UF|IFAS
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LID/GI Design and Effectiveness

Improving Water Quality with Green Infrastructure and Low Impact Development
December 4, 2019

FOR THE
#GATORGOOD

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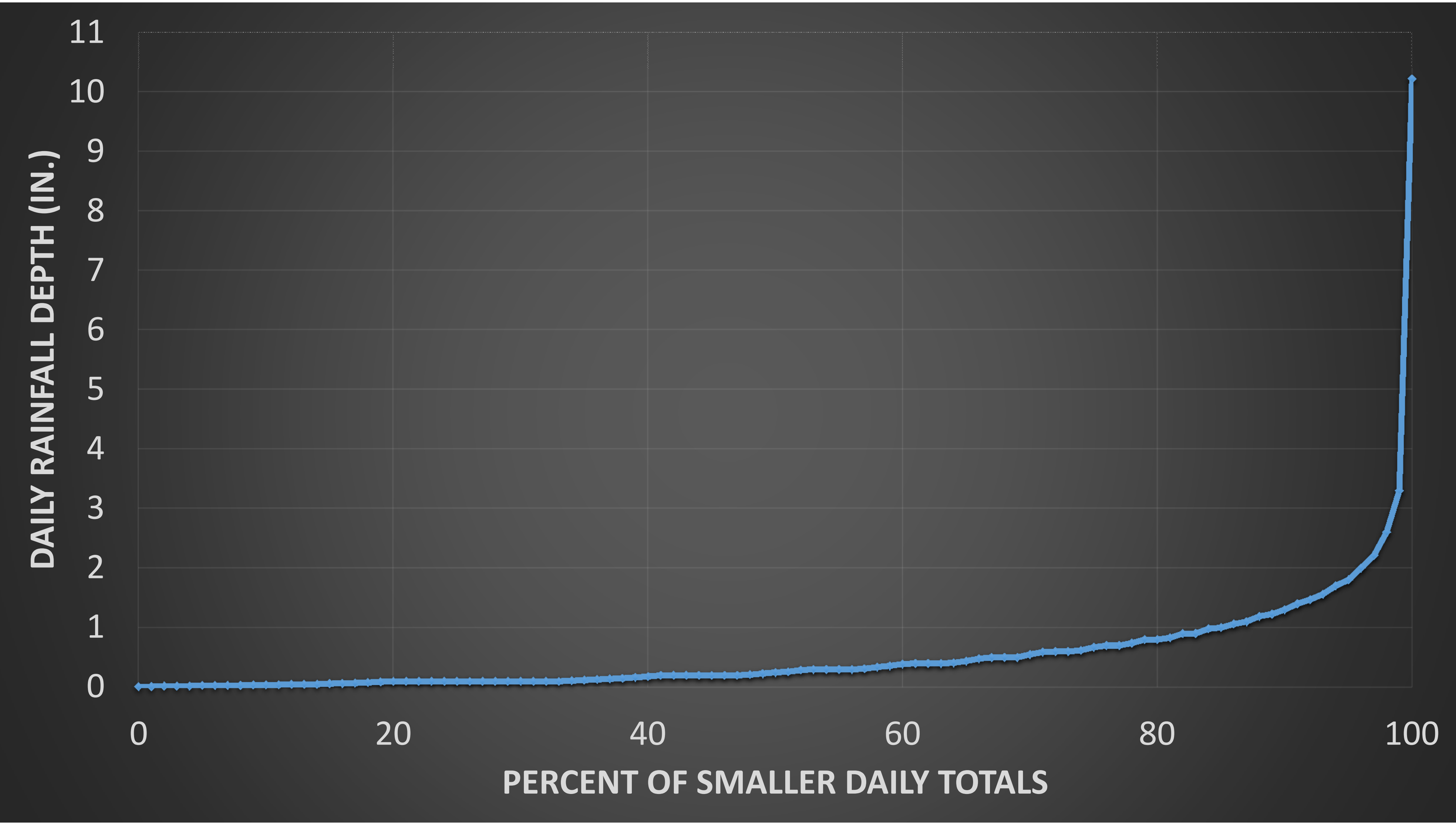
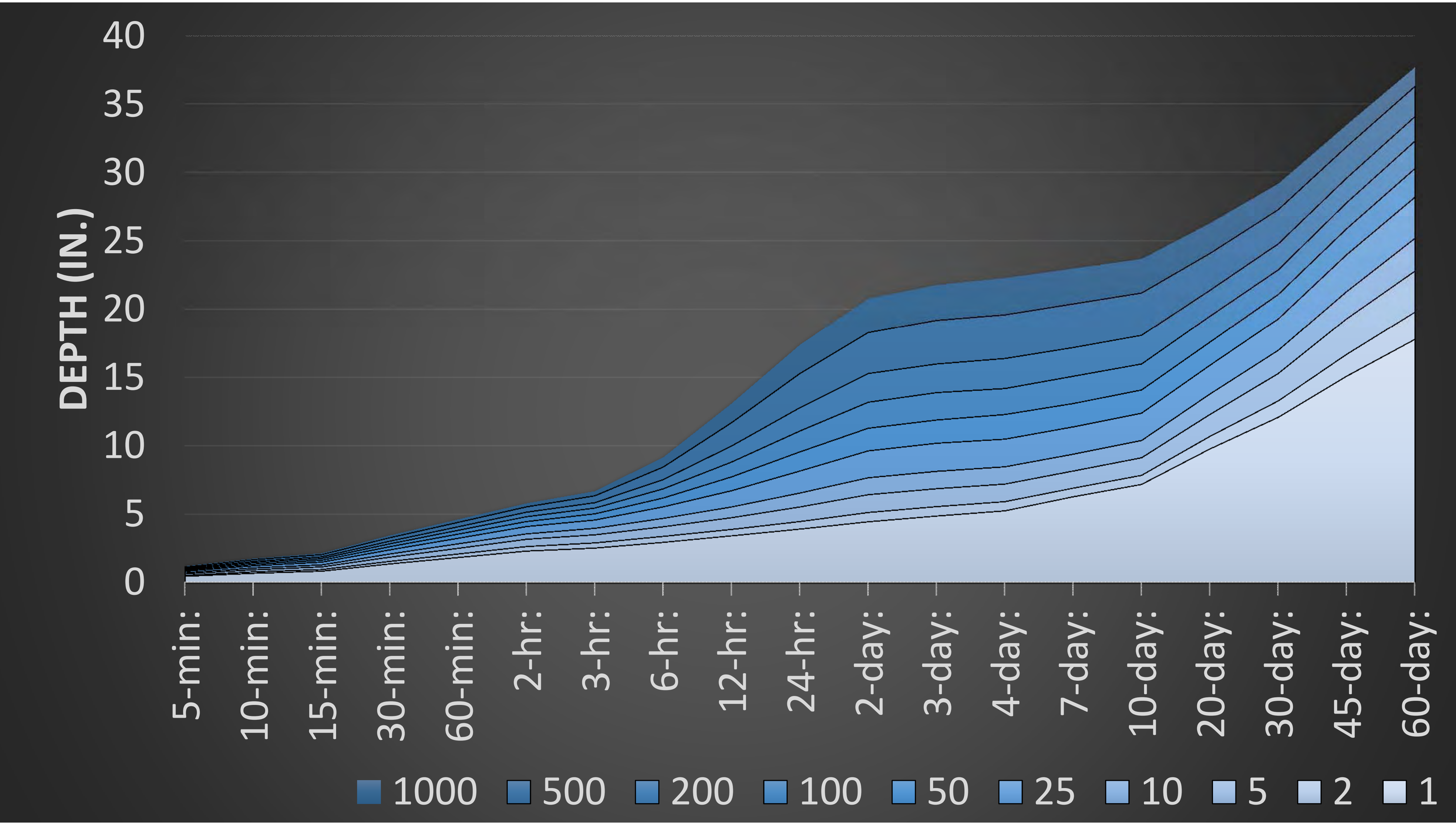
Definition of LID

*"A <u>site design strategy</u> for **maintaining or replicating the predevelopment hydrologic regime** through the use of <u>design techniques</u> that create a* **functionally equivalent hydrologic landscape**. *Hydrologic functions of **storage, infiltration, and ground water recharge,** plus <u>discharge volume</u> and <u>frequency</u> are **maintained** by integrated and distributed microscale stormwater retention and detention areas, reduction of impervious surfaces, and the lengthening of flow paths and runoff time. Other LID strategies include, but are not limited to, the **preservation of environmentally sensitive site features** such as natural upland habitat, wetlands, wetland buffers, and floodplains."*

