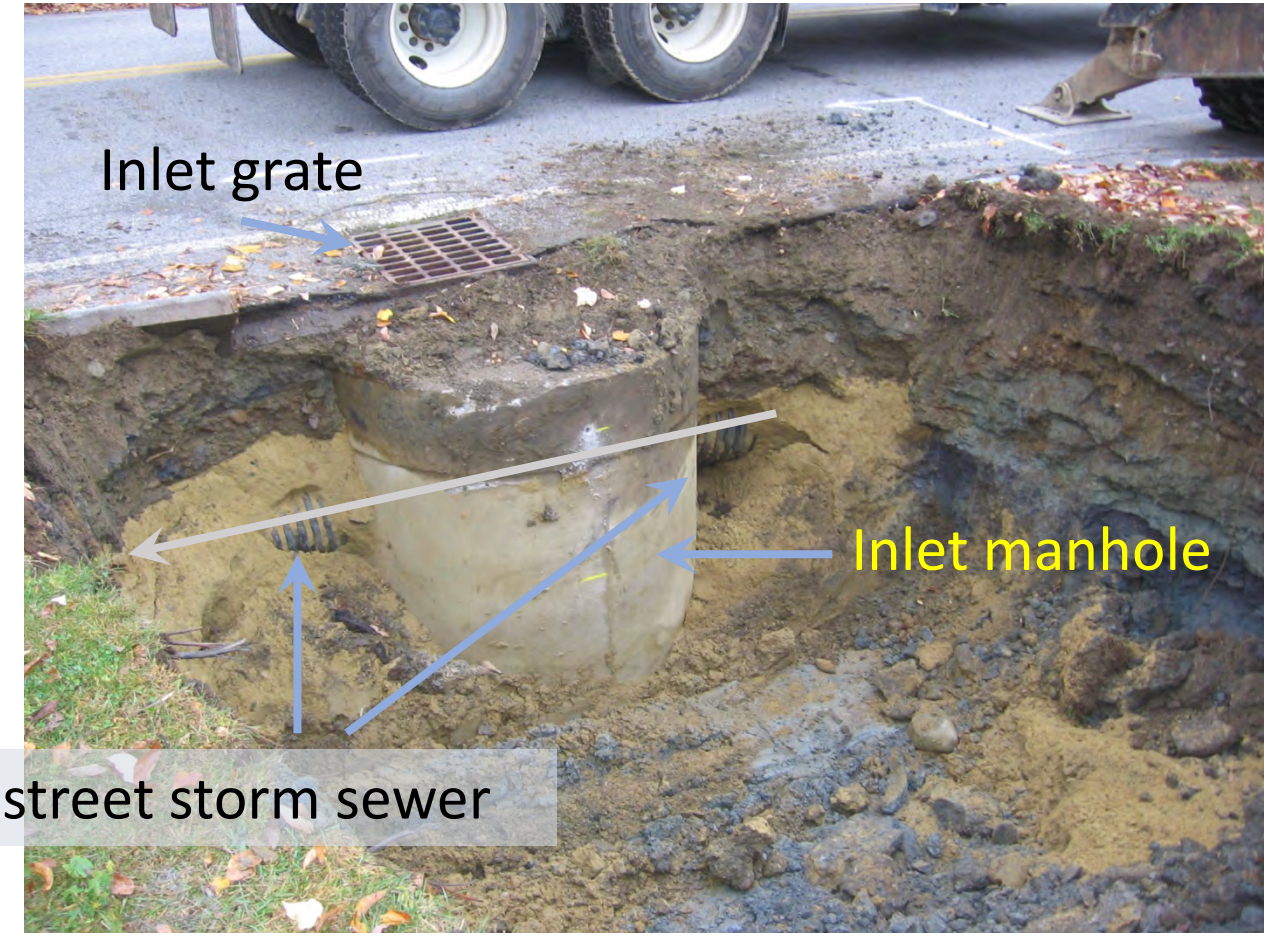
Road

Inlet grate

Curb line



Tree Trench Excavation



Coring Manhole



Retrofit Connection to Existing Infrastructure



Tree Trench Bedding



Tree Casket



Finished Slot



Room to Move



Connect to Manhole



Mortaring the Connection



Backfill Stone over Underdrain



Finishing the Overflow Riser



Cutting Inlet



Media and Tree Infill



Filled System

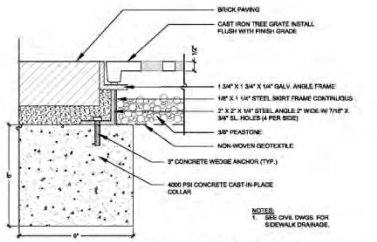


Finished Product



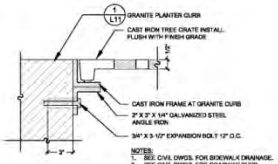
Proprietary TBF





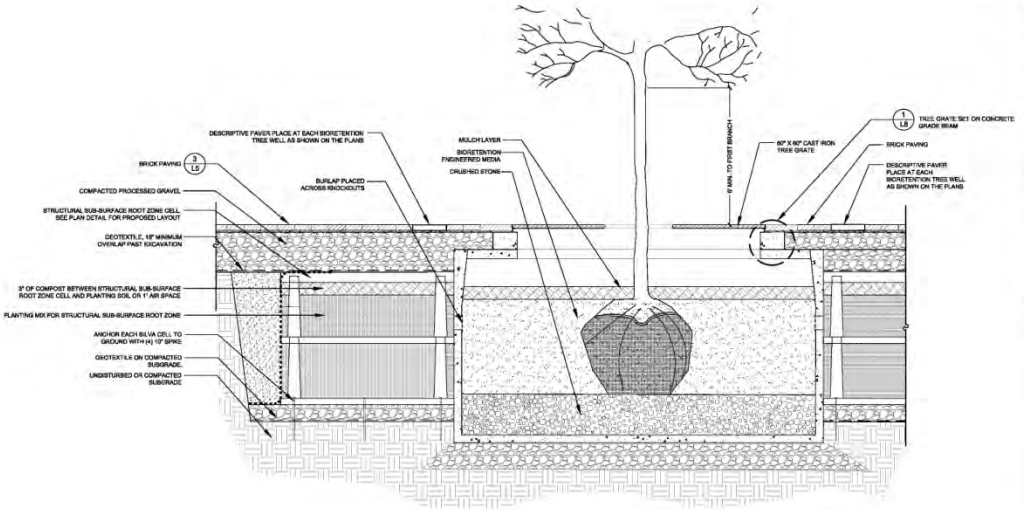
1 L8 **Tree Grate Set on Concrete Grade Beam**

NOT TO SCALE

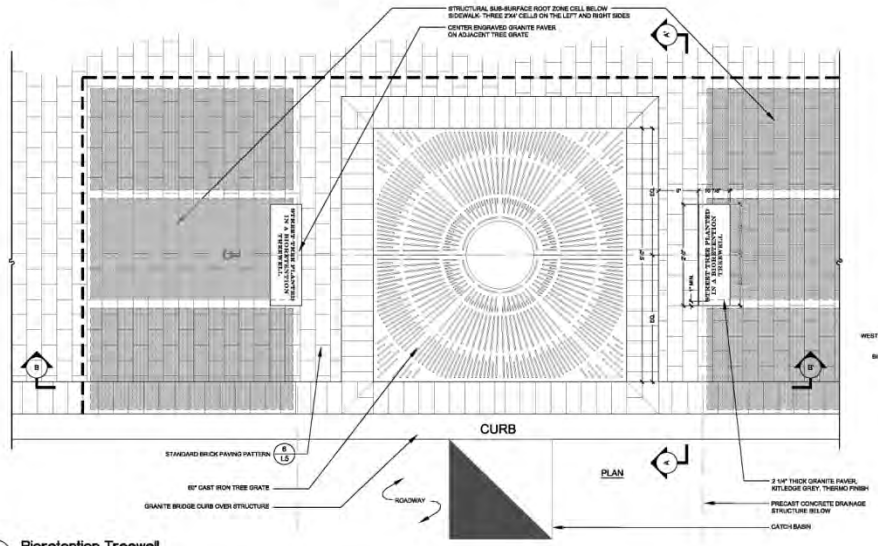


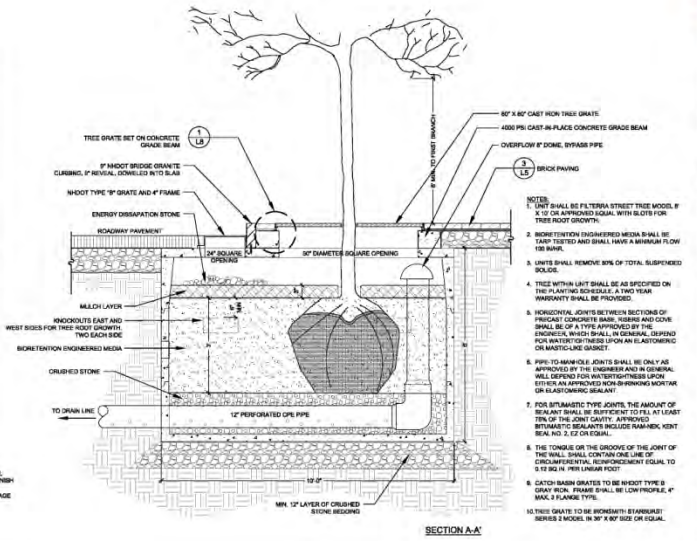
2 L8 **Tree Grate - Granite Curb Connection**

NOT TO SCALE



SECTION B-B'





SECTION A-A'

3 L8 **Bioretention Treewell**

NOT TO SCALE

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no.	revision	date	by
1	Issued for Bidding	7/09	JRH

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Civil/Structural/Traffic Engineering
Bedford, NH 03110 (603)472-5191
Gorham, ME 04038 (207)839-4004
www.cmaengineers.com
Ironwood design group, LLC
Landscape Architecture | Urban Design | Environmental Planning
Exeter, New Hampshire • www.2ewood.com

JEFFREY JAY LANG 026 LICENSED LANDSCAPE ARCHITECT STATE OF NEW HAMPSHIRE

designed by:	drawn by:	approved by:
JRH	JRH	JRH

date: July 2009
project no:
file name:
scale: 1"=30'-0" OR AS NOTED

City of Portsmouth, New Hampshire

State Street Utilities Upgrade and Roadway Improvements

Streetscape and Landscape Details

drawing no. L8

sheet: 31 of 36


SALE
Anderson
06-0958
40/60


CMA
ENGINEERS
NO PARKING ACTIVE DRIVEWAY



Proprietary TBF in Portsmouth NH



Watershed Area and Filter Area

- For GSI systems, the watershed areas should be less than 5 acres, but may be designed for larger
- Common to look at ratio of watershed area to filter area (20:1 common)
- Dynamic Bioretention Area Sizing $$Af = WQV * \frac{df}{(i(hf + df)tf)}$$
- Static System Sizing storage for the static WQV
- Water Quality Methods

$$WQV = (P)(R_v)(A) \qquad WQV = \left(\frac{P}{12}\right) x\ IA$$

Siting Considerations

- Public rights-of-way
- Wellheads
- Septic fields
- Basements
- Building foundations
- Property lines
- Outlet drainage
- Underdrains
- Soil restrictions
- Cross-lot drainage
- Groundwater
- Minimum depth criteria
- Slopes and existing grades
- Wooded areas
- Median and traffic island considerations
- Utilities

2-6% Slopes - Terraced



System Design

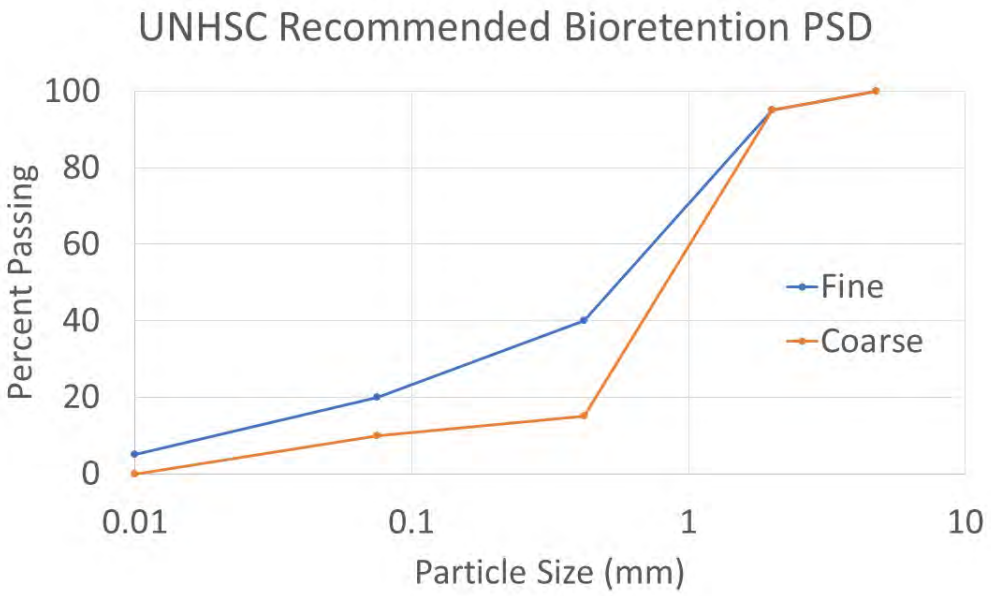
- Above-ground volume
- Inlet
- Layers
  - Media
  - thicknesses
- Surface area
  - Dynamic sizing
- Hydraulic structures
  - Media hydraulic conductivity
  - Secondary
  - Emergency/flood

Bioretention Soil Mix – Many Variations

- Sand: 50-85%
- Wood chips/shredded wood: 20%
- Compost: 10 – 20% **{no compost due to P issue}**
- Soil: 10-30%

- Preferably fines less than 5% (some specs still want 8 – 12%) UNHSC prefers <2%
- 5.5 < pH < 6.5
- Phosphorus index 10-30
- CEC > 10

UNHSC Bio Mix



- 50% Sand,
- 30% loam
- 20% wood chips

Sieve #	media	Sieve Size	in (mm)	% Passing
4	Coarse sand	0.187	(4.76)	100
10	Medium sand	0.079	(2)	95
40	Fine sand	0.017	(0.42)	40 - 15
200	Silt	0.003	(0.075)	10 - 20
<200	Clay	Pan		0 - 5

GRADED FILTER
Setting Bed – Separation Layer

- Pea stone common
- Need to prevent piping of wetland soil down to stone layer
- Characteristics based on particle stability, layer permeability, uniformity

Graded Filter Specification/Design

$$\frac{D_{15\ coarse}}{d_{85\ finer}} < 5 < \frac{D_{15\ coarse}}{d_{15\ finer}} < 40$$

Piping Permeability Uniformity

$$D_{15,\,COARSE\ \ SUBLAYER} \leq 5\ X\ D_{85,\,SETTING\ \ BED}$$

$$D_{50,\,COARSE\ \ SUBLAYER} \leq 25\ X\ D_{50,\ \ SETTING\ \ BED}$$

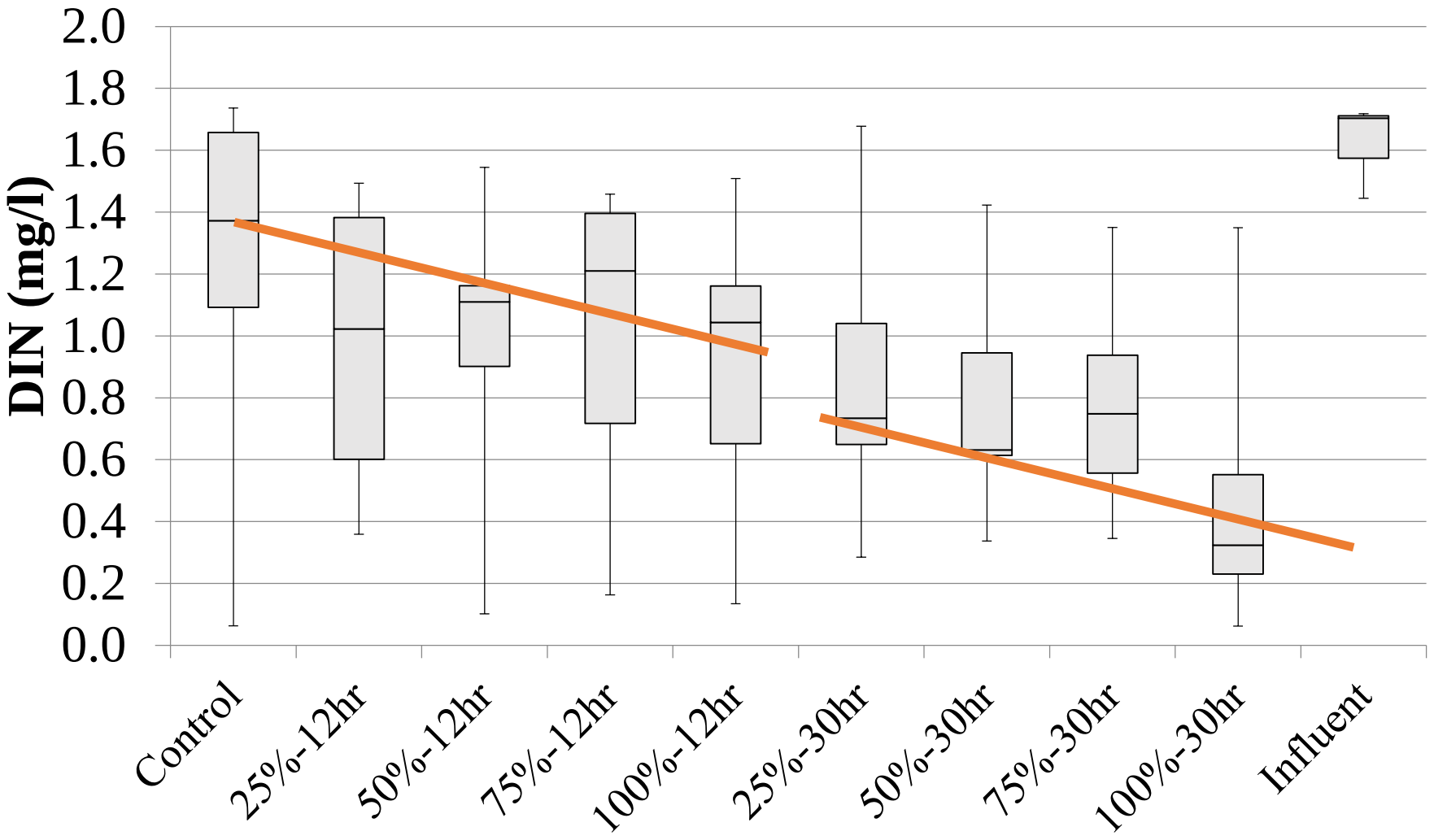
Soil Mix Amendments

- Zero Valent Iron
- Alum sludge
- Limestone sand
- Slag
- Expanded Shale
- Zeolite
- Proprietary

Column Study of Nutrient Removal

- Amendments for Phosphorus
  - Alum sludge
  - Zero valent iron
  - Limestone sand
  - Electric blast furnace slag
- Internal storage volume for nitrogen
- Effect of compost