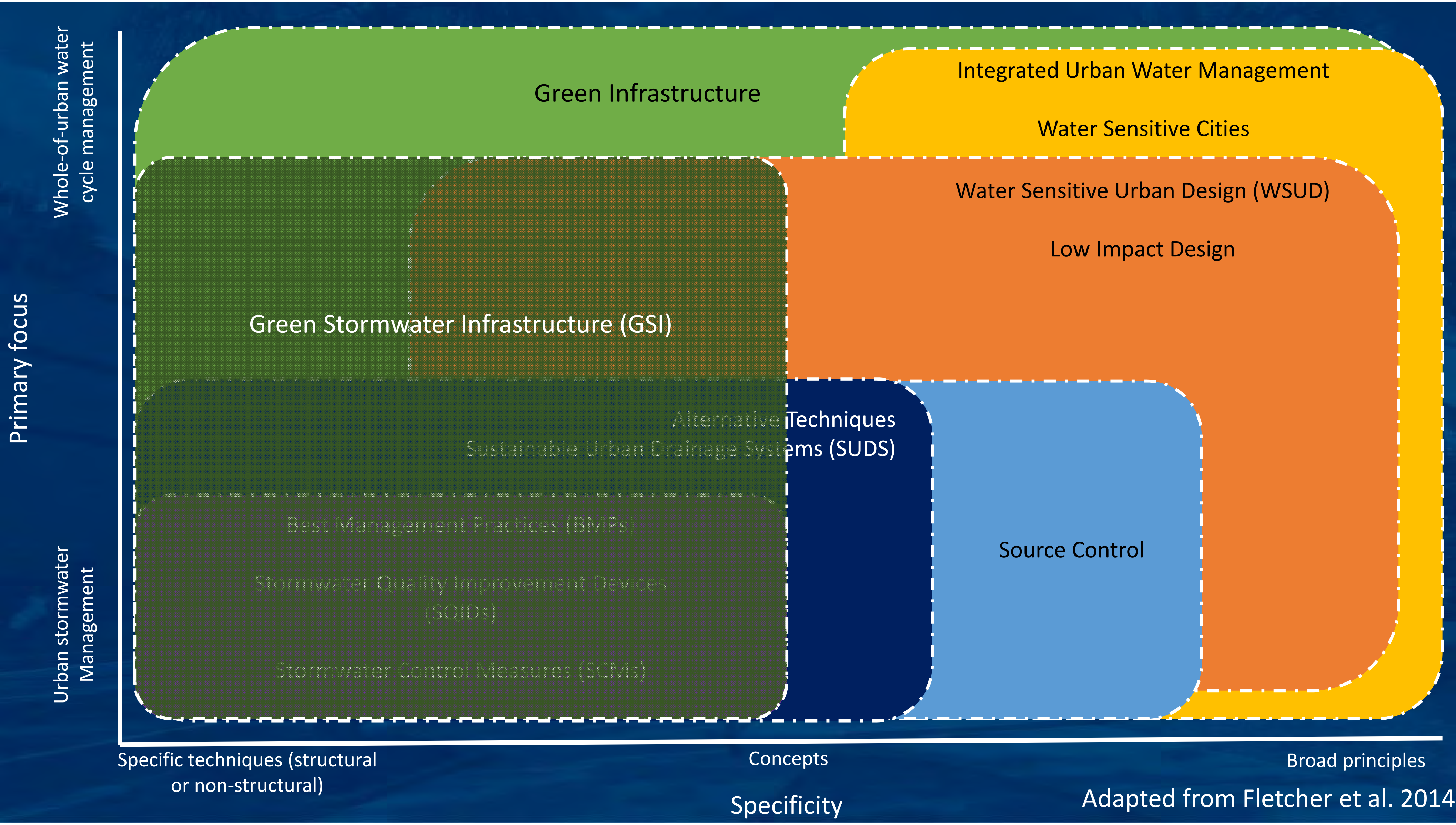
- Alachua County Unified Land Development Code 410-23.



DAILY RAINFALL DEPTH (IN.)
11
10
9
8
7
6
5
4
3
2
1
0
0
20
40
60
80
100
PERCENT OF SMALLER DAILY TOTALS



DEPTH (IN.)
40
35
30
25
20
15
10
5
0
5-min:
10-min:
15-min:
30-min:
60-min:
2-hr:
3-hr:
6-hr:
12-hr:
24-hr:
2-day:
3-day:
4-day:
7-day:
10-day:
20-day:
30-day:
45-day:
60-day:
1000
500
200
100
50
25
10
5
2
1


Primary focus
Whole-of-urban water cycle management
Urban stormwater Management
Green Infrastructure
Integrated Urban Water Management
Water Sensitive Cities
Water Sensitive Urban Design (WSUD)
Low Impact Design
Green Stormwater Infrastructure (GSI)
Alternative Techniques
Sustainable Urban Drainage Systems (SUDS)
Best Management Practices (BMPs)
Stormwater Quality Improvement Devices (SQIDs)
Stormwater Control Measures (SCMs)
Source Control
Specific techniques (structural or non-structural)
Concepts
Broad principles
Specificity
Adapted from Fletcher et al. 2014

Key Elements of LID

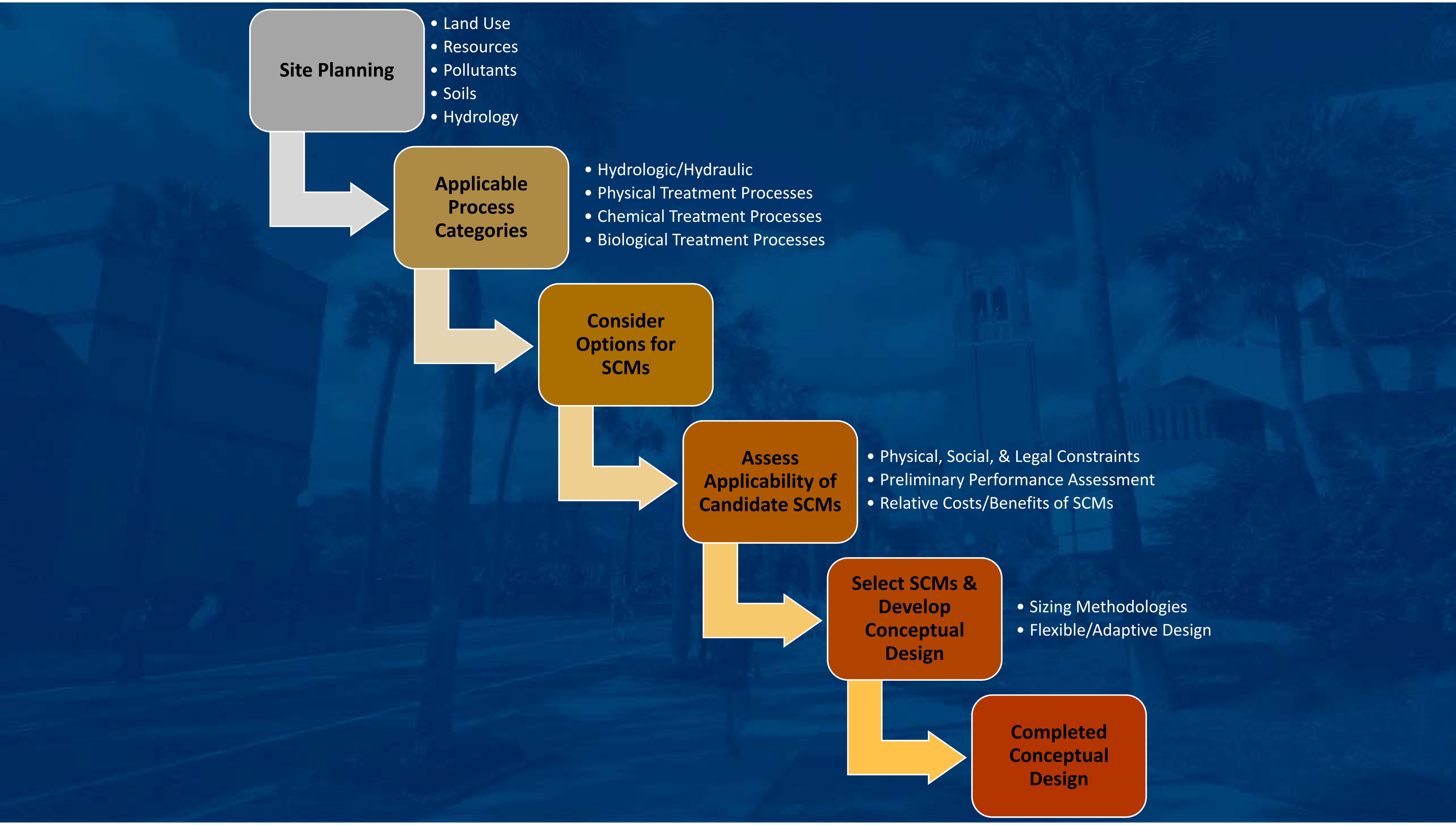
Conservation
Preserve native trees, vegetation and soils. Maintain natural drainage patterns.

Small-scale Controls
Mimics natural hydrology processes.

Customized Site Design
Ensures each site helps protect the entire watershed.

Maintenance, Pollution Prevention & Education
Reduces pollutant loads and increases efficiency and longevity. Educates and involves the public.

Direct Runoff to Natural Areas
Encourages infiltration and recharge of streams wetlands and aquifers.


Site Planning
• Land Use
• Resources
• Pollutants
• Soils
• Hydrology
Applicable Process Categories
• Hydrologic/Hydraulic
• Physical Treatment Processes
• Chemical Treatment Processes
• Biological Treatment Processes
Consider Options for SCMs
Assess Applicability of Candidate SCMs
• Physical, Social, & Legal Constraints
• Preliminary Performance Assessment
• Relative Costs/Benefits of SCMs
Select SCMs & Develop Conceptual Design
• Sizing Methodologies
• Flexible/Adaptive Design
Completed Conceptual Design


PAHs
Metals
Marynewsom.blogspot.com


Atmospheric Deposition
Organic Debris
Sediments
cleanwateroxford.org

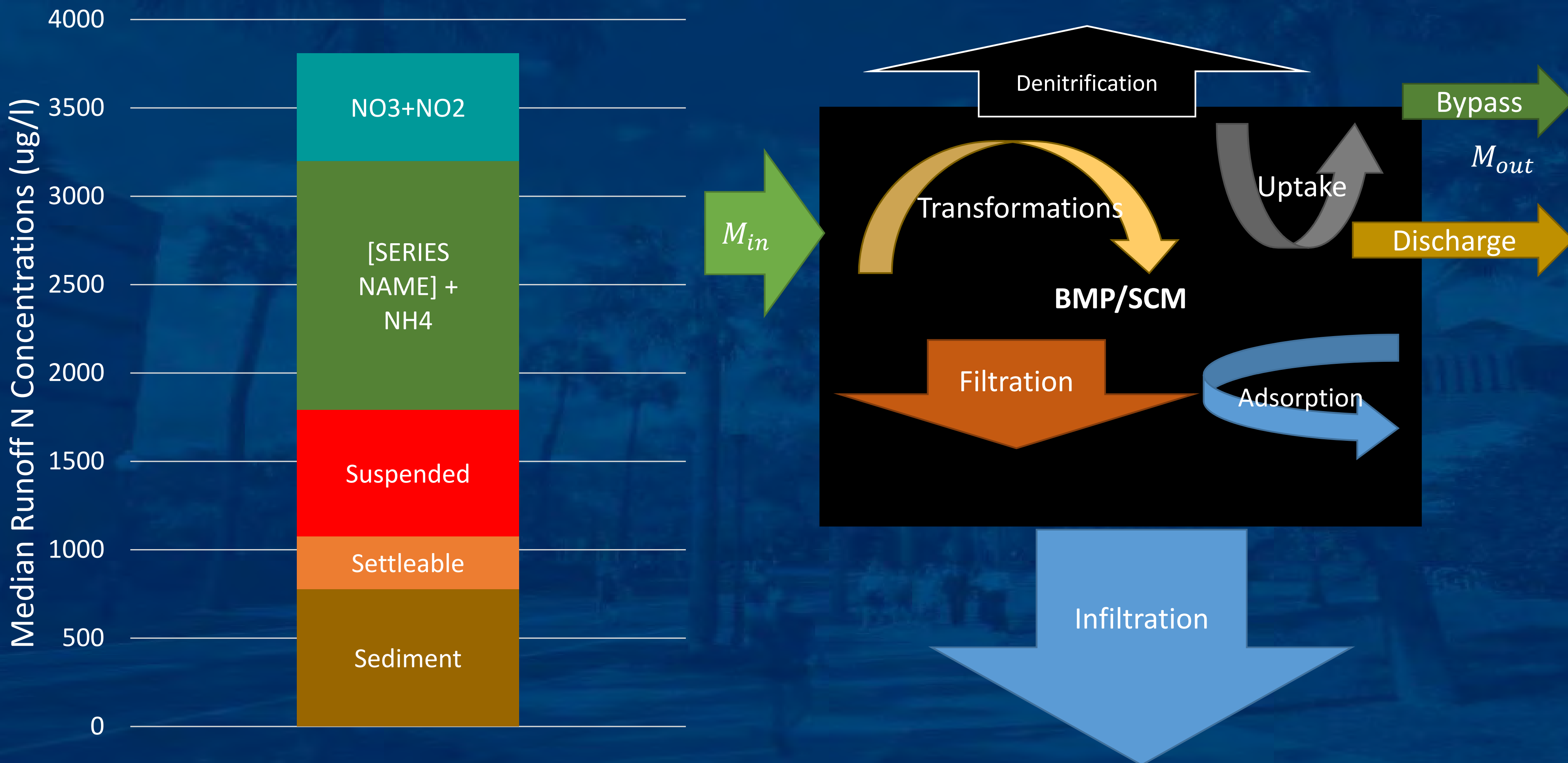

Nitrogen
Phosphorus
Lowes.com


Nutrients
Pathogens
liveearth.org

Treatment Processes and SCMs

Treatment Process/Function	SCM Options	What is Removed?	How Does It Happen?
Flotation	Skimmers Oil/water separators Density separators	Oil and other hydrocarbons Trash	Substances lighter than water are removed with units specifically designed for this purpose.
Settling / sedimentation	Bioretention Wetlands Wet or dry ponds Tree boxes Cisterns	Suspended solids Metals Particulate phosphorus Organics	Suspended particles settle by gravity, along with pollutants adhered to them. Forebays must capture and facilitate periodic removal of sediment. Avoid re-suspension of sediment.
Filtration	Sand / gravel filters Natural / amended soil Green roofs Infiltration tanks Horizontal wells	Suspended solids Metals Phosphorus Organics	Stormwater passes through a porous material, mechanically removing anything larger than the pore openings.
Sorption	Any BMP employing infiltration thru soils or other media, especially organic material or clay.	Dissolved nutrients Metals Bacteria	Contaminants adhere to irregularities in the surface of vegetation, to clay particles in soil, or are attached to other molecules by chemical bonds
Biological removal	Bioretention Enhanced ponds Floating islands	Nitrogen Phosphorus Organic molecules	Microorganisms and plants take in nutrients needed for their cell growth and break apart large organic molecules.