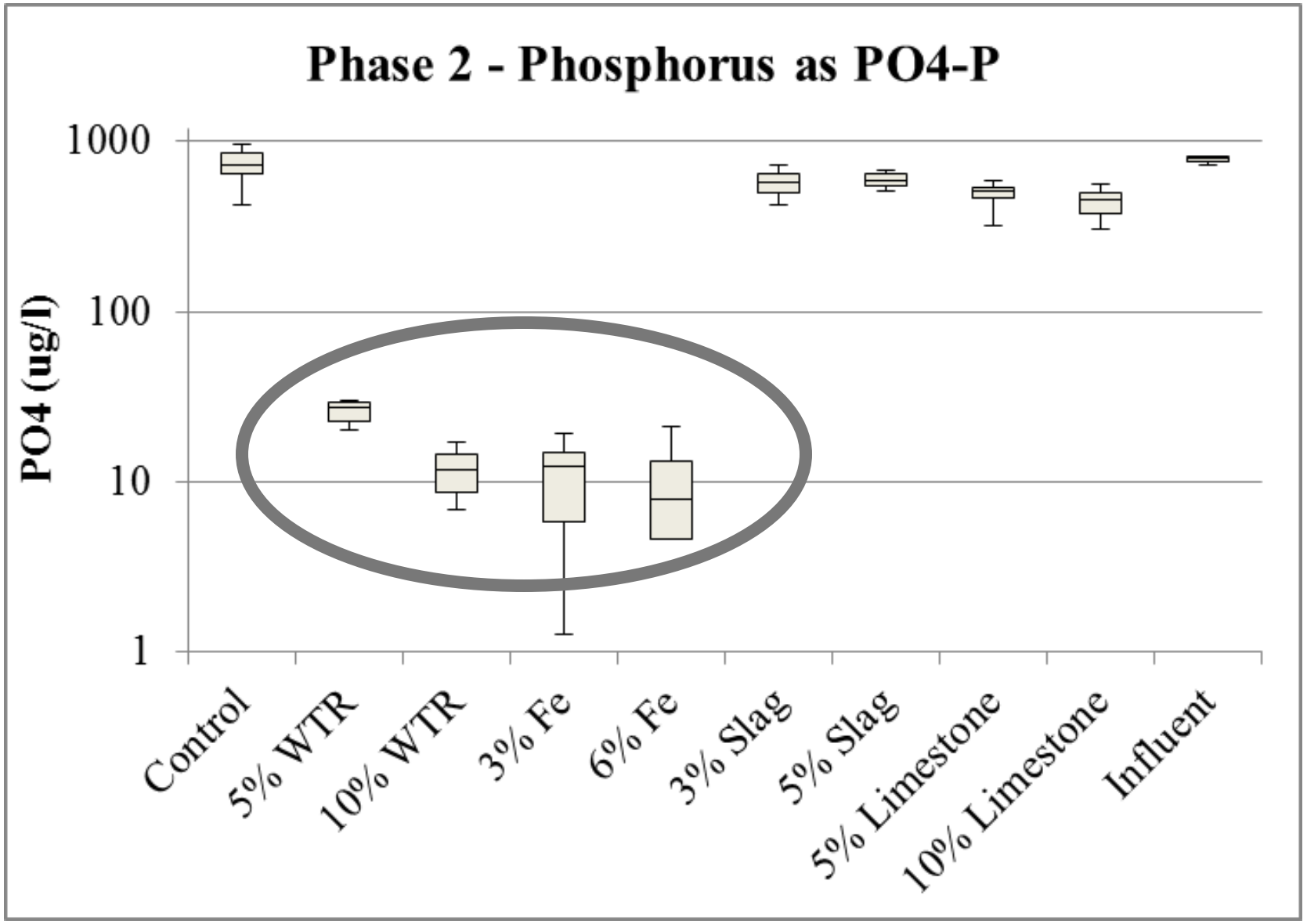
Nitrogen Results



Phase 2: Phosphorus

Column #	Soil Mix	Notes
T2-P0	UNHSC BSM (control)	• Drainage to filter ratio 80:1 • Soil depth in columns: 24” • 24 hour drain time • Soil tested: UNHSC mix
T2-P1	UNHSC 95% BSM + 5% WTR	
T2-P2	UNHSC 90% BSM + 10% WTR	
T2-P3	UNHSC 97% BSM+3% Fe_2	
T2-P4	UNHSC 94% BSM+6% Fe_2	
T2-P5	UNHSC 97% BSM+3% Slag	
T2-P6	UNHSC 95% BSM+5% Slag	
T2-P7	UNHSC 95% BSM +5% Limestone	
T2-P8	UNHSC 90% BSM +10% Limestone	

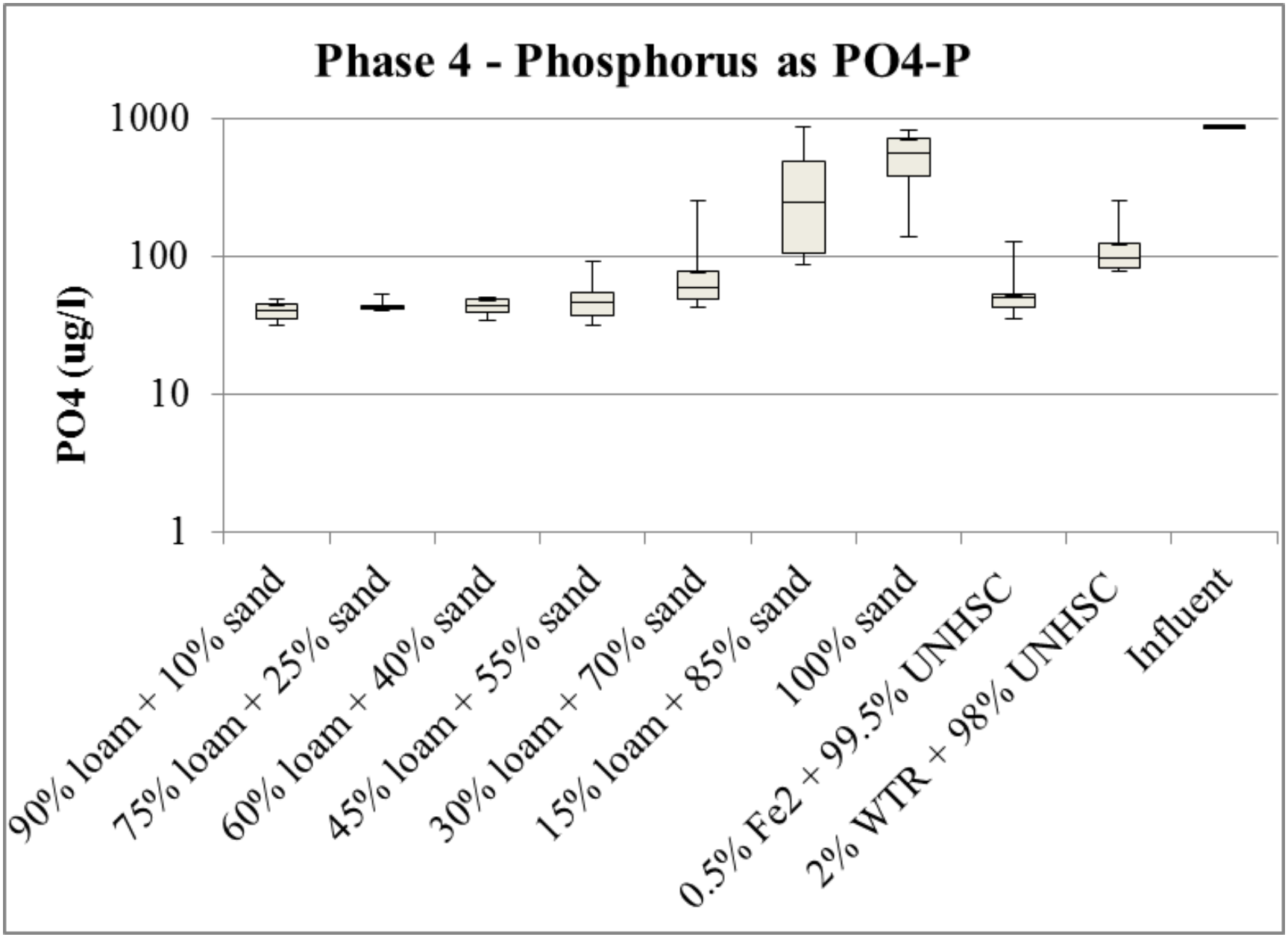
Phosphorus Results



Phase 3: Phosphorus Optimization

Column #	Soil Mix	Notes
T4-P1	90% Stantec loam + 10% sand	• Drainage to filter ratio 25:1 • Soil depth: 12” • Percentage of amending materials was based on test results from Phases 2 and 3
T4-P2	75% Stantec loam + 25% sand	
T4-P3	60% Stantec loam + 40% sand	
T4-P4	45% Stantec loam + 55% sand	
T4-P5	30% Stantec loam + 70% sand	
T4-P6	15% Stantec loam + 85% sand	
T4-P7	100% sand	
T4-P8	0.5% Fe_2 + 99.5% UNHSC mix	
T4-P9	2% WTR + 98% UNHSC mix	

Optimization Results



Media Thickness

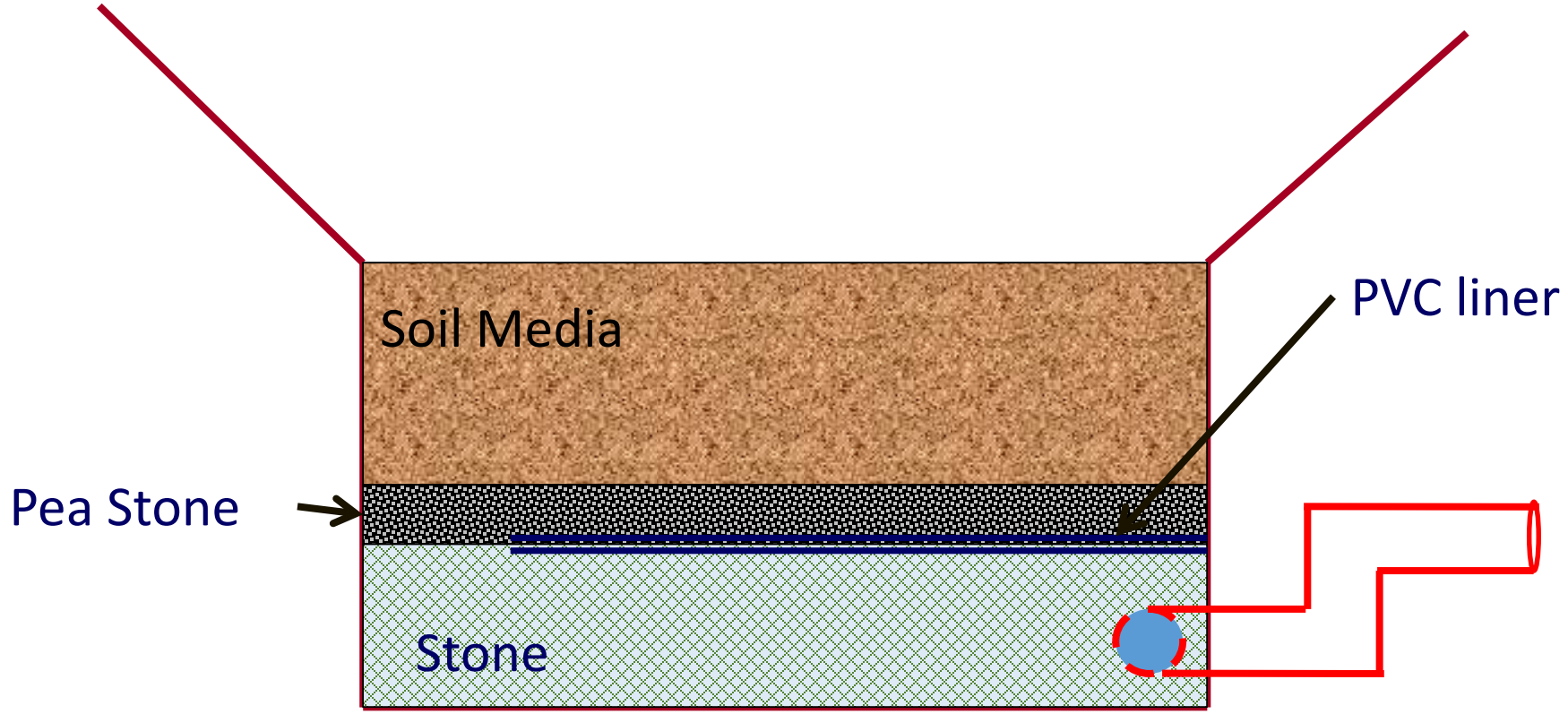
- Depends on plant root depths:
  - 12 in. for grasses, forbs
  - 18 – 24 in. for shrubs (NHDES min 18”
  - > 30 in. for trees

  Do not want roots to clog stone layer and drain pipe below the soil

Internal Storage Volume

- Promotes denitrification
  - May need liner at base in high K soils
  - > 1 ft thickness
  - Need to create plug flow through ISV
  - The longer the residence time, the better
    - > 1/3 of WQV
    - > 12 hours

ISV Plumbing



To Mulch or not to mulch, that is the question…

- If used, <7 in.
- Shredded bark or compost
- Needs to be periodically replaced
- May not be necessary if there is a thick groundcover



Be Careful With Floating Wood Products



Draindown Time

- 12 – 72 hours for WQV

  (hydraulic control at outlet)

  - Infiltration – soil K
  - Outflow – outlet rating curve

  In either case, storage indication routing accurately assesses draindown time.

Maximum Depth of Ponding

- 6 – 24 in.

Largely based on vegetation survival



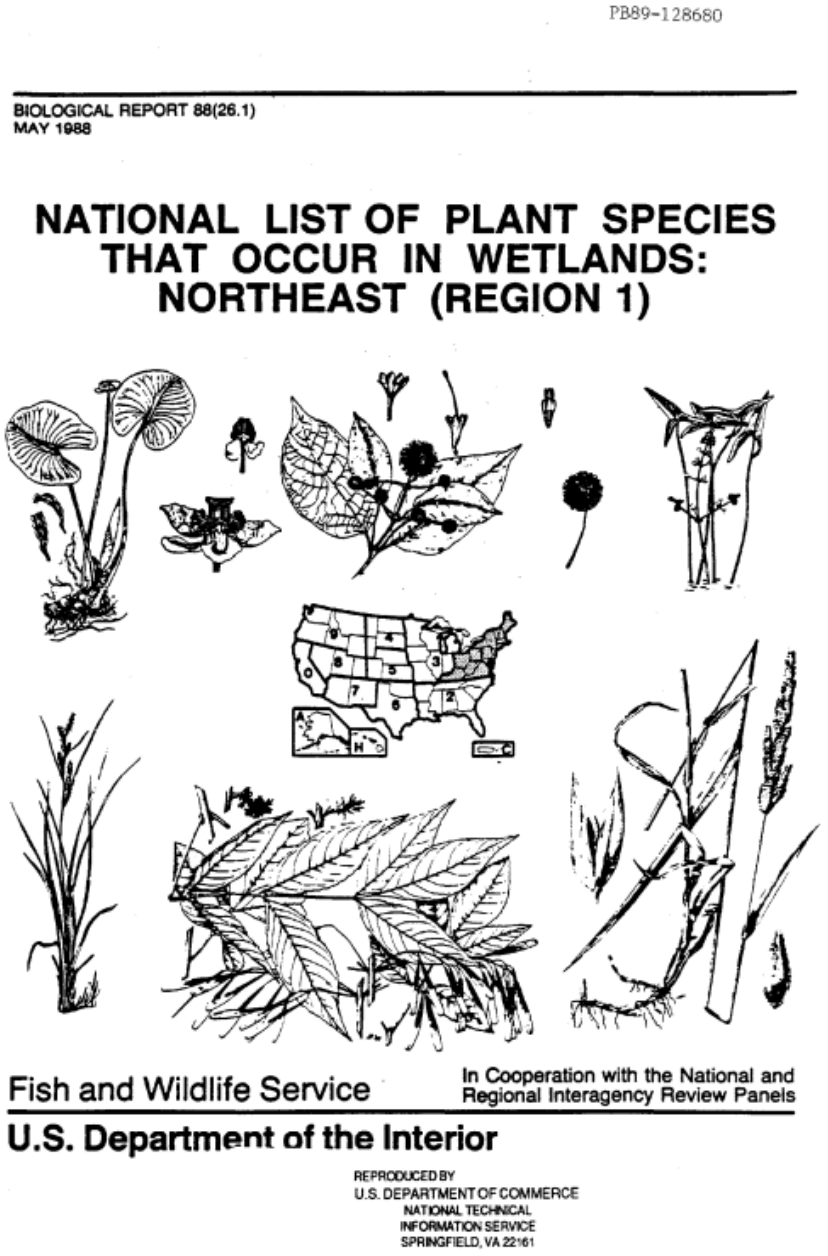
Vegetation

- Native plants always the best
- Cooperative Extension, USDA, NRCS good sources

- Forest
- Meadow
- Transition
- Ornamental

Plants

- There is little consensus and data WRT bioretention system plantings.
- Most manuals are out of step and out of date
- Planting decisions should be based on owner perceptions of O&M



PB89-128680

BIOLOGICAL REPORT 88(26.1)
MAY 1988

NATIONAL LIST OF PLANT SPECIES THAT OCCUR IN WETLANDS: NORTHEAST (REGION 1)

Fish and Wildlife Service

In Cooperation with the National and Regional Interagency Review Panels

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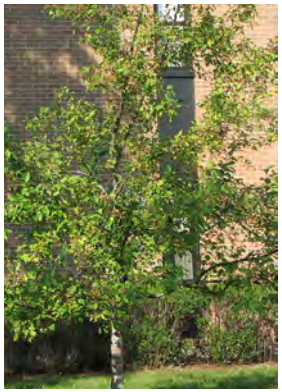
Trees

https://www.unh.edu/unhsc/



Crab Apple



Hawthorne



Honeylocust



Japanese Lilac



Ash



Red Maple



Sargent Cherry

Stormwater Treatment Practices: Subsurface Gravel Wetlands

System Design and Sizing



Design Criteria

- Water Quality Volume (WQv)
- Channel Protection Volume (Q2)
- Extreme Storm Volume (Q10)

Critical Design Elements

1.) Pretreatment: Can be hydrodynamic separators, swales, or other basin that is capable of holding 5-10% of the WQV.

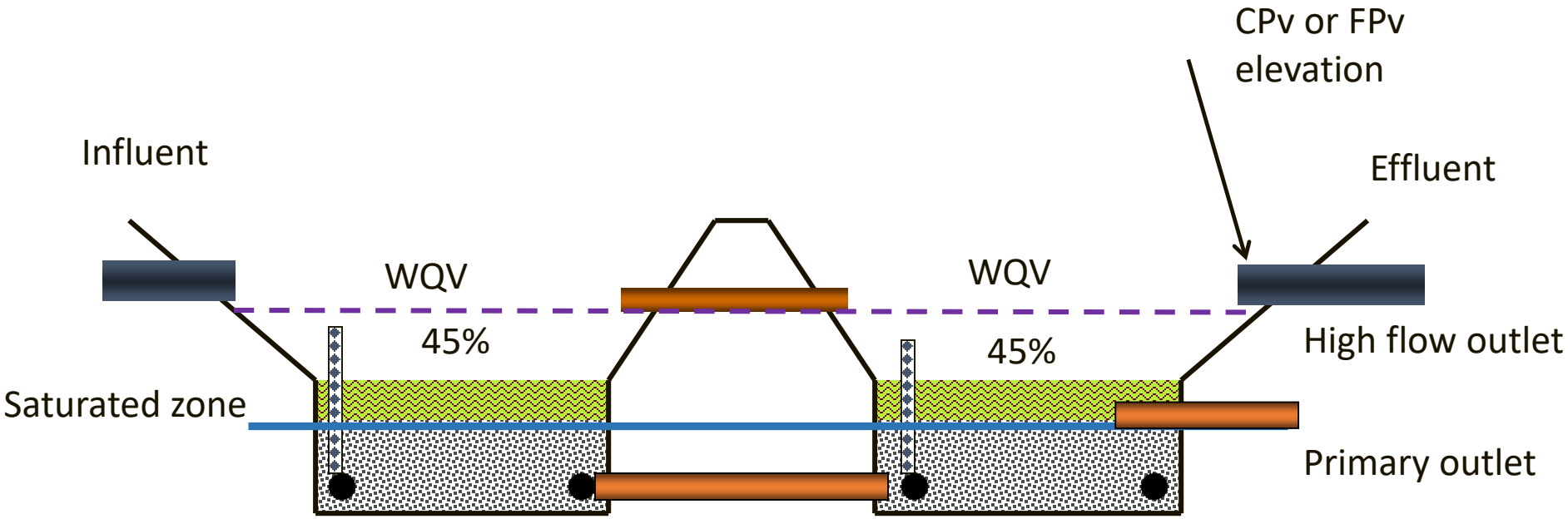
2.) Two Treatment Cells: 45% of the WQV held in each of 2 treatment cells ABOVE GROUND. Not the volume of internal storage reservoir.

3.) Travel length through the gravel should be a minimum of 15 ft

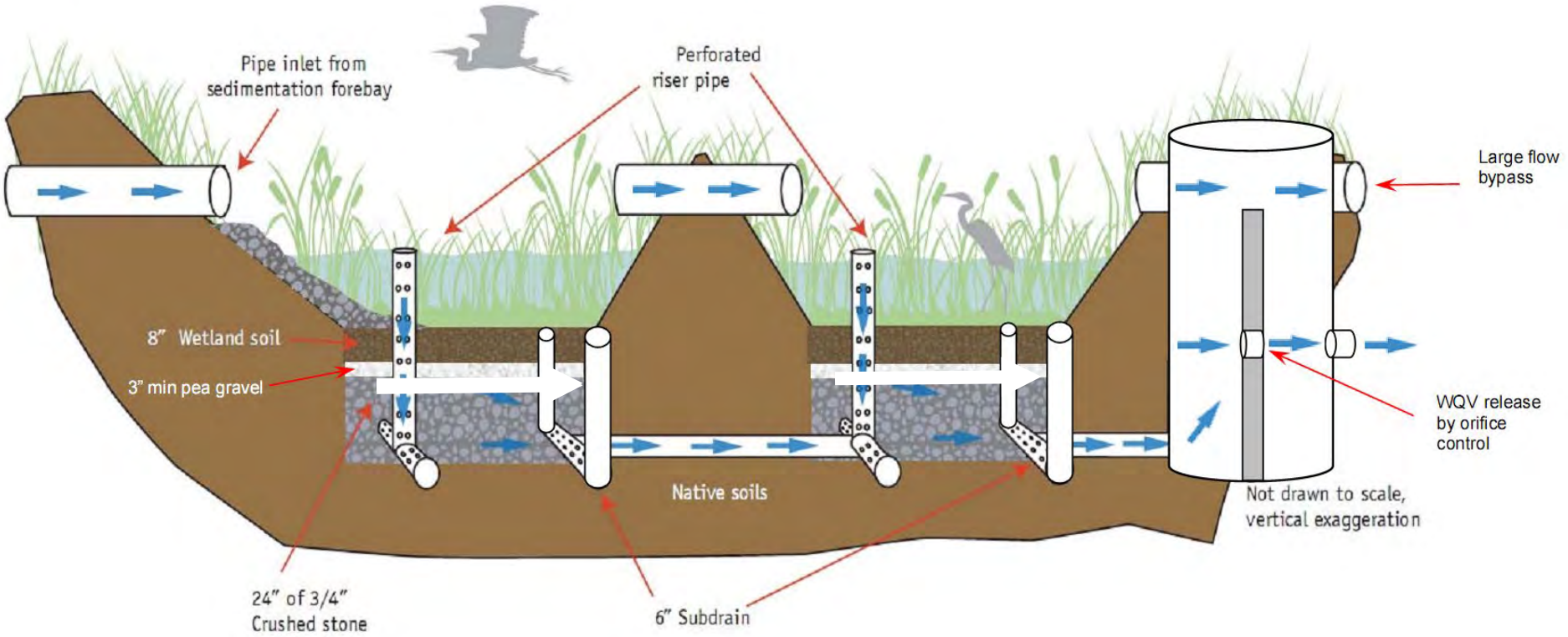
4.) No Geotextile between soil and crushed stone

5.) Underlying soils should have low permeability (hydraulic conductivity ≤ 0.03 ft/day), may need a liner if not

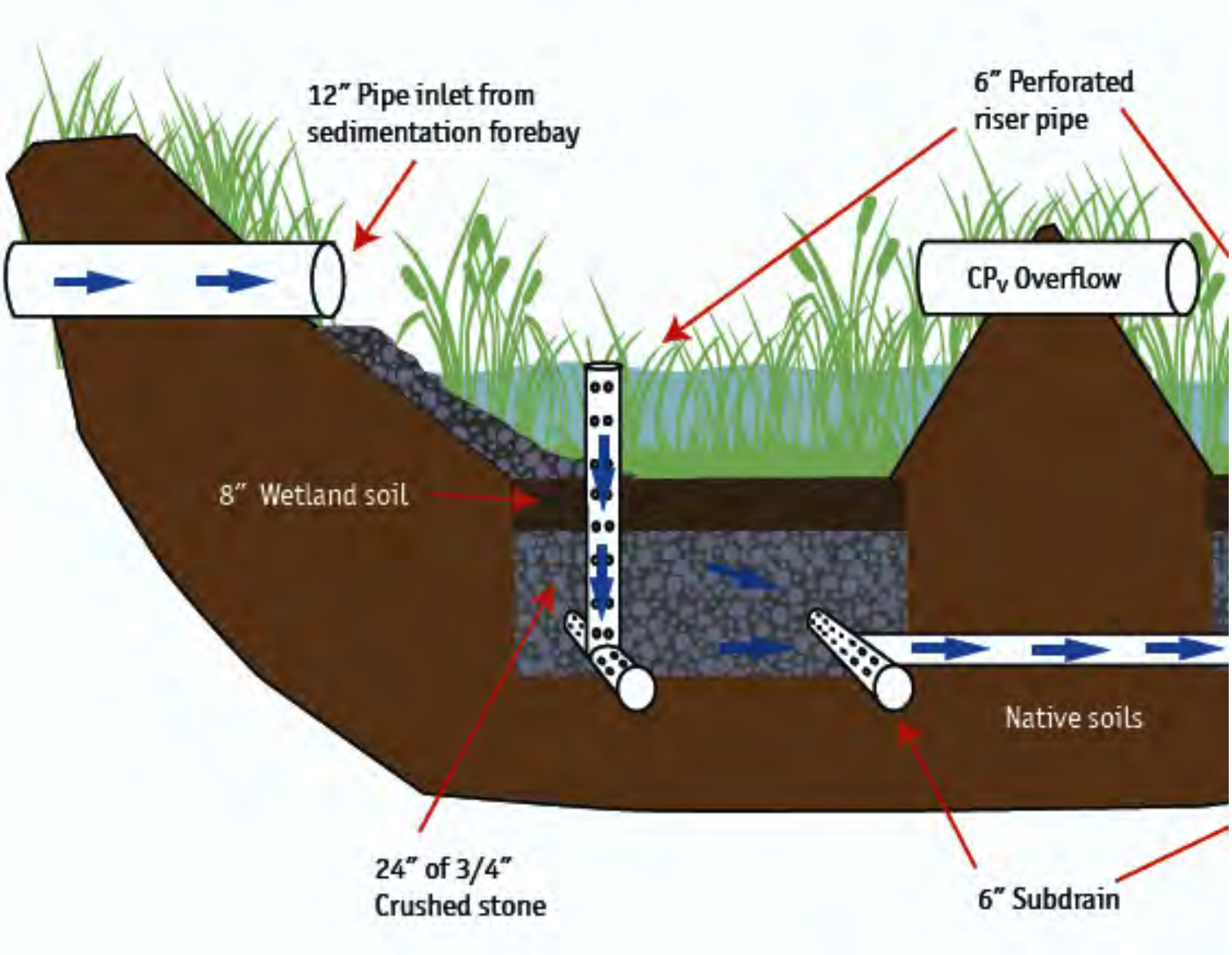
Generic Cross-Section



Subsurface Gravel Wetland - SGW

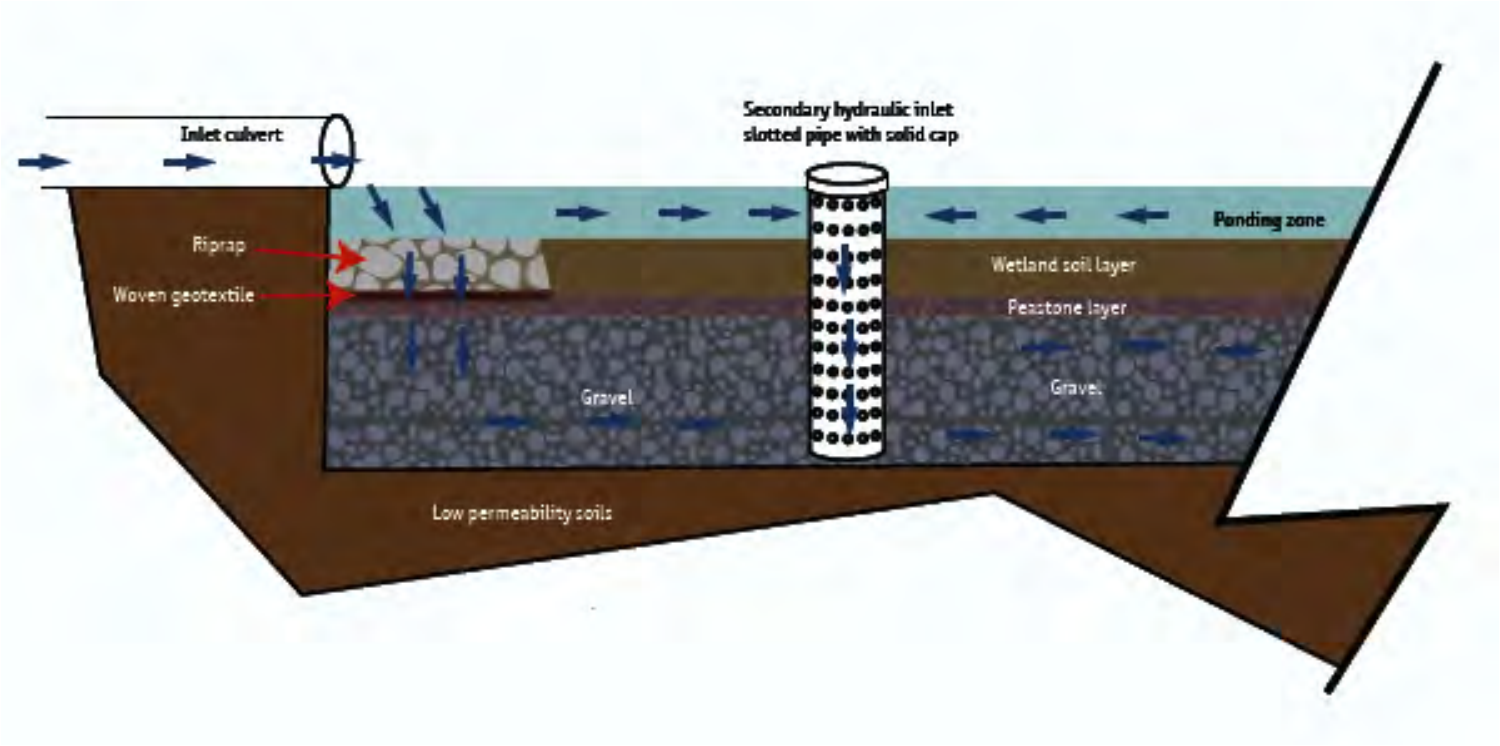


Conventional Plumbing



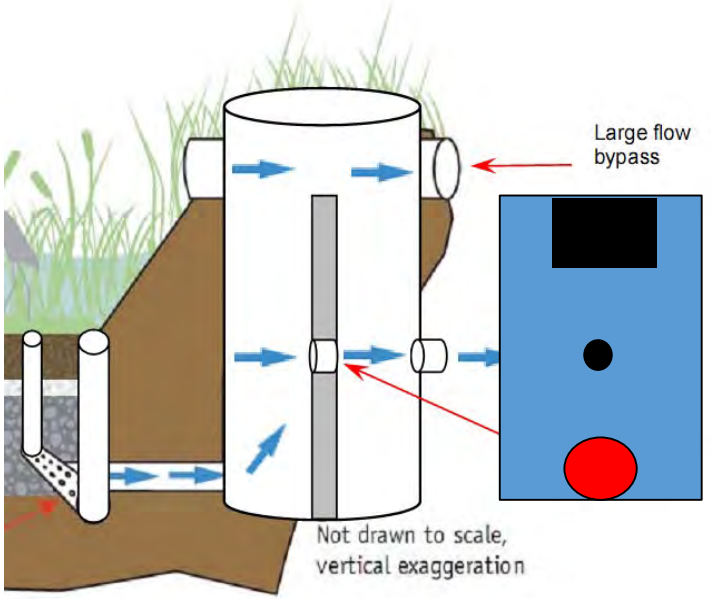
Getting the Water to the Stone Layer

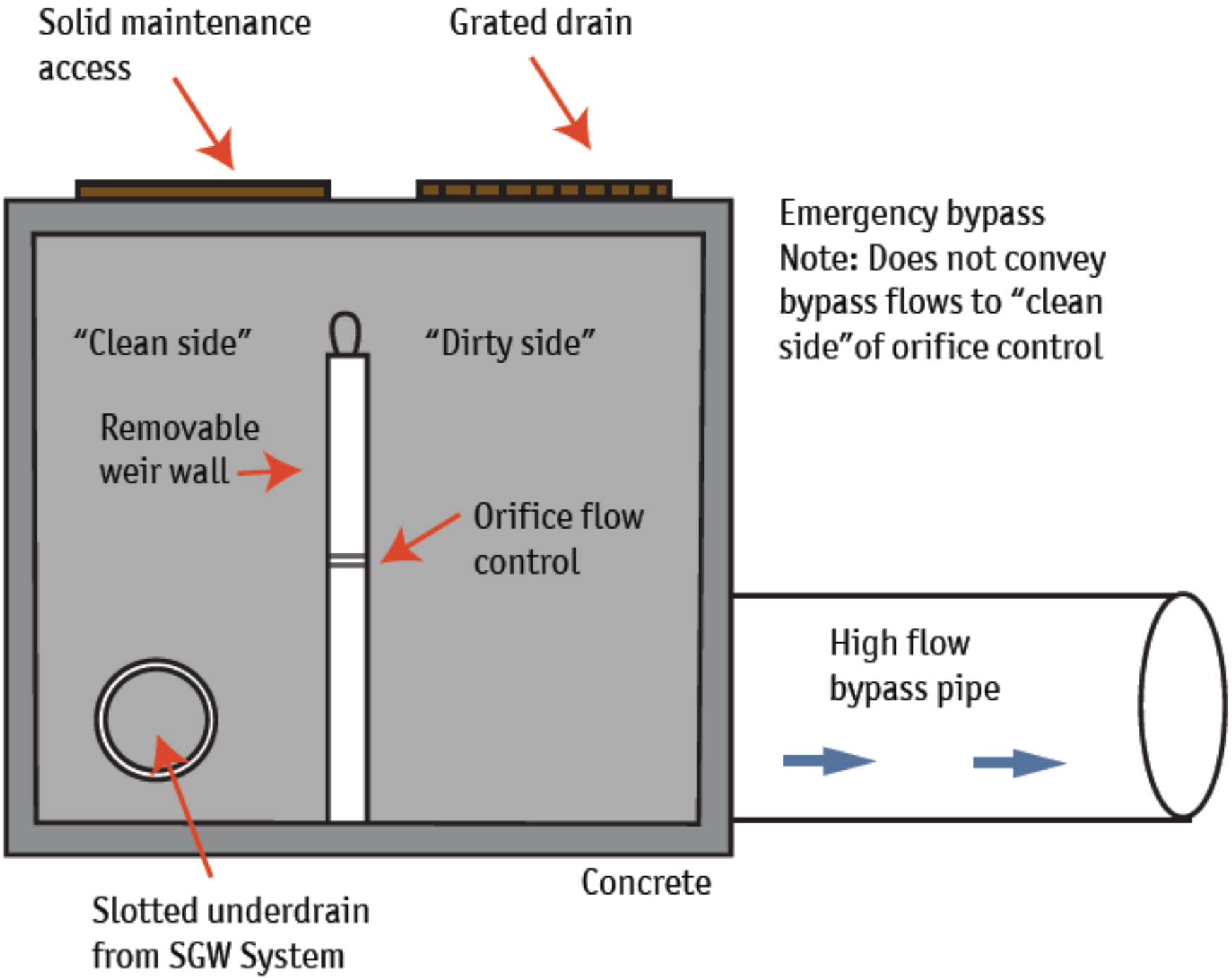
- Conventional
  - Slotted risers
- Alternative
  - Media



Hydraulic Outlet Structure

- An optional high capacity outlet below the primary outlet may be installed for maintenance.
- This maintenance port would be plugged during regular operation. This optional outlet allows for flushing of the treatment cells at higher flow rates and can be used to drain the system for maintenance or repairs.




Solid maintenance access
Grated drain
Emergency bypass
Note: Does not convey bypass flows to "clean side"of orifice control
"Clean side"
"Dirty side"
Removable weir wall
Orifice flow control
High flow bypass pipe
Concrete
Slotted underdrain from SGW System

Pictures from the field




Phoenix Precast
IPCH



Additional Details

- Depth of ponding is generally 6 – 18” could be more in a retrofit scenario (depends on vegetation)
- The Bypass outlet (emergency spillway, or secondary spillway) is sized to pass designs flows (10-year, 25-year, etc.). This outlet is sized by using conventional routing calculations of the inflow hydrograph through the surface storage.
- The primary outlet structure and its hydraulic rating curve are based on a calculated release rate by orifice control to drain the WQV in 24-48 hrs.

Wetland Soil Specification

- The wetlands soils must have low hydraulic conductivity
- Compost, sand, silt, and clay, with the clay component not exceeding 15% by volume.
- 10% to 20% organic content by mass.
- Leaf compost or peat with less than 5% dry weight of woody or green yard debris or other materials.

Wetland Soil

- The surface infiltration rates of the gravel wetland soil should be similar to a low hydraulic conductivity wetland soil (0.1-0.01 ft/day = 3.5 x 10^{-5} cm/sec to 3.5 x 10^{-6} cm/sec).
- Do not use geotextiles between the horizontal layers of this system as they will clog due to fines and may restrict root growth.