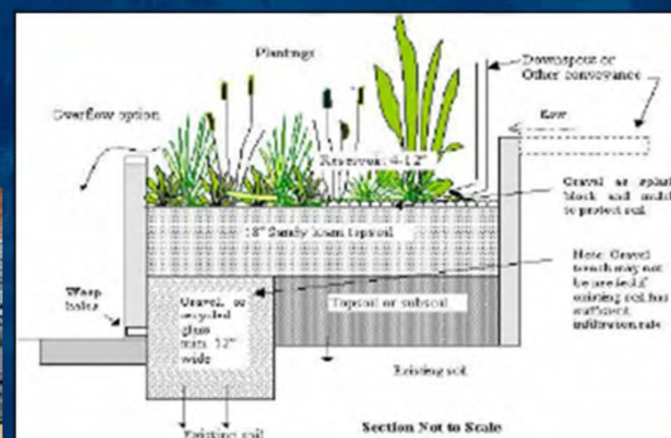
Match Pollutant with Process

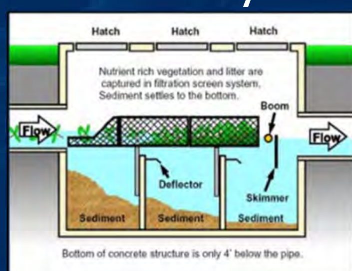


Zhang et al., 2015; NURP, 1986

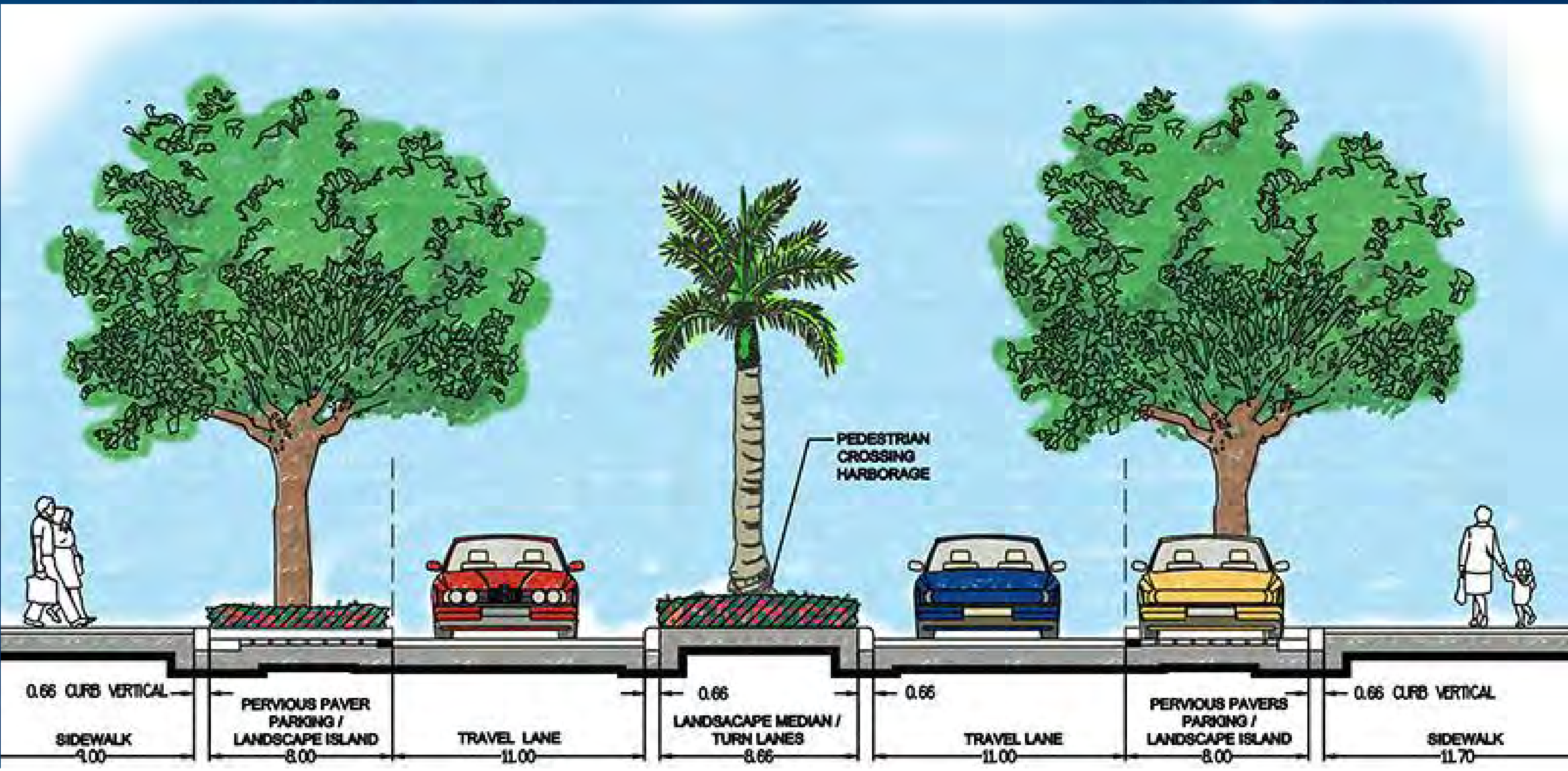
LID SCMs

- Non-structural LID SCMs
- General Structural SCM Design Criteria
- Structural SCMs
- Flow Control SCMs
- Flow-through SCMs
- Off-lot SCMs
- Other Treatment Systems





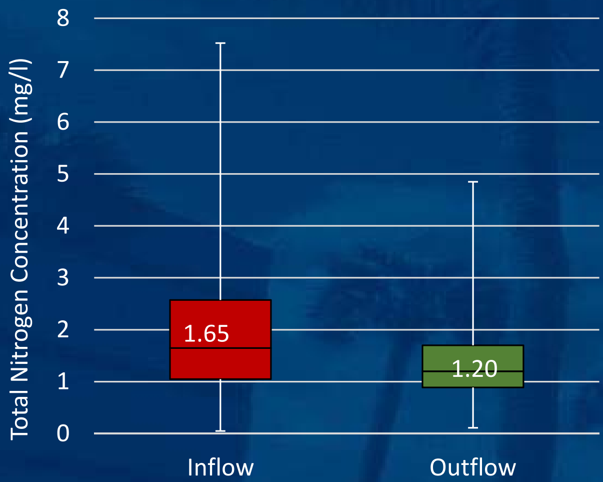
Identifying Site Constraints

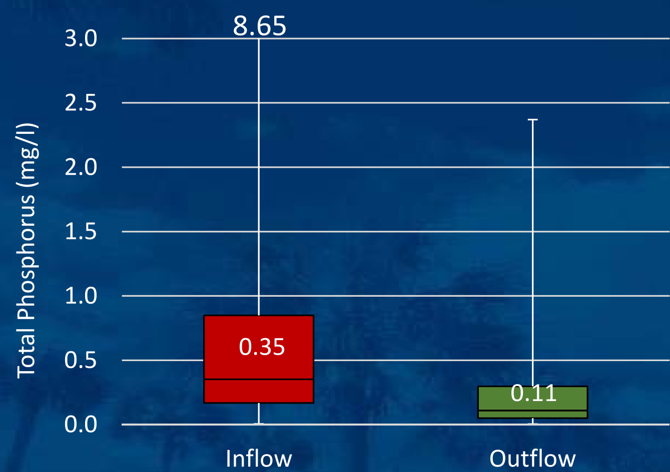


	Veg. Swale	Veg. Swale	Green Roof	Green Roof	Green Roof	Green Roof
	Cisterns	Cisterns	Cisterns	Cisterns	Cisterns	Cisterns
	Raingardens	Rain gardens	Curb Cuts	Planter Boxes	Planter Boxes	Curb Cuts
	Onsite WW	Bioretention	Perm. Pavement	Curb Cuts	Curb Cuts	Perm. Pavement
		Buffer Strips	Parking Lot Bioretention	Perm. Pavement	Perm. Pavement	Parking Lot Bioretention
		Enhanced Ponds	Exfiltration	Exfiltration	Exfiltration	Exfiltration
		Float. Wetlands	Basin Inserts	Basin Inserts	Basin Inserts	Basin Inserts
			Filter Systems	Filter Systems	Filter Systems	Filter Systems
			Enhanced Ponds	In-stream Bioreactors	In-stream Bioreactors	

Conventional Approach

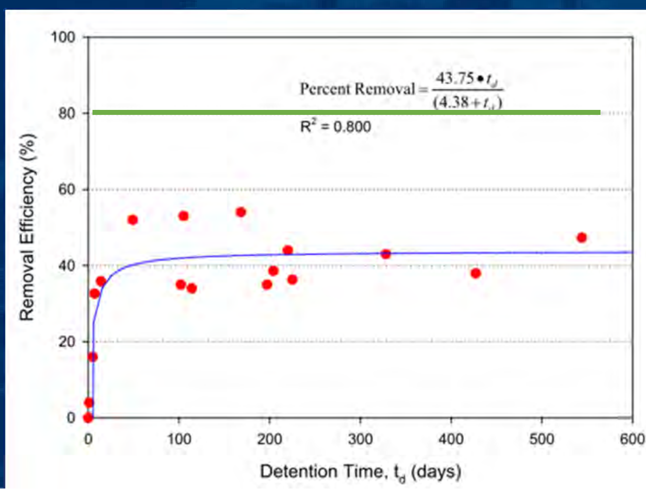
Stormwater Pond Performance

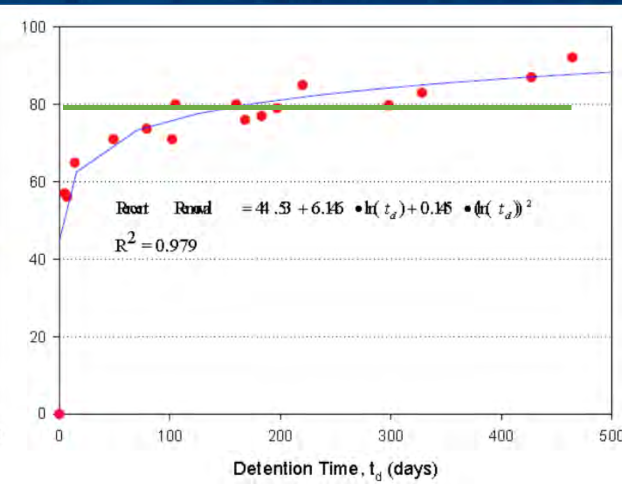




- Presumptive Compliance
- Impairment, TMDLs, BMAPs
- Numeric Nutrient Criteria

Paired sample results collected from 18 (N) and 23 (P) stormwater retention ponds in Florida. *International Stormwater BMP Database*





Low Impact Development/Green Stormwater Infrastructure Approach

Source Loading Calculations

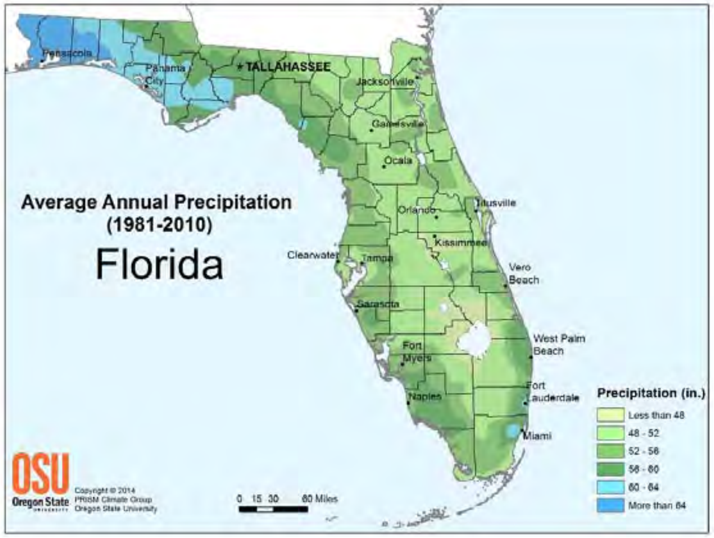
- Annual Mass Loading = Runoff Volume * Flow-Weighted Concentration
- Volume – Annual average runoff volume from source area per year
- Concentration – Event Mean Concentration (flow weighted concentration)