PSD and testing tolerances for wetland soil for the SGW system

US Standard Sieve Size in/mm	Percent Passing	Percent Passing Testing Tolerances
0.5/12.5	100	± 10.0
#10/2.00	90 - 75	± 5.0
#100/0.15	40-50	± 5.0
#200/0.075	25-50	± 5.0

Median particle size (D_{50}) of 0.15 mm and is a clay or silt loam

Wetland Vegetation

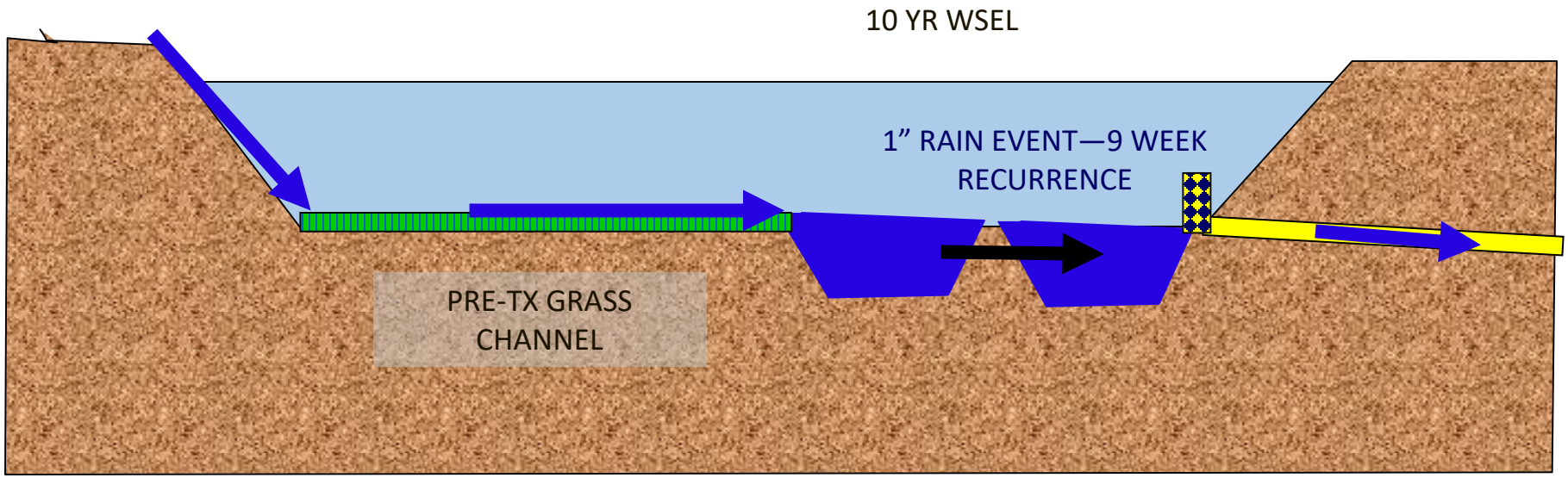
- Used New England Wetmix (wetland seed mix) from New England Wetland Plants Application Rate: 1 LB/2500 SQ. FT. (18 LBS/ACRE as a wet meadow seeding)
- http://www.newp.com
- Price: $125.00/LB**
- Gravel wetland – mixed wetland grasses, reeds, herbaceous plants and shrubs growing vigorously. 100% cover, except for open water in forebay. Very few upland plants. Healthy, diverse wetland system.

UNHSC – General Wetland Condition

- 53% of the planted species are still present (in areas that have not been re-constructed).
- Emergent obligate wetland species (e.g water lily, pickerelweed) survival was very low.
- All areas with standing water populated by Typha (cattail).
- No Phragmites, some Purple Loosestrife removed.
- Predominantly emergent marsh/wet meadow species.

BASIN RETROFIT

- Dry Pond Sized for 10 yr Event—Flood Control
- Gravel Wetland for 1”—WQ TX



Questions



Providence Stormwater Innovation Center

PROVIDENCE PARKS & RECREATION play · relax · explore

THE UNIVERSITY OF RHODE ISLAND

Audubon Society of Rhode Island

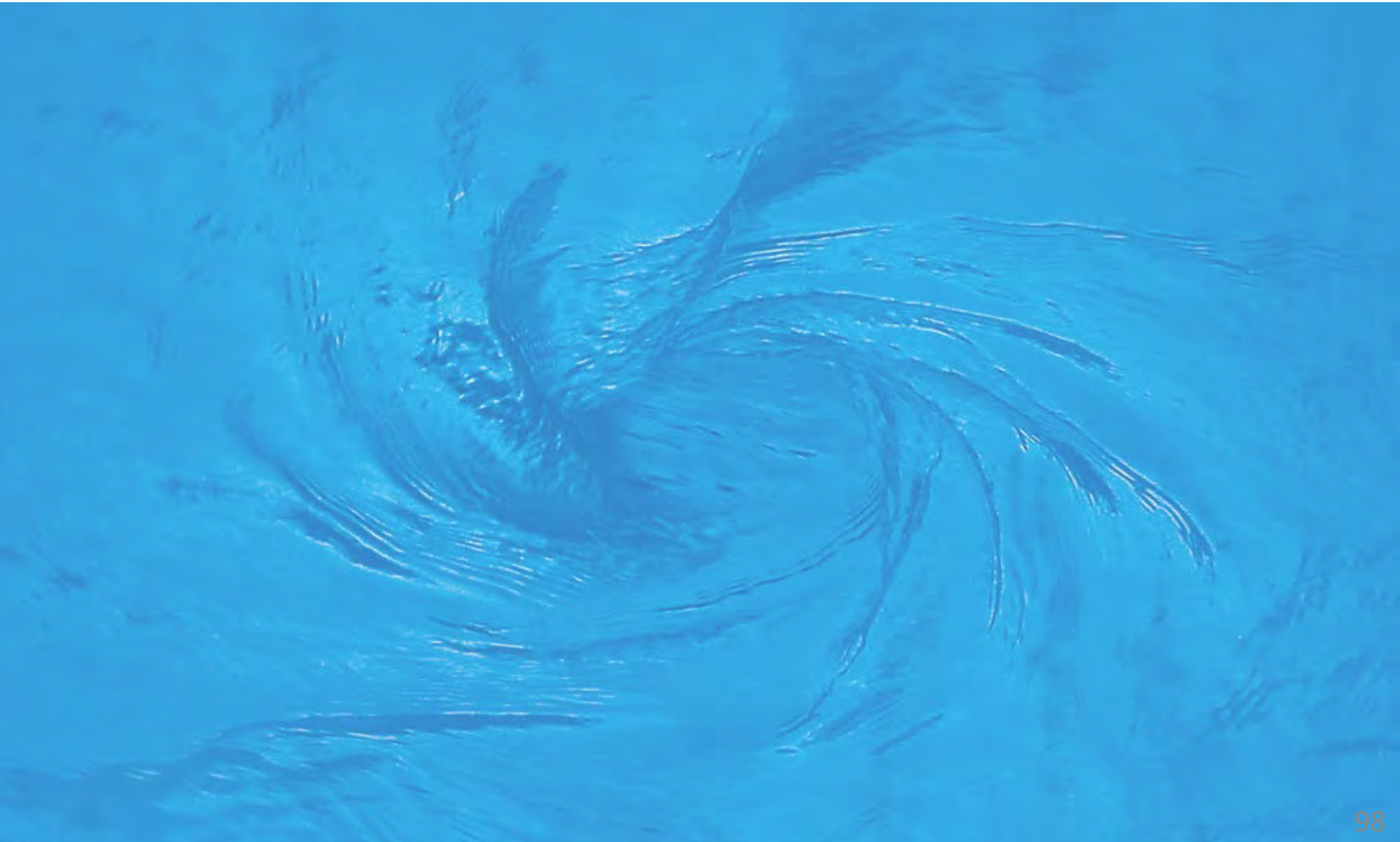
RESTORE AMERICA'S ESTUARIES

University of New Hampshire

The Nature Conservancy

SNEP

Infiltration BMPs



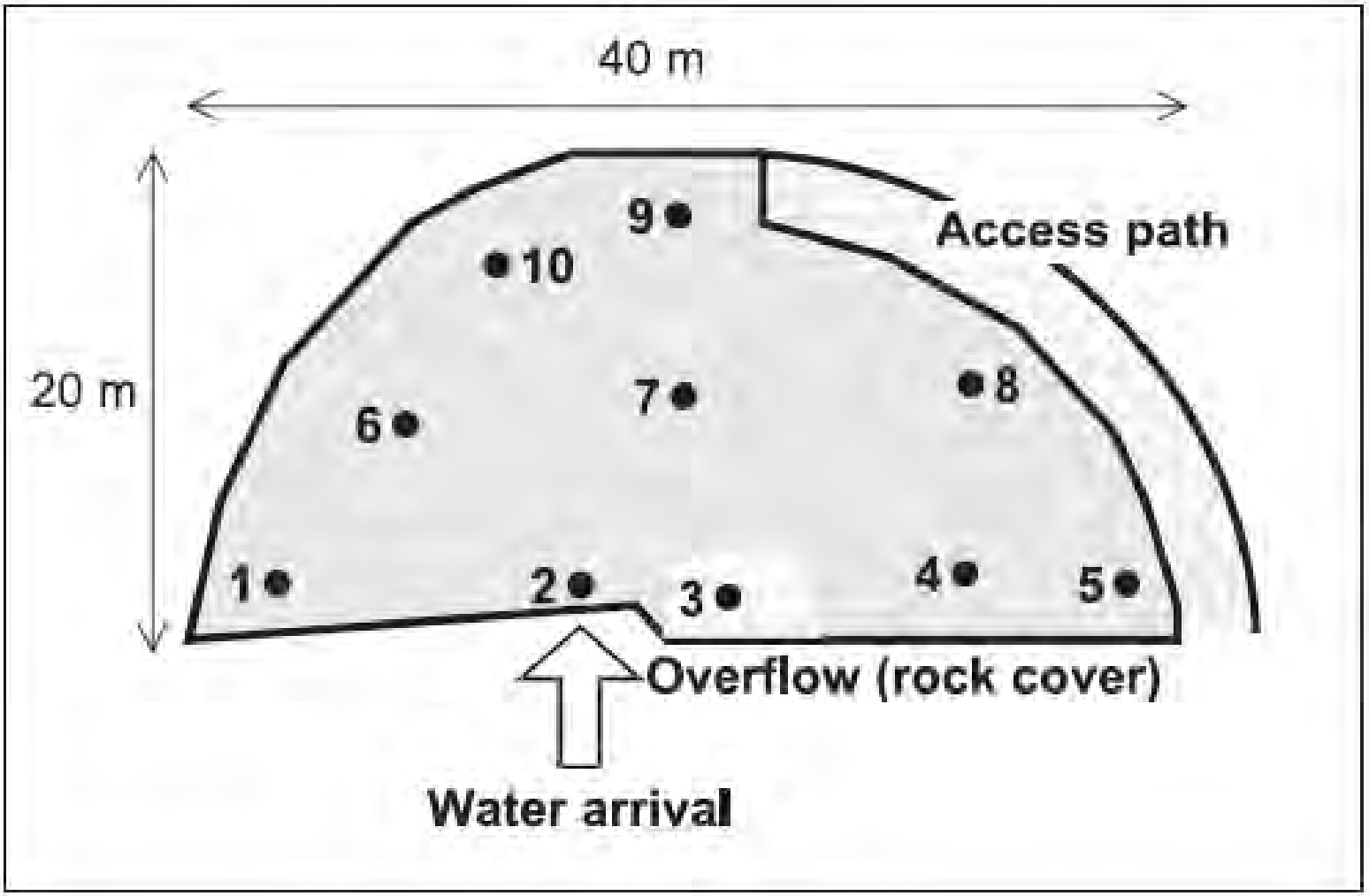
Infiltration

- Infiltration Capacity
- Saturated Hydraulic Conductivity
- Permeability

Published Infiltration Rates

- USDA – Web Soil Survey
- May be a need to field verify and utilize average Ksat values that include exfiltration over the wetted perimeter of the system.

Sampling points in a 30 year old infiltration basin in France

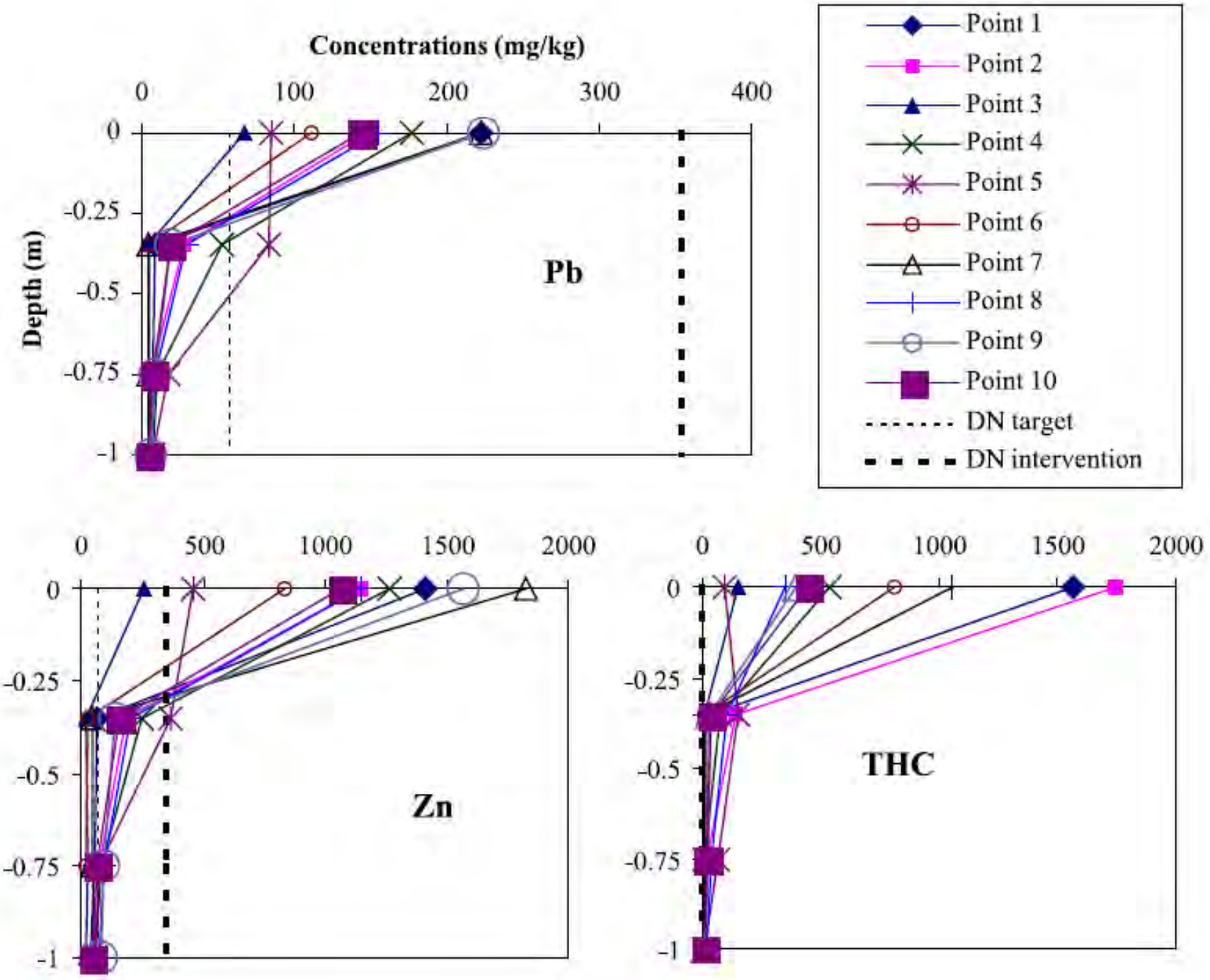


Deschesne et al, 2004

Soil analysis at the Centre Routier infiltration basin 10 points, 4 depths: A (surface), B (30–40 cm), C (60–70 cm), D (100–110 cm)

	pH	CEC meq/kg	Mineral matter %	TOC %	TN %	TP %	Cd mg/kg	Cr mg/kg	Cu mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Hg mg/kg	As mg/kg	THC mg/kg
1A	7.9	98.8	86	10.78	0.33	0.27	4.00	60.94	142.4	29.97	222.3	1414	0.11	7.99	1565
1B	9.3	11.0	99.1	1.07	0.02	0.07	0.51	13.69	7.61	7.61	8.62	65.9	<0.1	3.04	29.75
1C	9.3	9.0	99.2	0.73	0.02	0.07	0.51	14.68	8.10	8.10	7.08	56.2	<0.1	3.04	22.48
1D	9.4	12.8	99.2	1.08	0.01	0.07	0.49	11.37	6.43	7.42	4.94	38.1	<0.1	2.47	13.29
2A	8.1	76.5	87.6	10.67	0.24	0.32	3.53	49.42	110.4	23.20	147.8	1145	<0.1	6.56	1745
2B	8.9	16.0	98.7	1.3	0.03	0.09	0.94	18.24	14.03	10.29	28.07	182.0	<0.1	4.21	138.1
2C	9.3	9.0	99.3	1.02	0.02	0.09	0.47	14.46	7.47	7.47	6.53	71.9	<0.1	3.27	18.87
2D	9.3	9.6	99.3	0.89	0.02	0.07	0.45	13.59	7.25	9.06	4.98	66.1	<0.1	3.62	9.97
3A	9.0	25.8	97.8	2.45	0.04	0.09	0.97	22.74	24.68	11.61	67.73	255.5	<0.1	4.84	151.1
3B	9.4	6.8	99.4	1.05	0.03	0.07	0.50	10.53	2.51	6.52	5.01	19.0	<0.1	3.01	<10
3C	9.4	6.6	99	1.05	0.01	0.05	0.49	12.76	3.93	7.36	4.91	23.6	<0.1	3.44	<10
3D	9.5	7.9	99.2	1.11	0.01	0.05	0.53	20.82	3.20	9.07	5.34	21.9	<0.1	4.27	<10
4A	8.2	83.9	86.7	11.13	0.25	0.25	3.55	56.33	121.8	27.40	176.6	1269	0.107	8.12	538
4B	9.0	18.6	98.2	1.8	0.03	0.07	1.04	23.85	20.74	11.41	52.89	247.8	<0.1	4.15	72.82
4C	9.3	13.5	98.9	1.24	0.02	0.07	0.51	19.54	13.37	11.83	10.29	85.9	<0.1	4.11	<10
4D	9.4	13.2	98.9	1.11	0.02	0.07	0.52	19.22	10.91	12.99	6.75	52.0	<0.1	3.64	<10
5A	8.7	37.6	95.7	2.78	0.09	0.11	1.54	29.32	38.06	14.40	84.87	458	0.1	4.63	95.17
5B	8.9	28.0	97.3	1.72	0.04	0.09	1.01	29.91	29.40	14.19	83.13	371.0	0.1	4.06	151.5
5C	9.3	11.1	98.9	0.74	0.02	0.05	0.51	13.24	7.64	7.64	17.82	73.3	0.1	3.56	63.26
5D	9.4	27.5	98.5	0.74	0.02	0.11	0.51	22.87	14.23	19.31	7.11	54.4	0.1	5.59	<10

- Soils are highly permeable calcareous sand, pebbles and rocks. Hydraulic conductivity was measured > 140 in/hr (0.1 -.001 m/s)


Concentrations (mg/kg)
0
100
200
300
400
Depth (m)
0
-0.25
-0.5
-0.75
-1
Pb
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6
Point 7
Point 8
Point 9
Point 10
DN target
DN intervention
0
500
1000
1500
2000
Zn
THC

Weiss, et al. 2008 SAFL

- Increased application of stormwater infiltration practices necessitates examination of possible contamination to soil and groundwater—a legitimate concern for the protection of human and environmental health.
- Although a fair number of studies in this pioneering field are available, some areas have been neglected and most warrant further study.
- The appropriate information regarding the pollution risks associated with choosing infiltration—and the often greater pollution risks of *not* choosing infiltration—must be available to optimize and execute appropriate water resources management decisions.

Stormwater Treatment Practices: Infiltration Practices... That may also include a filtration component

- including but not limited to infiltration trenches, infiltration basins, dry wells
- Permeable pavements
- Manufactured Treatment Devices: subsurface chambers and vaults.