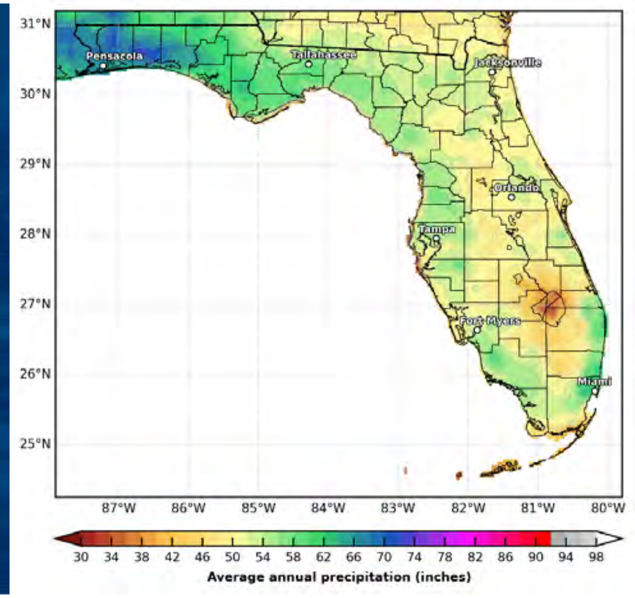
- Background and examples
- https://www.florida-stormwater.org/assets/MemberServices/Seminars/2016/02 - runoff and pollutant loadharper.pdf

Average Annual Runoff Volume

- Long-term assessment

- Based on Rationale Method
- $Q = CiA$
  - Q – annual runoff volume (ac-in.)
  - C – equivalent runoff coefficient
  - i – average annual rainfall (in.)
  - A – drainage area (ac.)

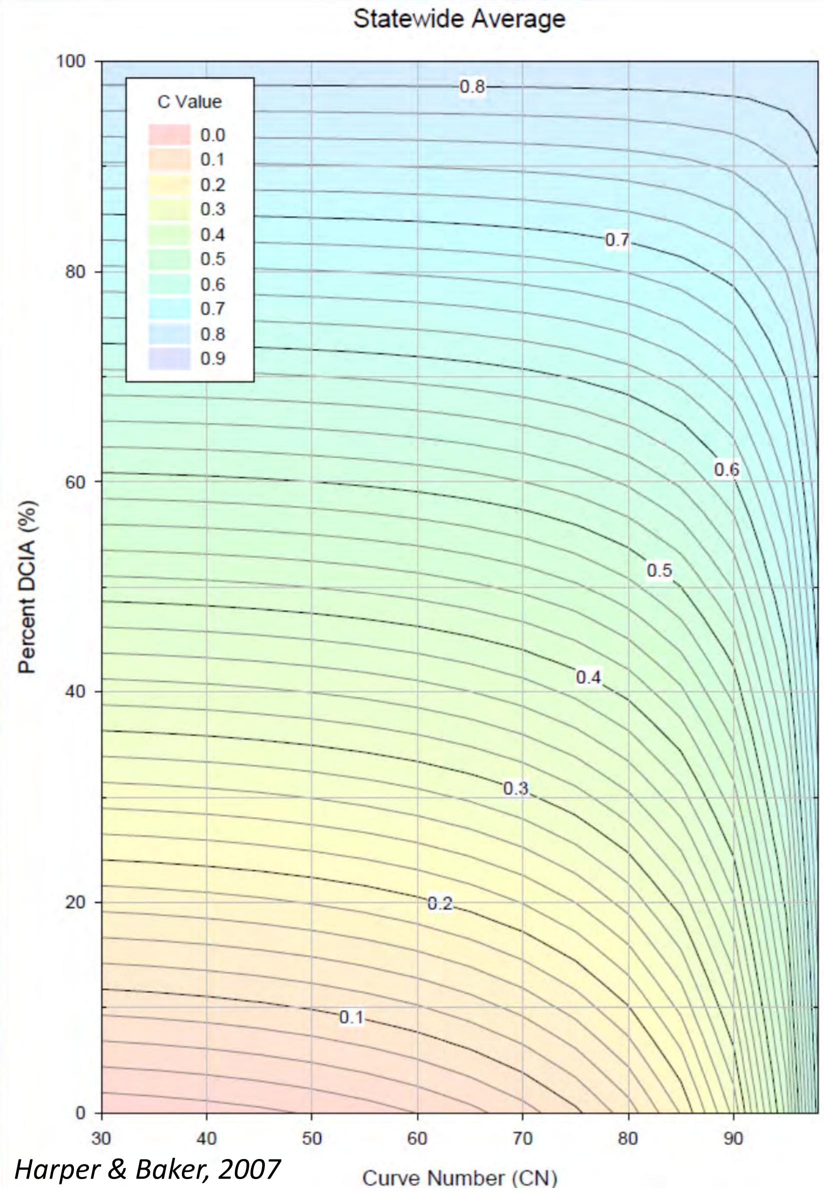




Annual Runoff Coefficient

Equivalent Long-Term Runoff Coefficient for Curve Number

- Area Composition
  - Impervious
    - Percent Directly Connected (DCIA)
    - Non-DCIA
  - Pervious
    - Soil type
- Rainfall Characteristics
  - Region specific values



Harper & Baker, 2007

FDEP Event Mean Concentrations

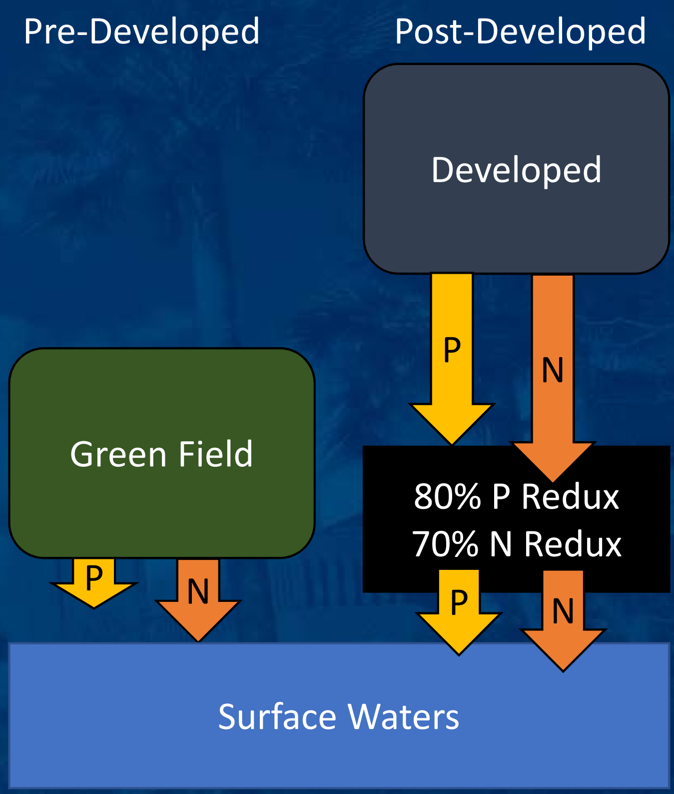
LAND USE CATEGORY	TYPICAL RUNOFF CONCENTRATION (mg/l)						
	TOTAL N	TOTAL P	BOD	TSS	COPPER	LEAD	ZINC
Low-Density Residential	1.61	0.191	4.7	23.0	0.008	0.002	0.031
Single-Family	2.07	0.327	7.9	37.5	0.016	0.004	0.062
Multi-Family	2.32	0.520	11.3	77.8	0.009	0.006	0.086
Low-Intensity Commercial	1.18	0.179	7.7	57.5	0.018	0.005	0.094
High-Intensity Commercial	2.40	0.345	11.3	69.7	0.015	--	0.160
Light Industrial	1.20	0.260	7.6	60.0	0.003	0.002	0.057
Highway	1.64	0.220	5.2	37.3	0.032	0.011	0.126
Undeveloped / Rangeland / Forest	1.15	0.055	1.4	8.4	--	--	--

Data available for various green field conditions.