Stormwater Treatment Practices: Filtering Practices that may include infiltration

surface sand filters

- underground sand filters
- tree box filters
- bioretention systems
- Manufactured Treatment Devices: media filters, cartridge filters and others…

Overview of Stormwater Infiltration

- Inlet, pretreatment
- Infiltration system (need infiltration capacity $\geq$ 0.5 in/hr)
  - Trench
  - Basin
  - Subsurface structures
- Outlet/underdrain

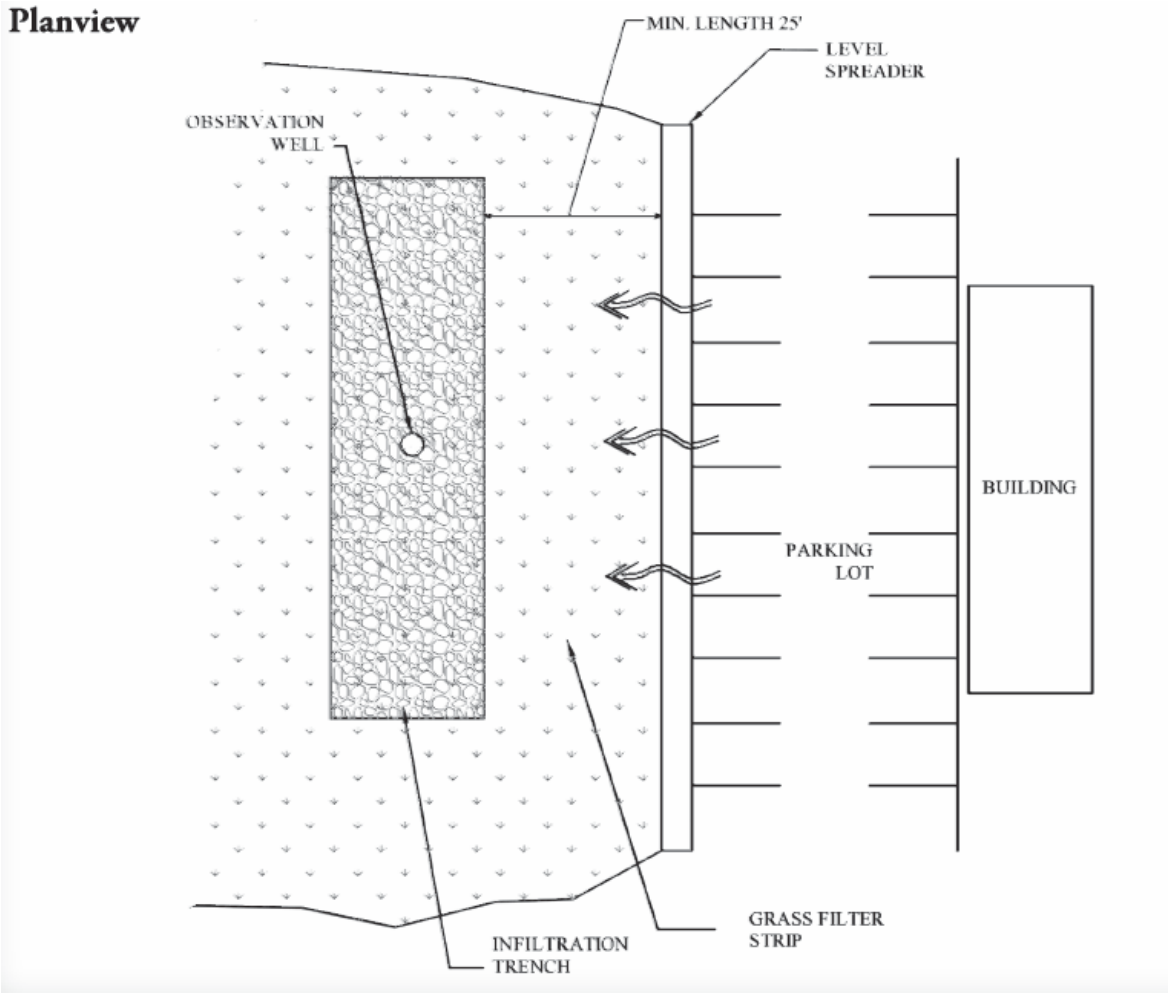
Site Screening

- Depth to Bedrock
- Depth to SHWT

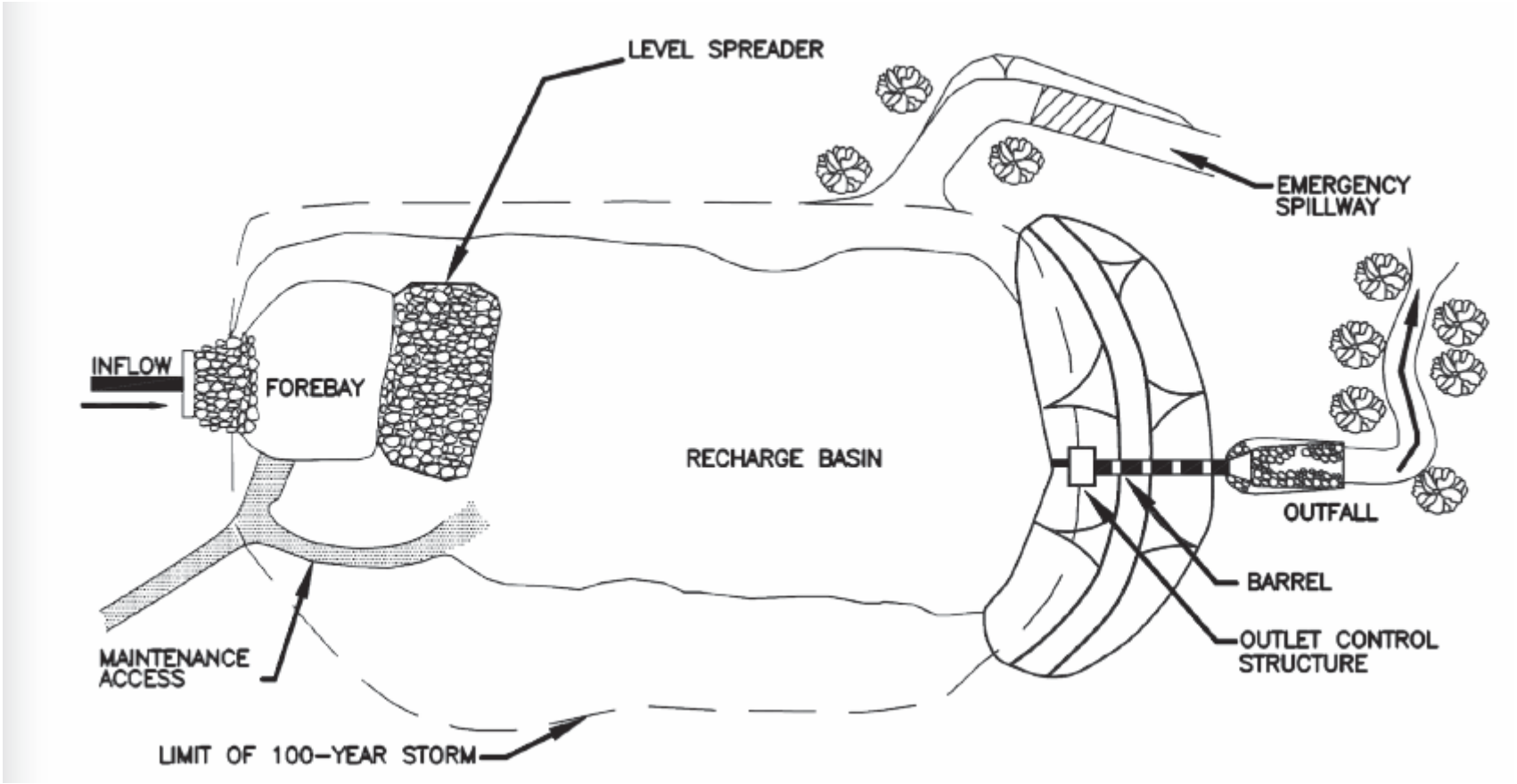
} Excavate to at least 5 ft below system infiltration surface

- Vulnerable receptors (wells, surface water, basements, utility trenches, wells)
- Existing contamination
- Sensitive habitat
- Wetlands/Aquifers
- Fill
- Floodplain
- Karst
- Excessive K (poor treatment)
- Low K (insufficient capacity)
- Slope (< 15%) – be careful about mounding and breakout

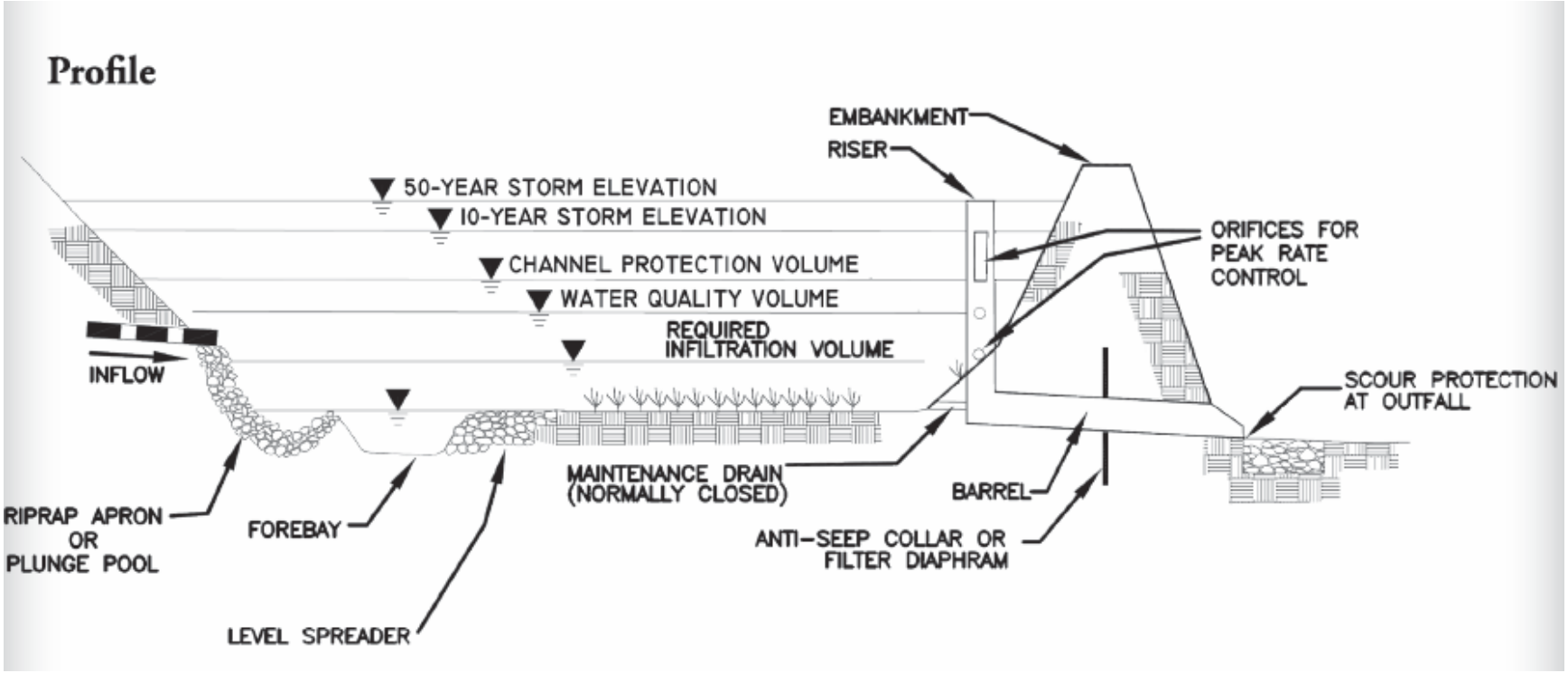
Trench - Plan


Planview
MIN. LENGTH 25'
LEVEL SPREADER
OBSERVATION WELL
BUILDING
PARKING LOT
GRASS FILTER STRIP
INFILTRATION TRENCH

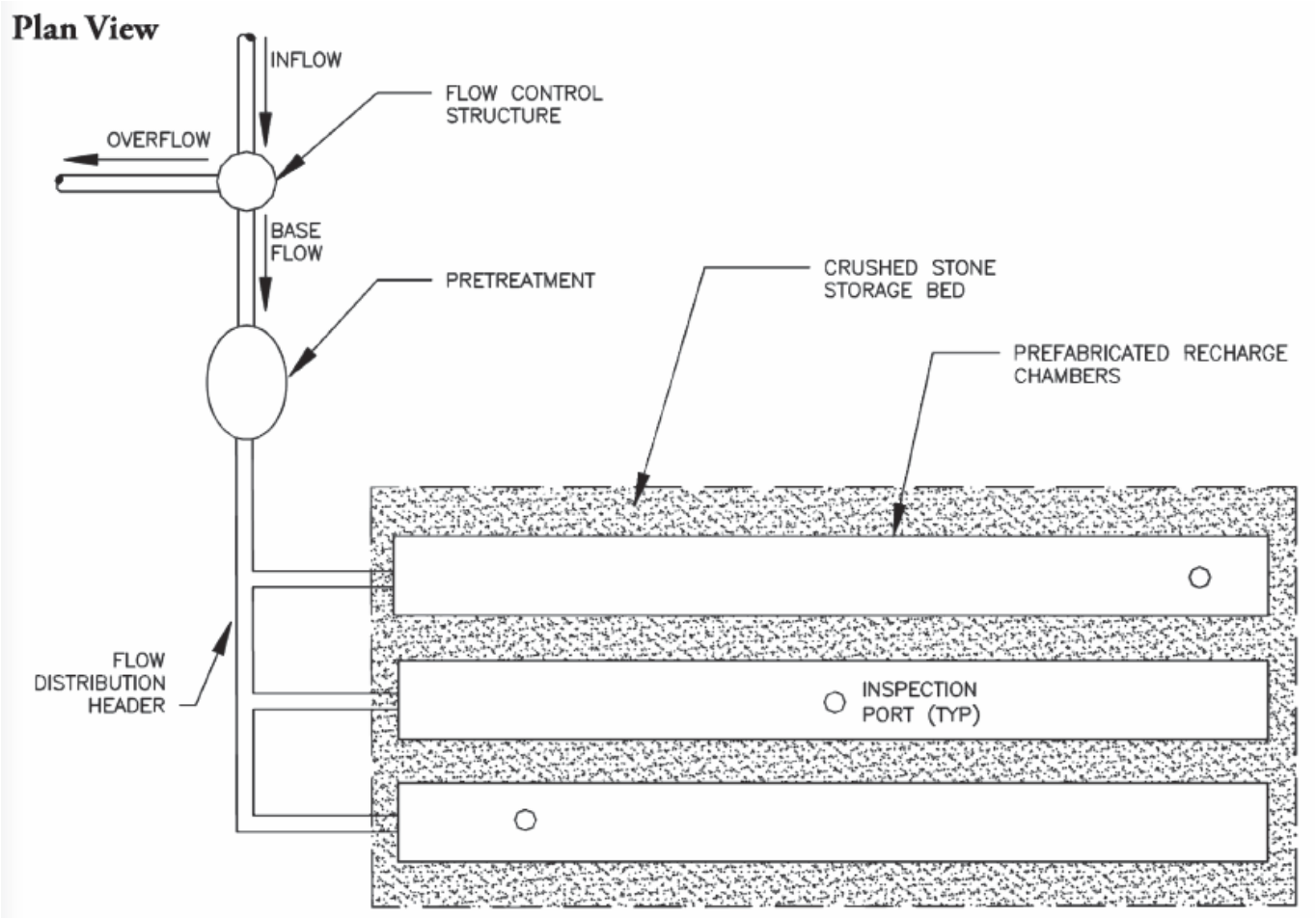
Basin - Plan


LEVEL SPREADER
EMERGENCY SPILLWAY
INFLOW
FOREBAY
RECHARGE BASIN
OUTFALL
BARREL
OUTLET CONTROL STRUCTURE
MAINTENANCE ACCESS
LIMIT OF 100-YEAR STORM

Basin – Cross section

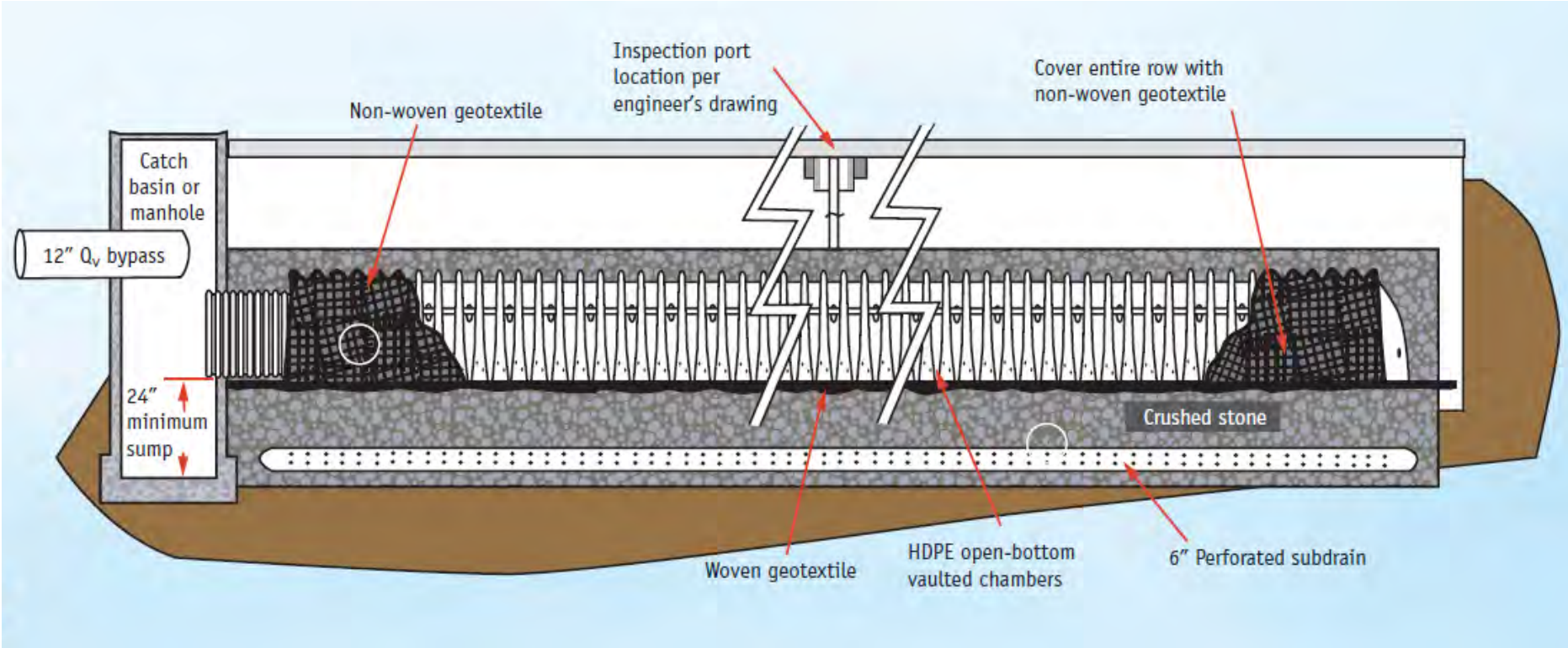


Subsurface - Plan



Subsurface Type – Cross section

- Similar to trench



Estimating Infiltration

- Infiltration Capacity
- Saturated Hydraulic Conductivity
- Permeability

NOTE: infiltration capacity is NOT hydraulic conductivity

Infiltration capacity is the sustained rate of water movement into the soil or a media

Hydraulic conductivity is the ability of water to move through pore spaces

In the vertical dimension, the infiltration capacity is the hydraulic conductivity multiplied by the energy gradient

Published Infiltration Rates

- USDA – Web Soil Survey
- County/state soil surveys
- May be a need to field verify and utilize average K_{sat} values that include exfiltration over the wetted perimeter of the system.

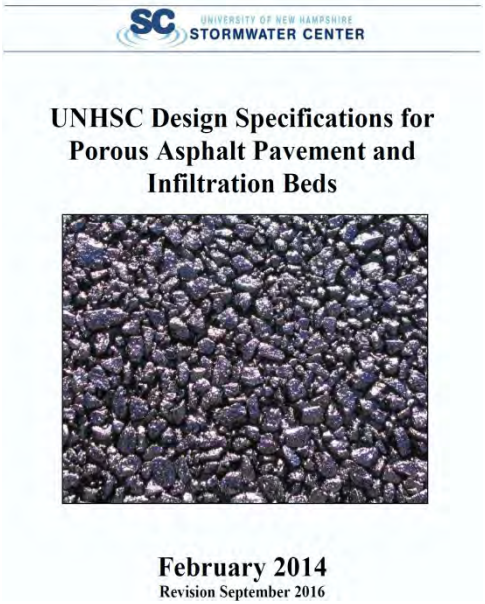
What are Permeable Pavements?

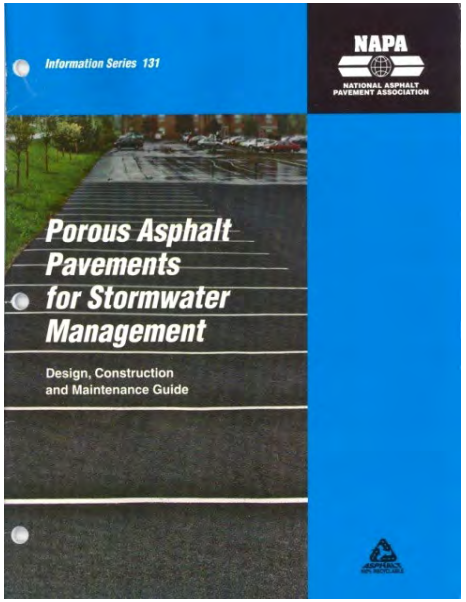
- Designed transportation surfaces that incorporate void spaces at the wearing layer to allow water to infiltrate the surface and sublayers
- Permeable Pavement Types:
  - **Interlocking Impermeable Blocks (Pavers)**
  - **Infilled Synthetic Geomatrix**
  - **Pervious Concrete**
  - **Porous Asphalt**
  - **Other (Xeripave, Flexipave, etc.)**

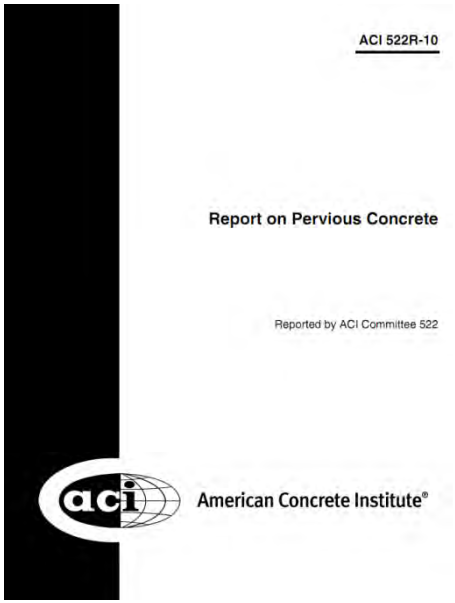
The commonality of these systems is that they all offer very high infiltration capacity Via high surface porosity

System Selection

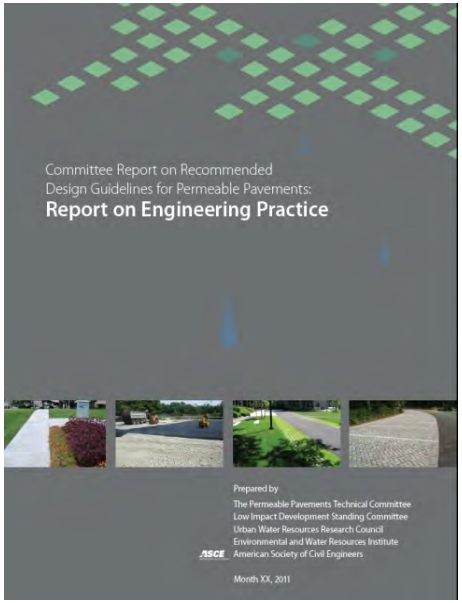
- The most important aspect of selection is the intended use (load).
- Geomatrices and Other types may be best-suited for residential and low impact use surfaces, like fire lanes, auto parking, storage, and sidewalks.
- Pavements (asphalt, concrete, pavers) may be best used for parking lots and low traffic roadways

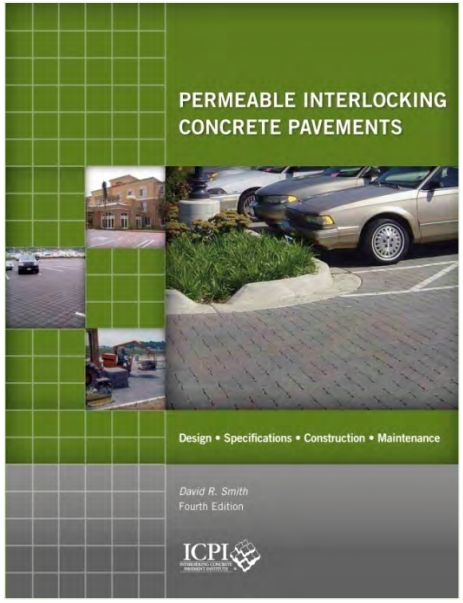

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER
UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds
February 2014
Revision September 2016


Information Series 131
NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION
Porous Asphalt Pavements for Stormwater Management
Design, Construction and Maintenance Guide


ACI 522R-10
Report on Pervious Concrete
Reported by ACI Committee 522
aci
American Concrete Institute®


Pervious
Concrete
Pavements


Committee Report on Recommended Design Guidelines for Permeable Pavements:
Report on Engineering Practice
Prepared by
The Permeable Pavements Technical Committee
Low Impact Development Standing Committee
Urban Water Resources Research Council
Environmental and Water Resources Institute
American Society of Civil Engineers
ASCE
Month XX, 2011


PERMEABLE INTERLOCKING CONCRETE PAVEMENTS
Design • Specifications • Construction • Maintenance
David R. Smith
Fourth Edition
ICPI

Design, Installation, Mix, and Material References

OVERVIEW

- ASCE, Recommended Design Guidelines for Permeable Pavements, 2011

POROUS ASPHALT

- UNHSC PA Design Specification, 2016
- NAPA Porous Asphalt Pavements for Stormwater Management, 2008

PERVIOUS CONCRETE

- PCA, Hydrologic Design of Pervious Concrete, 2007
- ACI 522R-06, Pervious Concrete, 2006

PERMEABLE PAVERS

- ICPI, Permeable Interlocking Concrete Pavements, 2011

Design Overview

1. Common Design and Installation Pitfalls
2. Design and Installation Specifications
3. Maintenance
4. Repairs

Where Should We Use PP?

- Parking Areas
- Low to moderate use/residential roadways
- Porous Asphalt strength, without admixtures, can be 1/3 -1/2 that of DMA
- Pervious Concrete may be limited by cost and where deicing is an issue
- Permeable Pavers may be best for small sites and where aesthetics are a priority

Where should we NOT use PP?

- Heavy load areas commercial/industrial
- Drinking water wells (75 ft min)
- *Pollution “hot spots” or anywhere infiltration may not be suitable
- *Areas with shallow seasonal high groundwater
- *High groundwater table or shallow depth to bedrock
- *Any threat to groundwater contamination

* These areas could be lined and underdrained

Common Pitfalls

- Inappropriate PP mix selection WRT to durability leads to raveling and low durability
- Poor subbase compaction—tendency to under-compact due to concerns regarding infiltration leads to rutting
- Poor asphalt compaction—tendency to under-compact due to weaker subbase leads to low pavement durability

All issues can be addressed through qualified engineering oversight

Subbase Materials





- Subbase refers to constructed materials comprised of select materials underlying pavement.
- Subgrade is native materials over which subbase is placed.

Cold Climate Considerations

Thickness of sub-base materials is determined based on various factors

1. Penetration of frost design

   Total system thickness $\geq 0.65 \times D_{max}$ frost depth

   Ex. if D_{max} = 48” sub-base depth = 32”

2. The high voids content of the reservoir course creates a capillary barrier to prevent wicking of moisture in subbase minimizing winter freeze-thaw and heaving

Gradations of choker, filter, and reservoir course materials

US Standard Sieve Size Inches/mm	Percent Passing (%)			
	Choker Course (AASHTO No. 57)	Filter Course (Modified NHDOT 304.1)	Reservoir Course (AASHTO No. 3)	Reservoir Course Alternative* (AASHTO No. 5)
6/150	-	100	-	
2½/63	-		100	-
2 /50	-		90 – 100	-
1½/37.5	100		35 – 70	100
1/25	95 - 100		0 – 15	90 – 100
¾/19	-		-	20 - 55
½/12.5	25 - 60		0 - 5	0 - 10
3/8/9.5	-		-	0 - 5
#4/4.75	0 - 10	70-100	-	
#8/2.36	0 - 5		-	
#200/0.075		0 – 6**		
% Compaction ASTM D698 / AASHTO T99	95	95	95	95

Filter Course

- Gravelly sand (aka. Bank run sand, NHDOT 304.1) with < 6% passing #200 or equivalent should be used for the filter course.
- The materials should have a final hydraulic conductivity of 5-30 ft / day at 95% compaction standard proctor (ASTM-D1557)

Filter Blanket/Reservoir Course

- Where applicable reservoir course and setting bed can be combined and constructed with pea gravel (3/8" stone)
- Setting bed prevents migration of fine materials from the filter course. Aggregate size is calculated based on HEC 11 (3/8" stone is most common)

$$\frac{D_{15\,coarse\ layer}}{D_{85\,fine\ layer}} < 5 < \frac{D_{15\,coarse\ layer}}{D_{15\,fine\ layer}} < 40$$

- The reservoir course is designed such that materials have sufficient void space to store the design storm (Ex. 25-year storm, 5.1" rainfall depth, 0.3 reservoir void space sub-base thickness = 17" >5.1" /0.3)



Recommended Installation

Subgrade Preparation

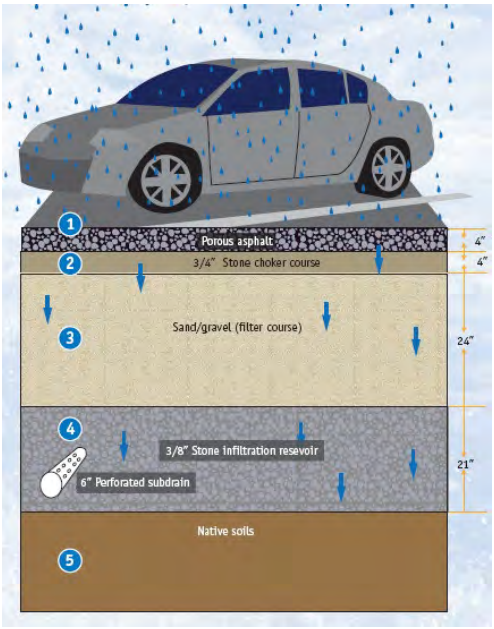
- Do not compact the native subgrade prior to the placement of the sub-base materials
- Follow same guidelines for construction of any BMP (erosion control, site stabilization)
- Minimize traffic upon subgrade
- In most instances travel upon subgrade is unavoidable, therefore careful assessment of degree of subgrade compaction is needed
- Tilling and or removal of compacted subgrade may be needed

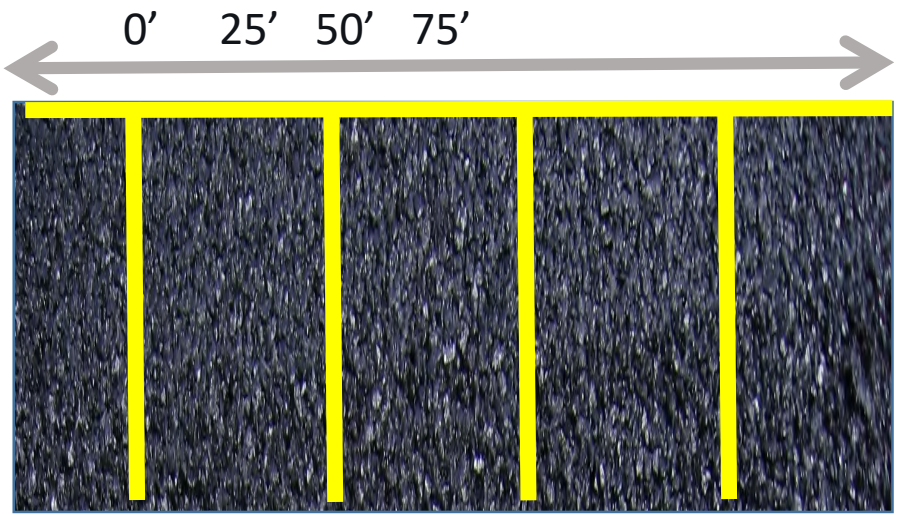
Geotextiles

- Recommendations vary on the usage of geotextiles in pervious pavement systems.
- At minimum, geotextiles should be used on soils with poor load bearing capacity, high fines content
- Geotextiles can also be used on the sides of the excavation to prevent in-migration of fines.
- Infiltration/filtration systems, such as pervious pavements, that are subject to soil movement and deposition should carefully consider the usage of geotextiles or geogrids to enhance system stabilization.
- Do not use geotextiles in the vertical cross section

Sub-drains

- Subdrains, if included, are commonly elevated at minimum 4” from bottom to provide storage and/or infiltration for 1” water quality volume.
- Subdrains are perforated pipe, 4-6” diameter with 2” cover
- Spacing should be a 25’ on center or appropriate to the discretion of the design engineer.
- Leaching catchbasins can be used as system redundancy





Routine Maintenance







Design for Maintenance Avoidance

- Avoid run-on from adjacent vegetated areas
- Use of curbs and/or stone edge
- Avoid excessive runoff from adjacent impervious areas
- Avoid areas where tracking on of materials will be expected
- High use areas should consider heavy duty pavement

Pavement Cleaning

- 1-2X/yr minimum, Spring & Fall
- Clean porous pavement to remove sediment and organic debris on the pavement surface via vacuum street sweeper.
- Adjacent non-porous pavement vacuumed
- Clean catch basins (if available)



Controlling Run-On

- 2-4 times a year
- Adjacent vegetated areas, inspect for signs of erosion and run-on to porous pavement
- Apply appropriate stabilization measures



Erosion and Sediment Controls Were Removed Too Soon at this Project Site, Causing Sediment-Laden Stormwater Runoff to Temporarily Clog the Porous asphalt Pathway, Campbelltown, PA (Source: CH2M HILL)

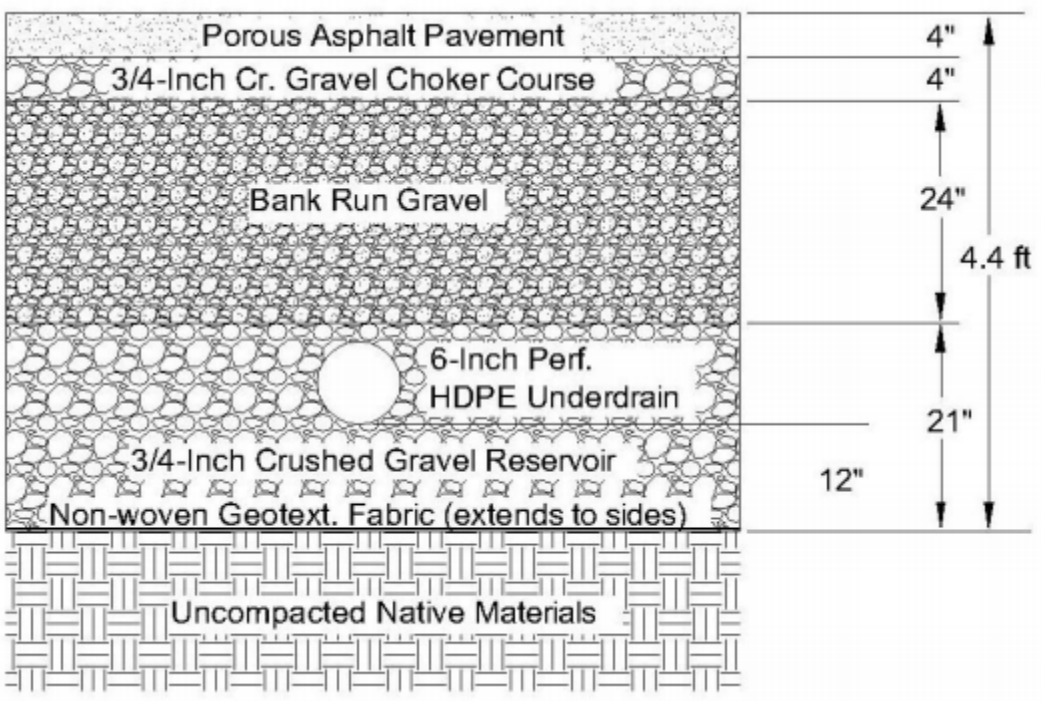
Pavement Drainage and Infiltration

- Annual inspections
- Pavement has been cleaned
- Chronic clogging locations have been pressure washed
- Standing water is not evident after rain event





Modeling Permeable Pavements



41 inches to invert of underdrain

Cross section of UNH PA pavement

Lag time of system design for curve number modeling of hydrograph peak (not volume)