Load Reduction

Calculate loadings for Pre- & Post- conditions

- Average Annual Runoff Volume
  - DCIA & NDCIA CN for region
- Event Mean Concentrations



Required Loading Reductions:

Discharge to Surface Waters – TN: 70% Post; TP: 80% Post

Discharge to Outstanding Florida Waters – TN/TP: 95% Post

Impaired Waters – TN/TP: Post < [Pre - 10%]

Net Improvement Standard

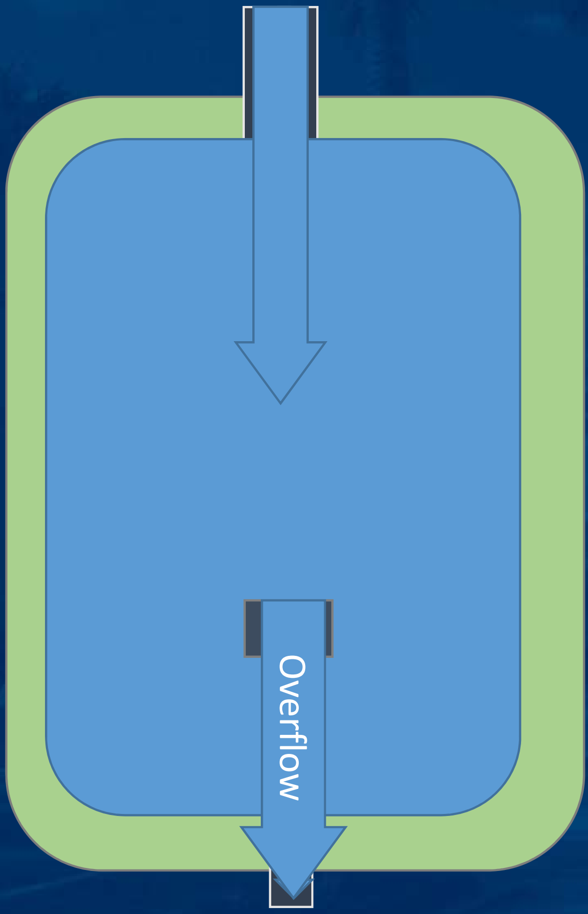
Statewide BMP Efficiencies

TABLE 1: EFFICIENCIES FOR NONPOINT SOURCE MANAGEMENT BMPS

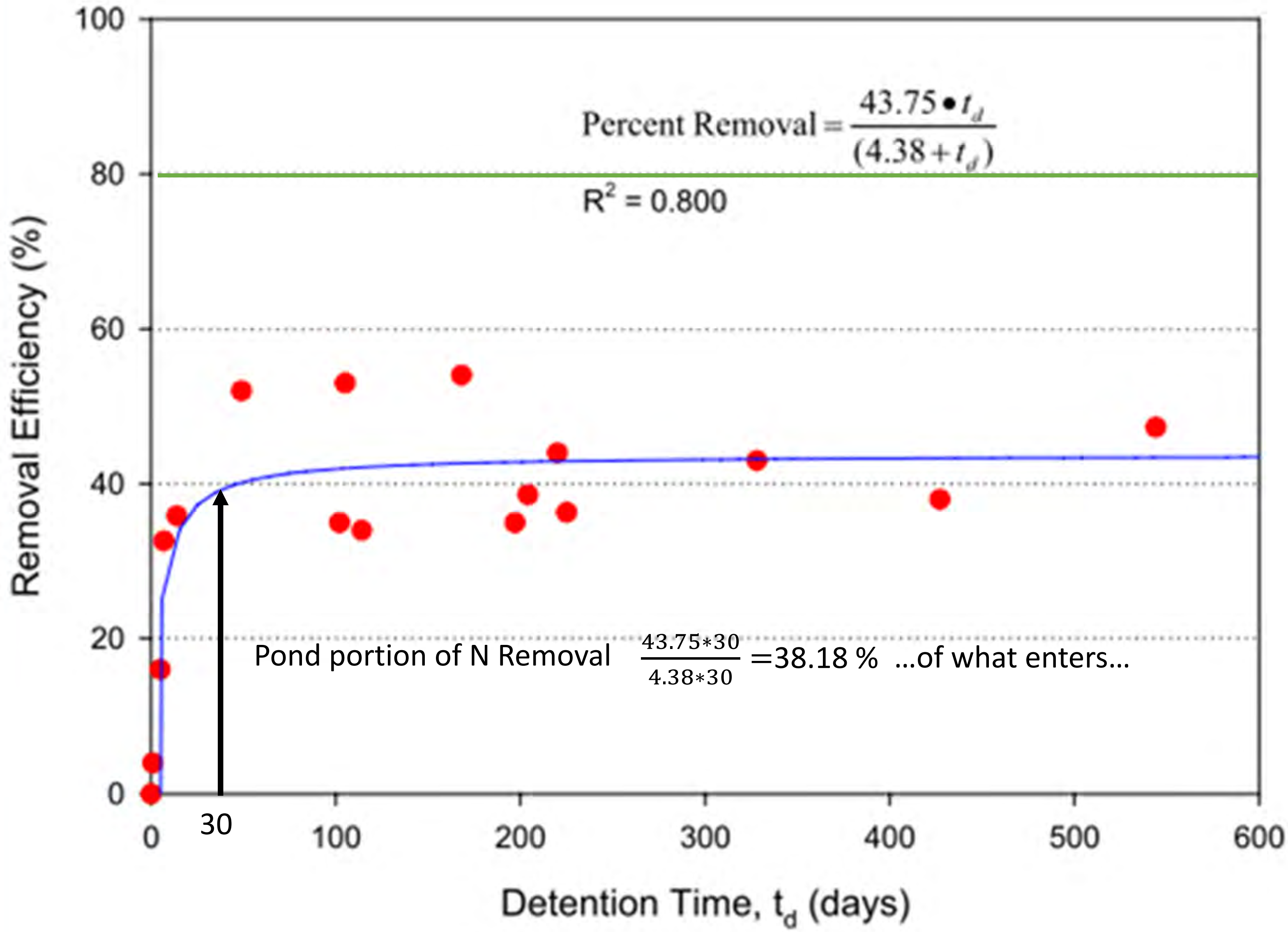
N/A = Not applicable
* This is a change from the previous method. The benefits of a baffle box—including BMP maintenance—are included in the baffle box credits when they are installed.

STANDARD BMPS	TP % REDUCTION	TN % REDUCTION	DATA SOURCE
Off-line retention BMPs	40% - 84 % (see Table 5 for formulas)	40% - 84% (see Table 5 for formulas)	Harper, H. & D. Baker. 2007. *Evaluation of Current Stormwater Design Criteria within the State of Florida.*
On-line retention BMPs	30% - 74% (see Table 5 for formulas)	30% - 74% (see Table 5 for formulas)	DEP Evaluation/Regression of Harper, H., and D. Baker 2007
Grass swales with swale blocks or raised culverts	Use on-line retention BMPs above	Use on-line retention BMPs above	DEP Evaluation/Regression of Harper, H., and D. Baker 2007
Grass swales without swale blocks or raised culverts	50% of value for grass swales with swale blocks or raised culverts	50% of value for grass swales with swale blocks or raised culverts	DEP Evaluation/Regression of Harper, H., and D. Baker 2007
Wet detention ponds	Formula shown on Figure 13.2 of the Draft Stormwater Treatment Applicant's Handbook- (see Figure 1 below for formula)	Formula shown on Figure 13.3 of the Draft Stormwater Treatment Applicant's Handbook (see Figure 2 below for formula)	Draft Stormwater Treatment Applicant's Handbook, March 2010
Dry detention ponds	10%	10%	DEP Evaluation/Regression of Harper, H., and D. Baker 2007
BMP treatment trains using a combination of BMPs	BMP Treatment Train equation: Efficiency = Eff1 +((1-Eff1) *Eff2) or BMPTRAINS model	BMP Treatment Train equation: Efficiency = Eff1 +((1-Eff1) *Eff2) or BMPTRAINS model	Draft Stormwater Treatment Applicant's Handbook, March 2010 UCF Stormwater Management Academy BMPTRAINS model
Baffle boxes- First generation (hydrodynamic separator)	2.30%	0.50%	First and second generation: Final Report Contract S0236 Effectiveness of Baffle Boxes Plus Media Filter: UCF and City of Casselberry studies
Baffle boxes—Second generation	15.5%	19.05%	
Baffle boxes—Second generation plus Bold & Gold® media filter	70%	75%	
Baffle boxes—Second generation plus Vault-Ox® media filter	8%	50%	
Alum injection systems	90%	50%	DEP Evaluation/Regression of Harper, H., and D. Baker 2007

On-Line (Flow Through)

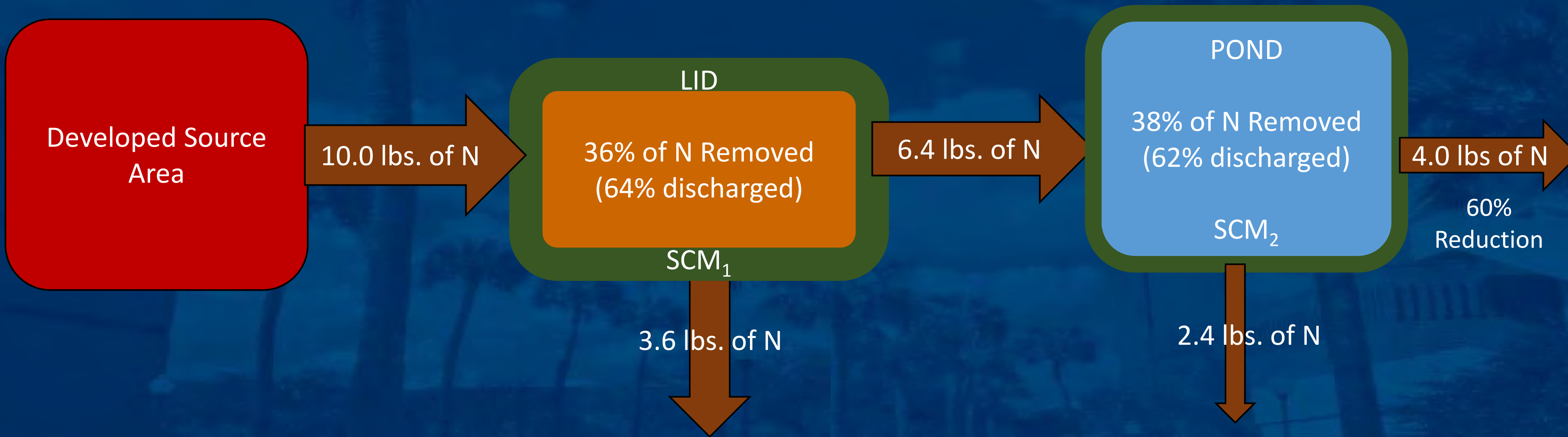


Off-Line



$$\text{Percent Removal} = \frac{43.75 \bullet t_d}{(4.38 + t_d)}$$
$R^2 = 0.800$
Removal Efficiency (%)
100
80
60
40
20
0
0
30
100
200
300
400
500
600
Detention Time, t_d (days)
Pond portion of N Removal $\frac{43.75*30}{4.38*30}$ =38.18 % ...of what enters...