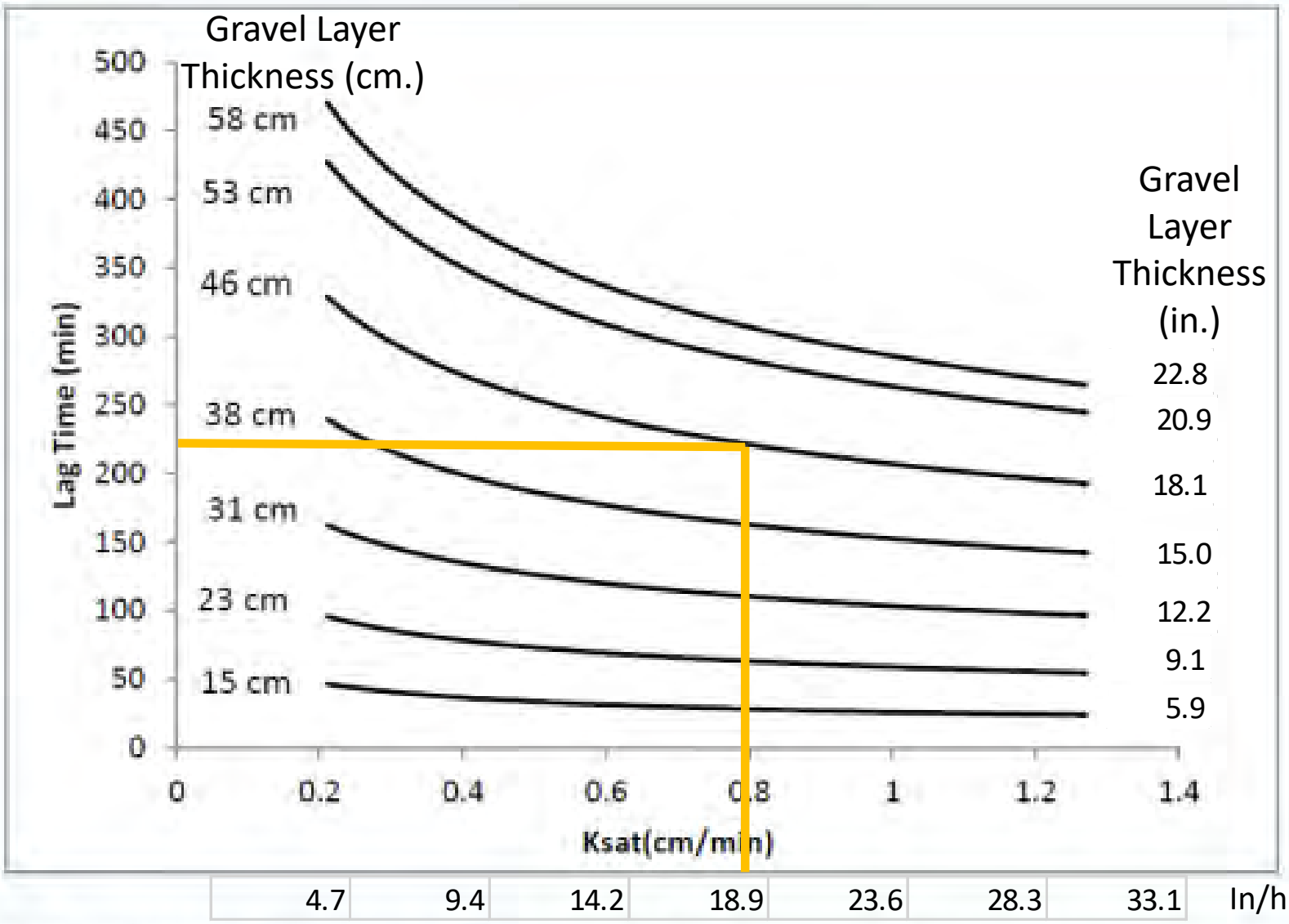
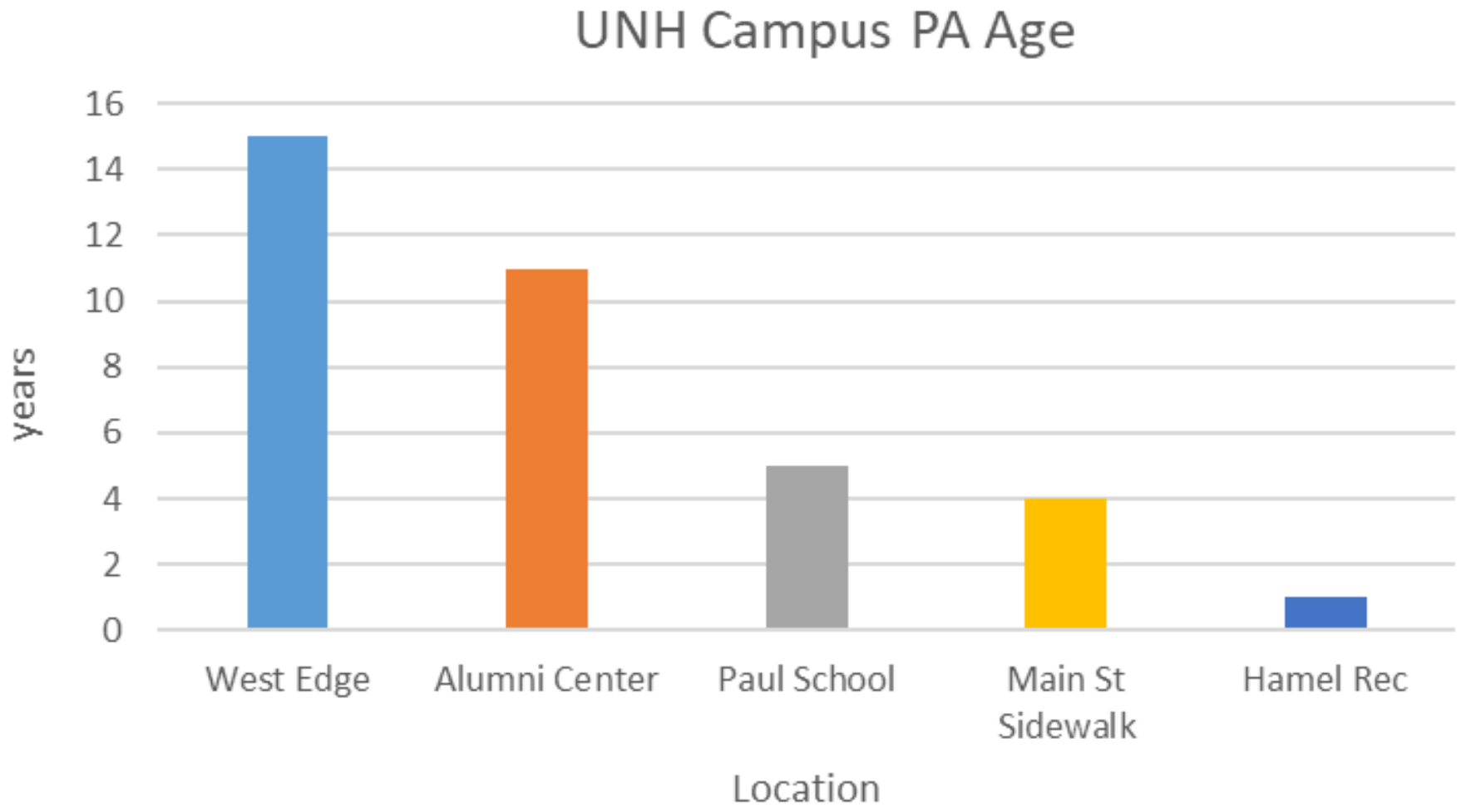
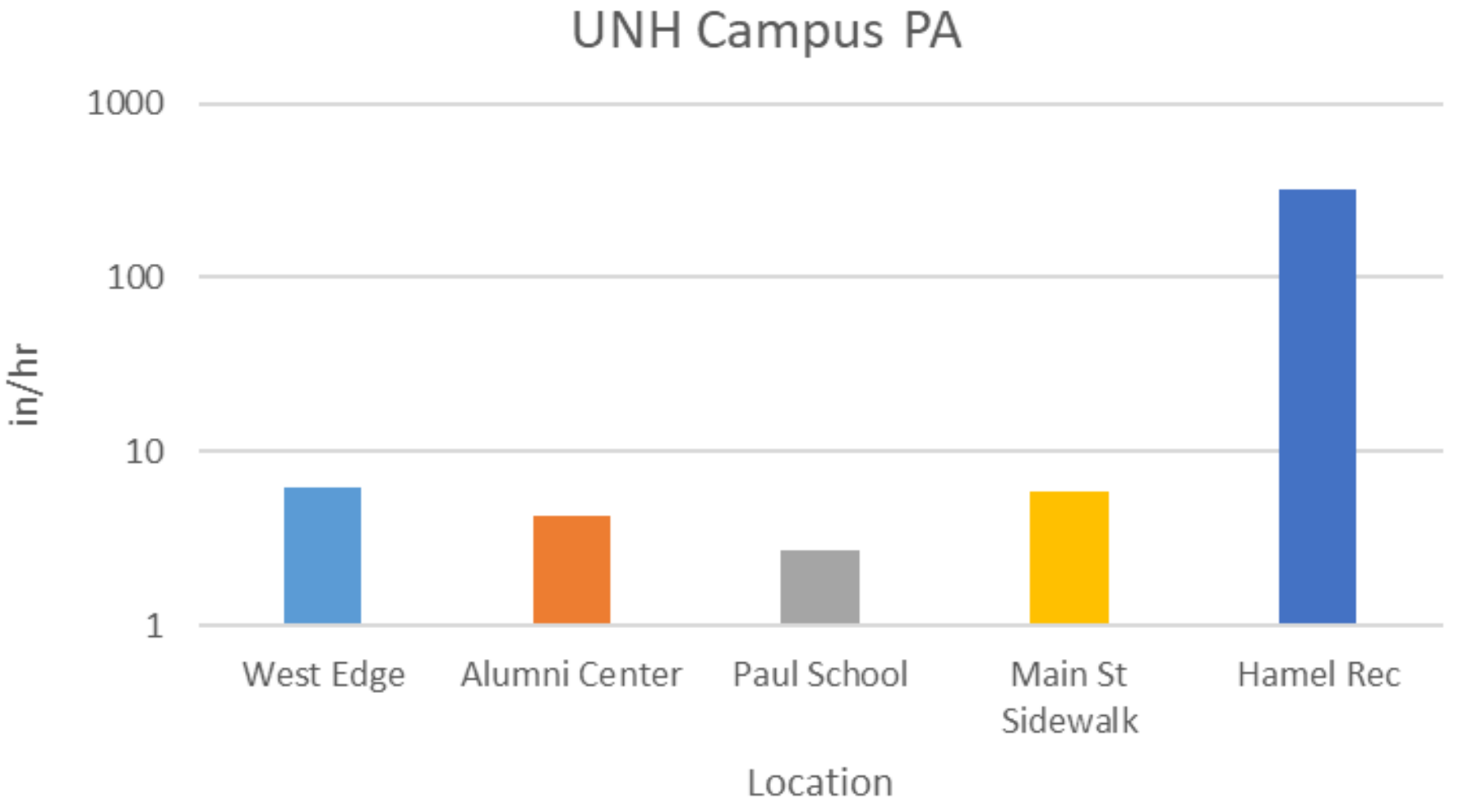


Figure 38 – Lag time through the filter media for permeable pavement systems with various thicknesses and hydraulic conductivities

UNH Permeable Pavement Research

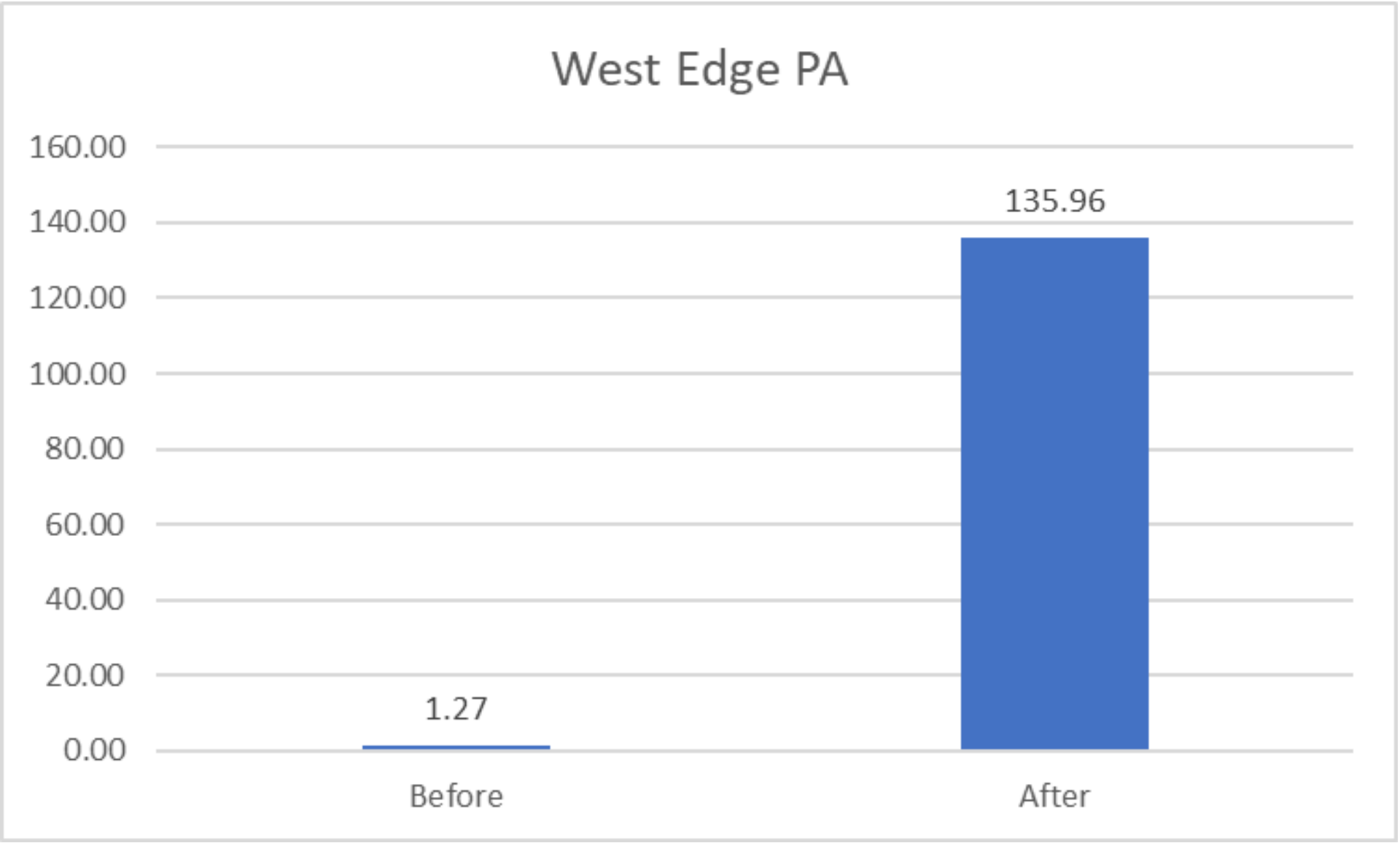


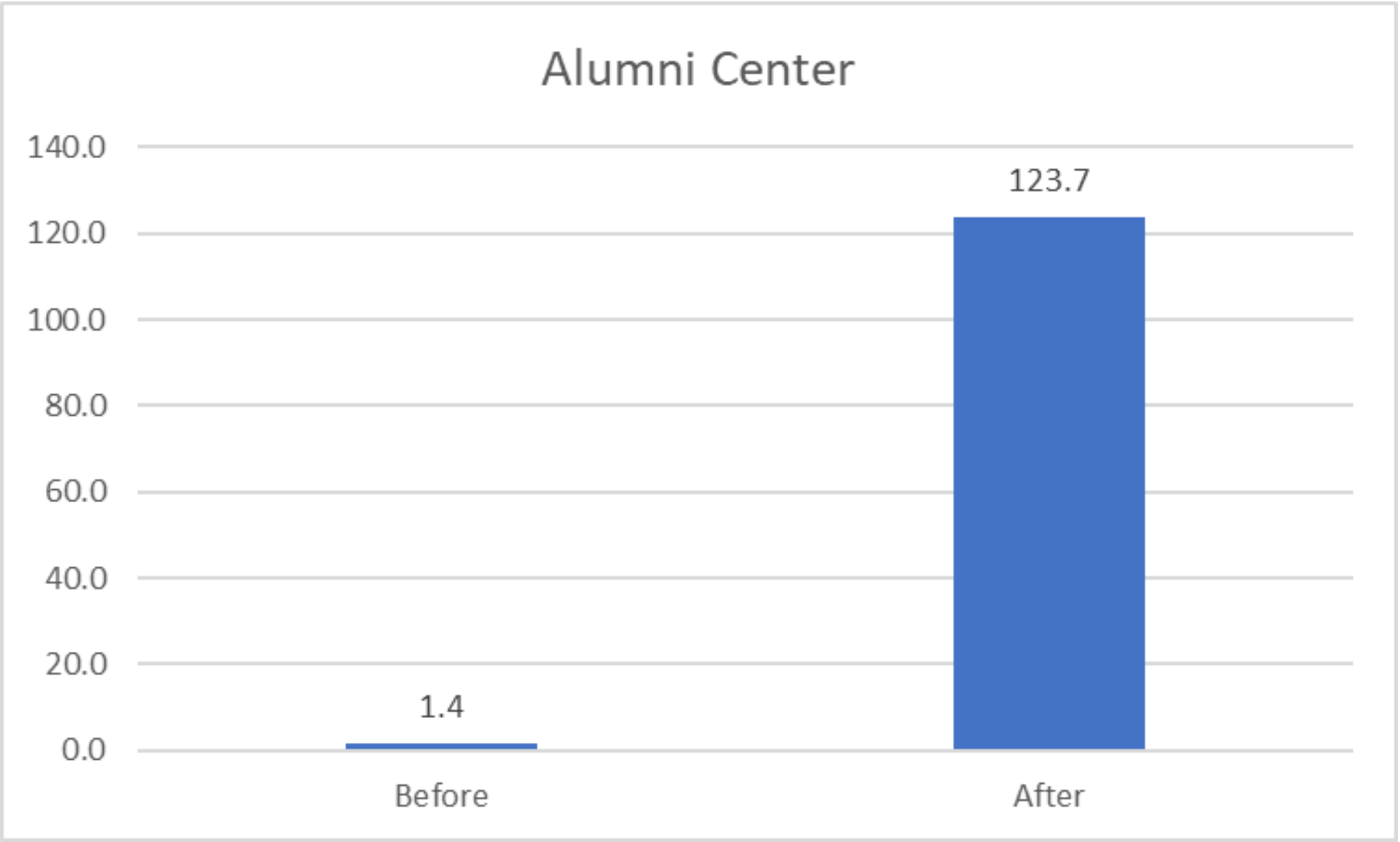
UNH Permeable Pavement Research



New Tools




West Edge PA
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
135.96
1.27
Before
After


Alumni Center
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
123.7
1.4
Before
After

Infiltration: Pre-Existing Site



System Construction



Field Measured Infiltration Results

Location	Double Ring (in/hr)
1	0.03
2	0.29*
3	0.08*
4	0.46*

DRI Median = 0.215 in/hr

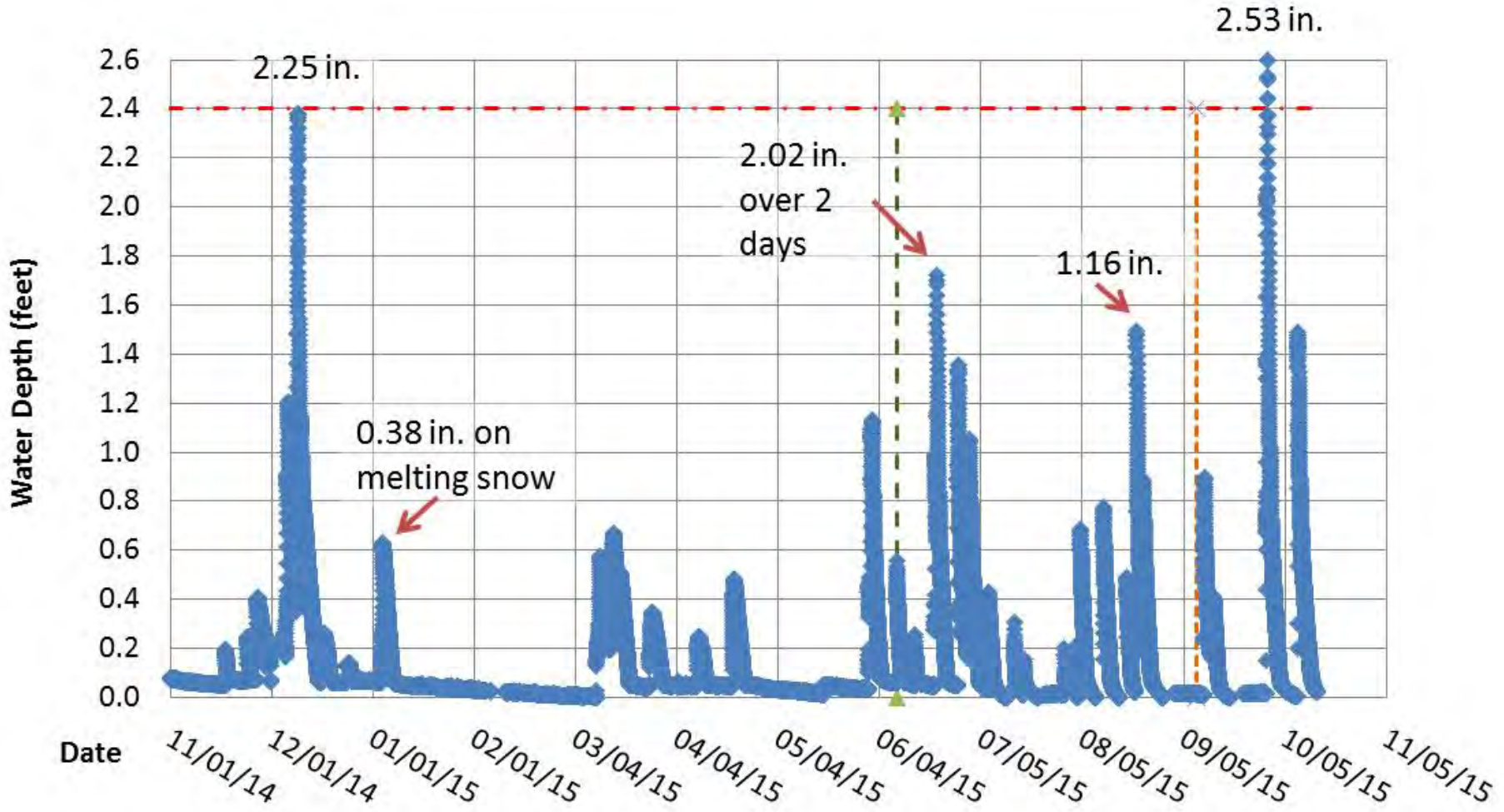
Construction



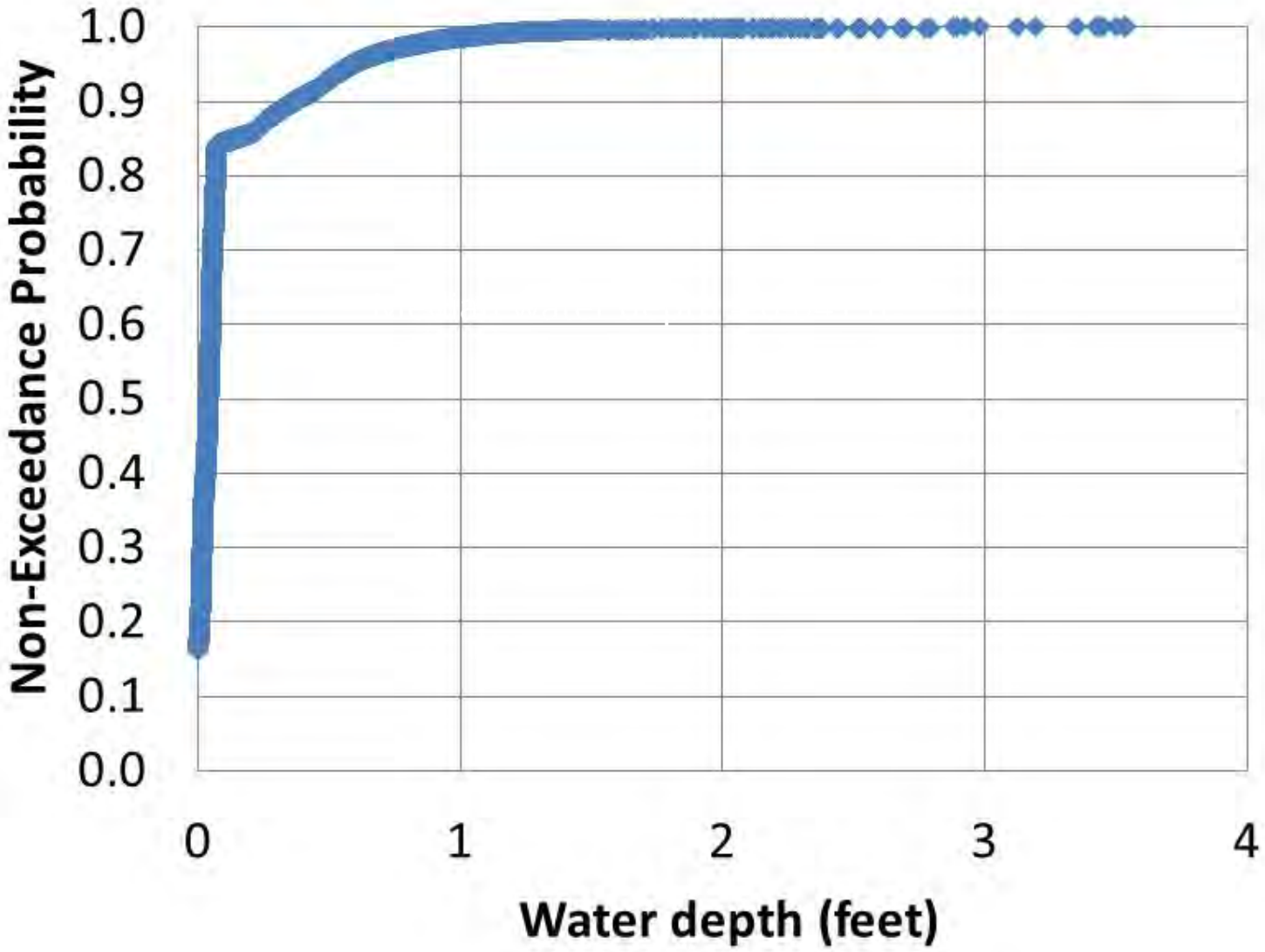
Construction



Results


2.53 in.
2.25 in.
2.02 in. over 2 days
1.16 in.
0.38 in. on melting snow
Water Depth (feet)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Date
11/01/14
12/01/14
01/01/15
02/01/15
03/04/15
04/04/15
05/04/15
06/04/15
07/05/15
08/05/15
09/05/15
10/05/15
11/05/15

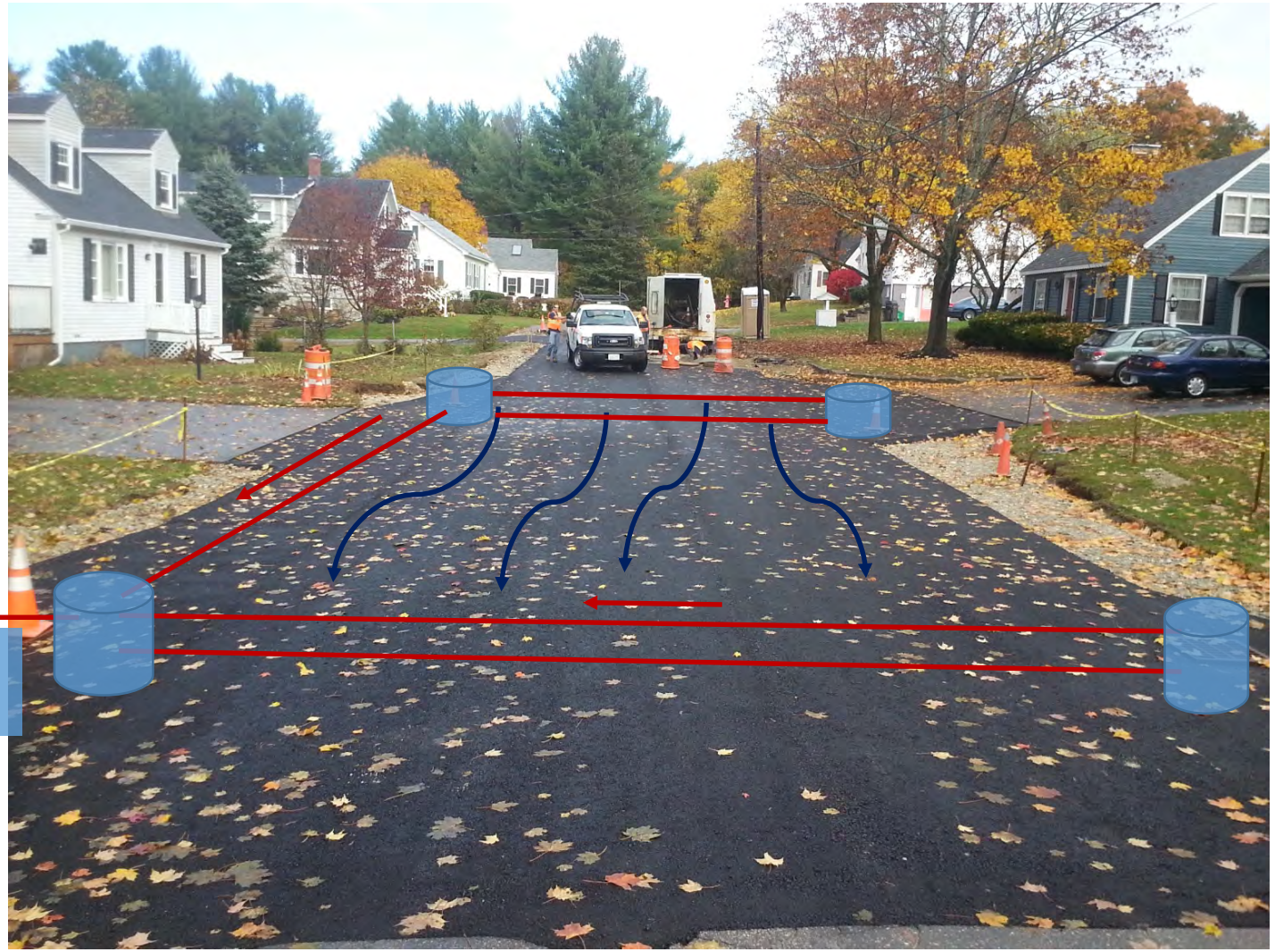
Water Depth Probability



Infiltrated Volume

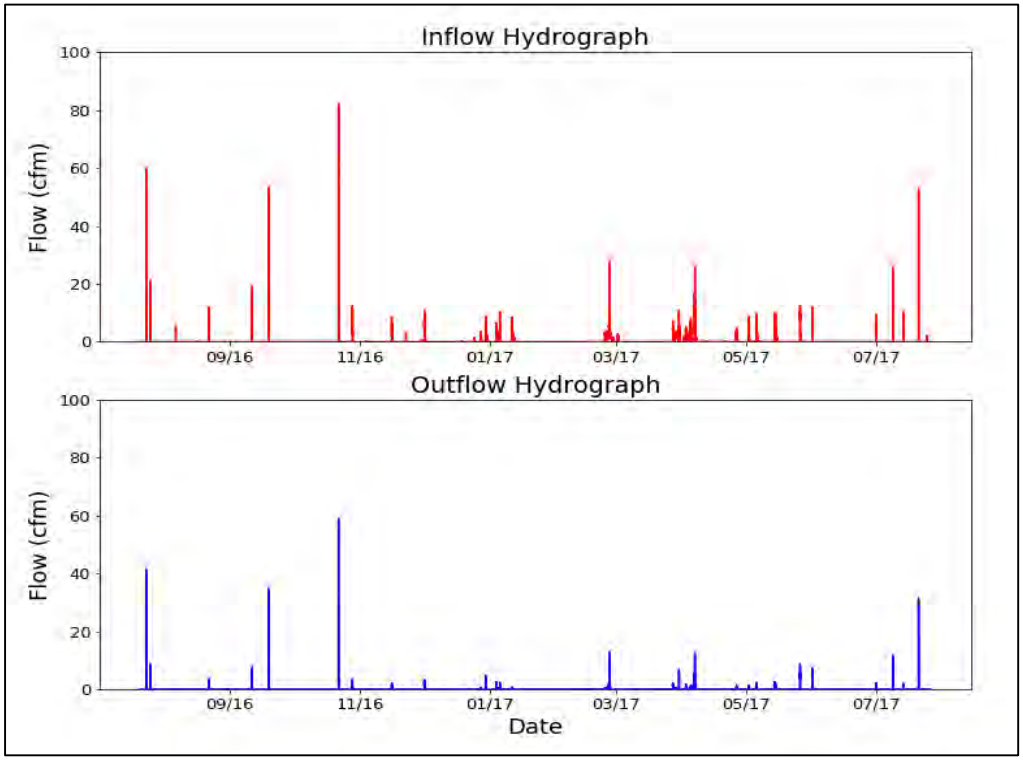
- For the 366 day period
  - **41.47 in. precip.**
  - **Precip. Volume = 87,300 ft^3**
  - **Runoff volume from asphalt (C = 0.92) = 80,330 ft^3**
  - **Infiltrated volume = 64,583 ft^3 (estimated from water depth)**
  - **Volume reduction = 80% (20% not infiltrated occurred in just 2 storms)**

GI: Subsurface Gravel Filter



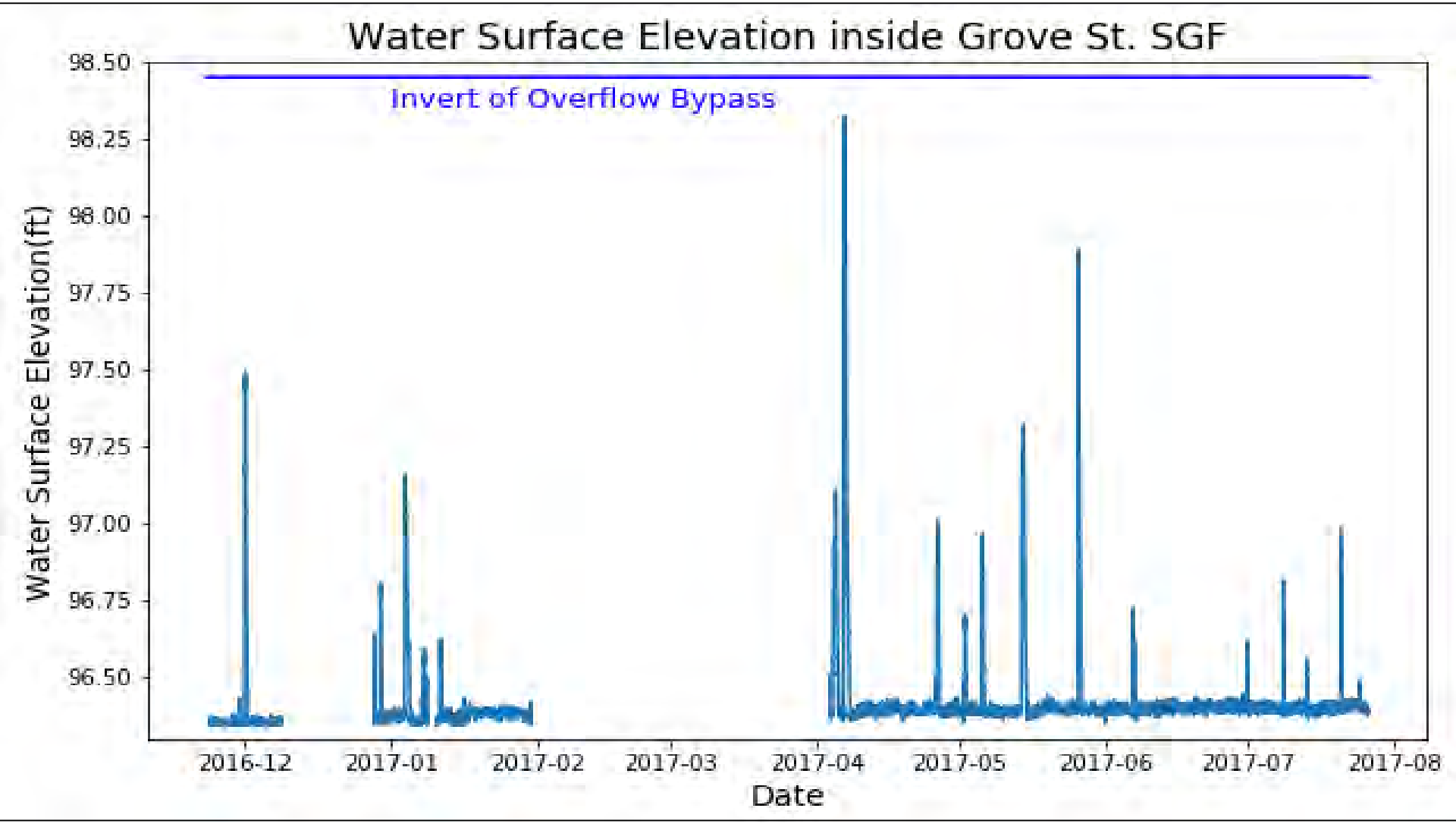
Performance Analysis using Water Balances

- **Grove St Performance Summary:**
- **Cumulative runoff volume reductions of 83%**
- **System never completely filled**
  - **Maximum water depth of 1.94ft for 1.25-inch rain event on 4/6/2017**



Cumulative Flow Volumes (ft^3)	
Inflow Volume	76,695
Outflow Volume	12,272
Infiltration Volume	64,423

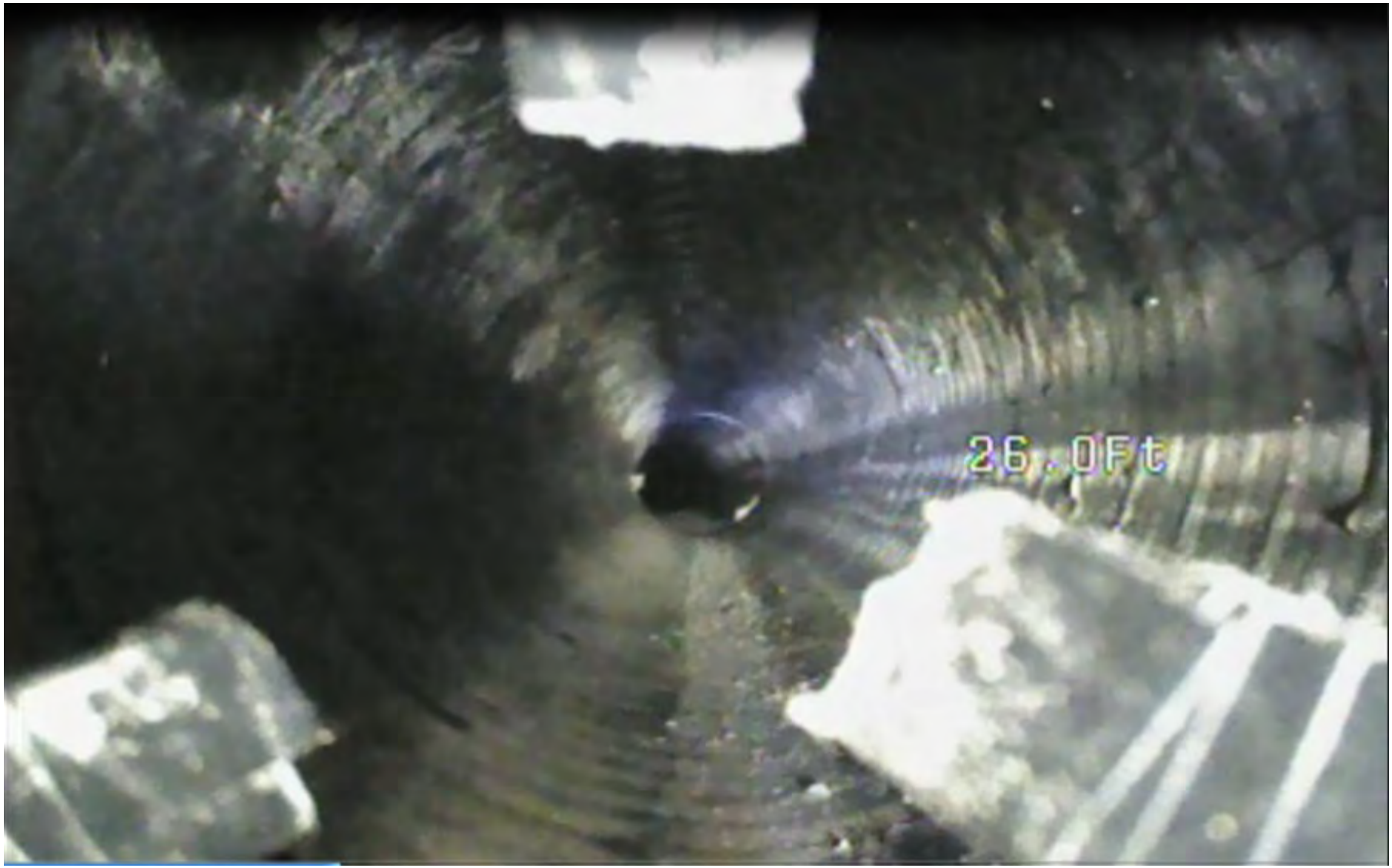
Measured WSE Inside Grove St SGF



Infiltration Longevity

- Hydraulic inlets to infiltration systems need to be accessible, monitorable and maintainable over time


25.1Ft


26.0Ft

Questions



Providence Stormwater Innovation Center

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Audubon Society of Rhode Island

RESTORE AMERICA'S ESTUARIES

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SNEP