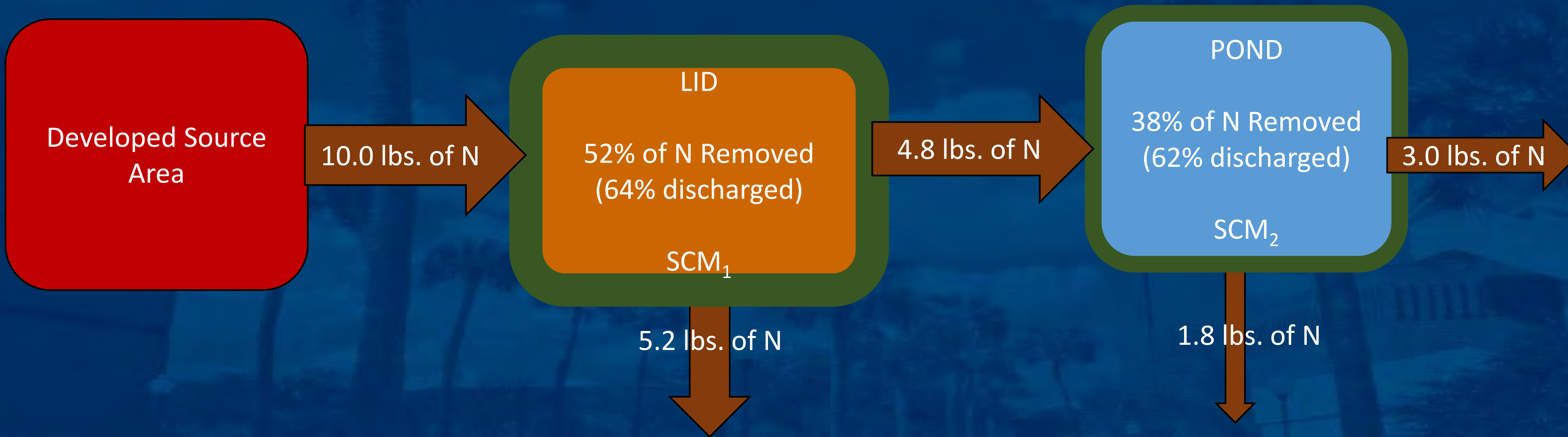
Treatment Train – SCMs in Series



$$Treatment\ Train\ Efficiency = \ Eff_1 + ((1 - Eff_1) * Eff_2$$

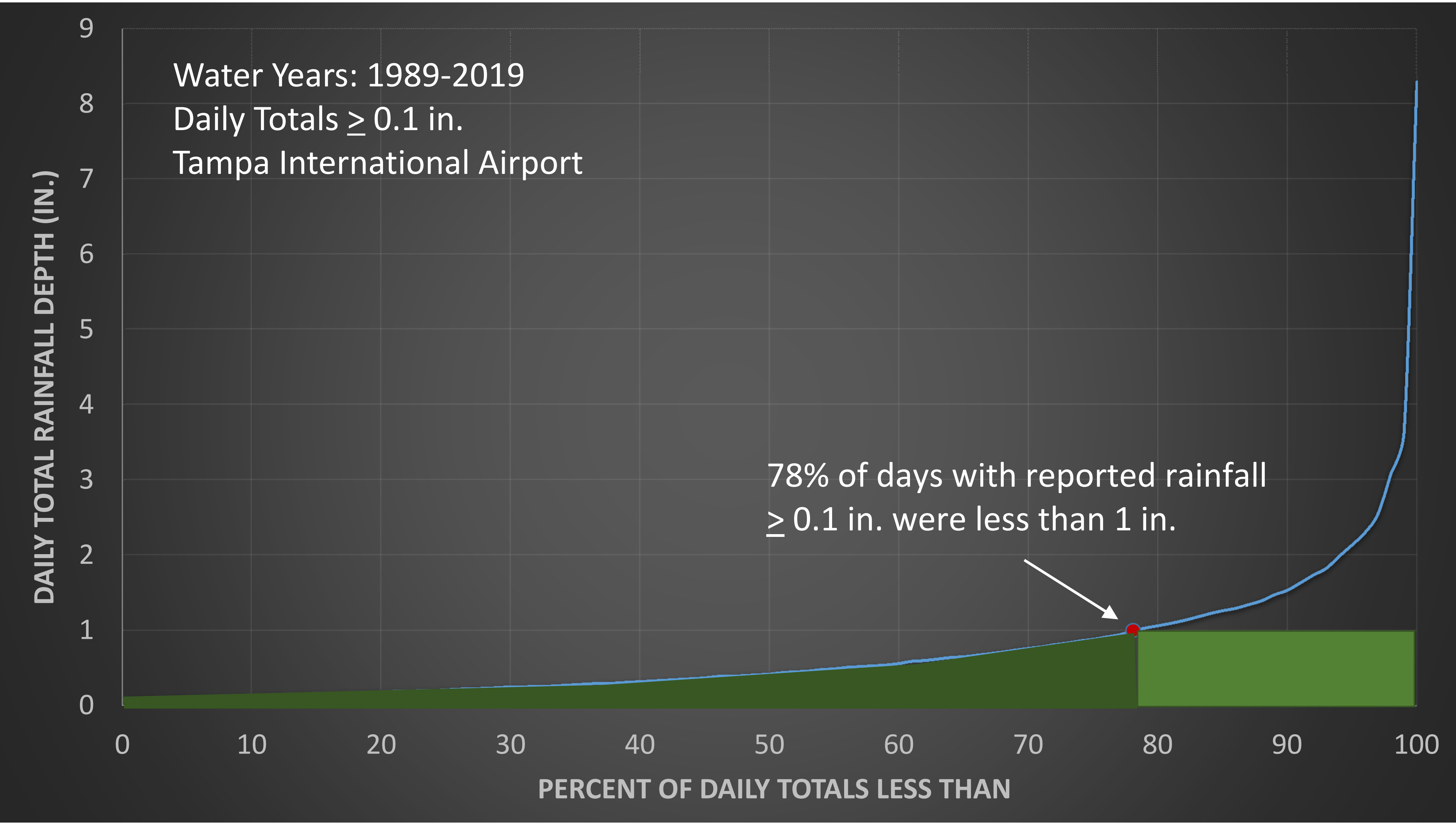
$$36\% + ((1 - 36\%) * 38\% = 36\% + 24\% = 60\%$$

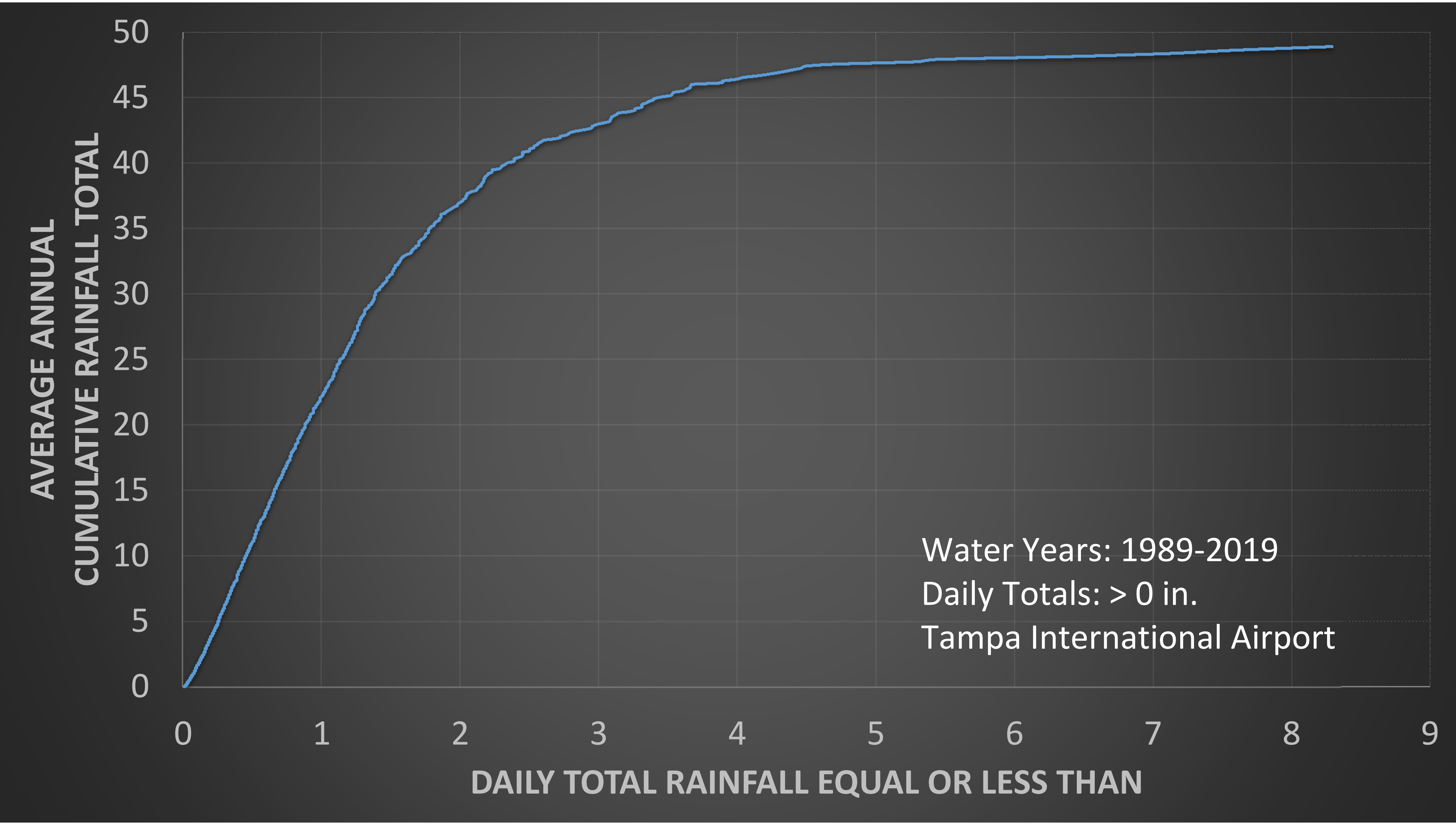
Treatment Train – SCMs in Series

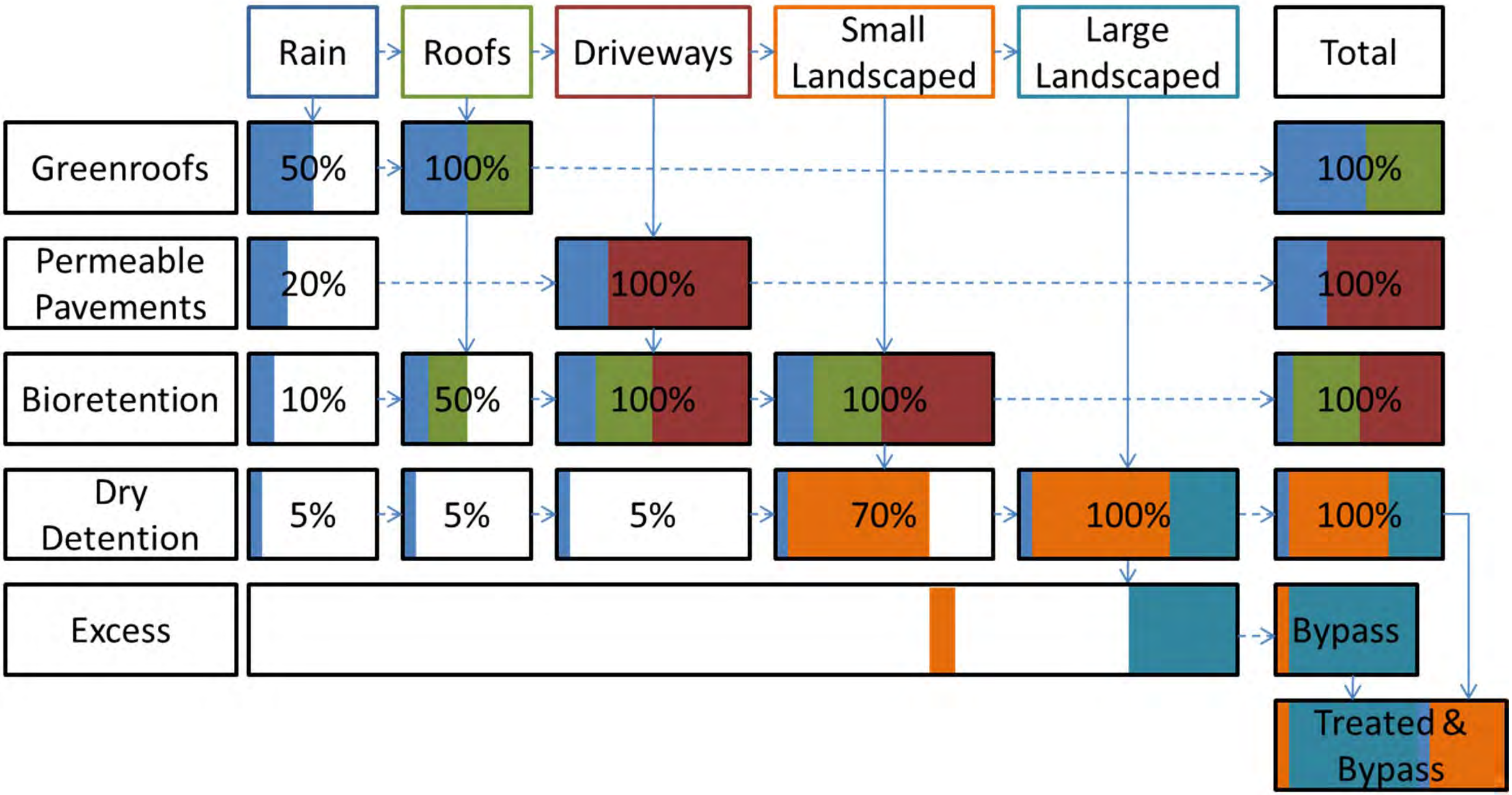


$$Treatment\ Train\ Efficiency = \ Eff_1 + ((1 - Eff_1) * Eff_2$$

$$52\% + ((1 - 52\%) * 38\% = 52\% + 18\% = 70\%$$


Water Years: 1989-2019
Daily Totals ≥ 0.1 in.
Tampa International Airport
78% of days with reported rainfall
≥ 0.1 in. were less than 1 in.
DAILY TOTAL RAINFALL DEPTH (IN.)
PERCENT OF DAILY TOTALS LESS THAN
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100


50
45
40
35
30
25
20
15
10
5
0
AVERAGE ANNUAL
CUMULATIVE RAINFALL TOTAL
0
1
2
3
4
5
6
7
8
9
DAILY TOTAL RAINFALL EQUAL OR LESS THAN
Water Years: 1989-2019
Daily Totals: > 0 in.
Tampa International Airport


Rain
Roofs
Driveways
Small Landscaped
Large Landscaped
Total
Greenroofs
50%
100%
100%
Permeable Pavements
20%
100%
100%
Bioretention
10%
50%
100%
100%
100%
Dry Detention
5%
5%
5%
70%
100%
100%
Excess
Bypass
Treated & Bypass

Design Process

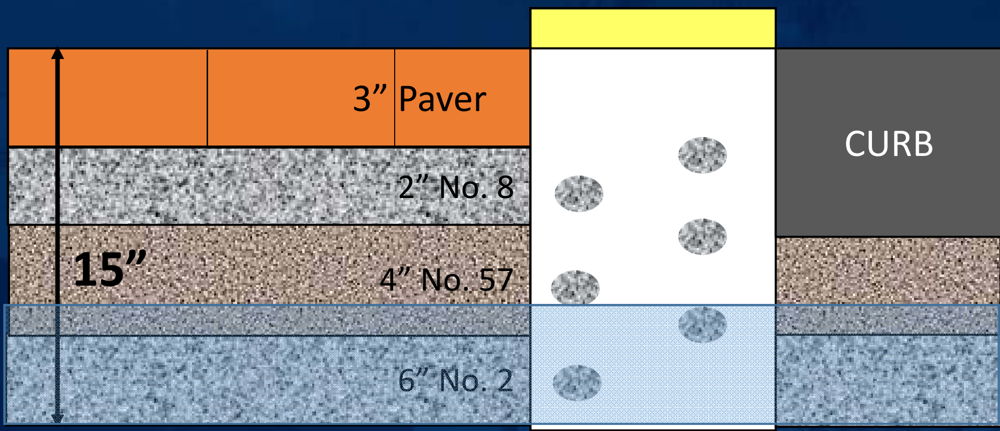
Unique for each type of LID SCM but in general…

1. Capture Volume
    - Contributing Area
    - Runoff Depth
    - Pore Space

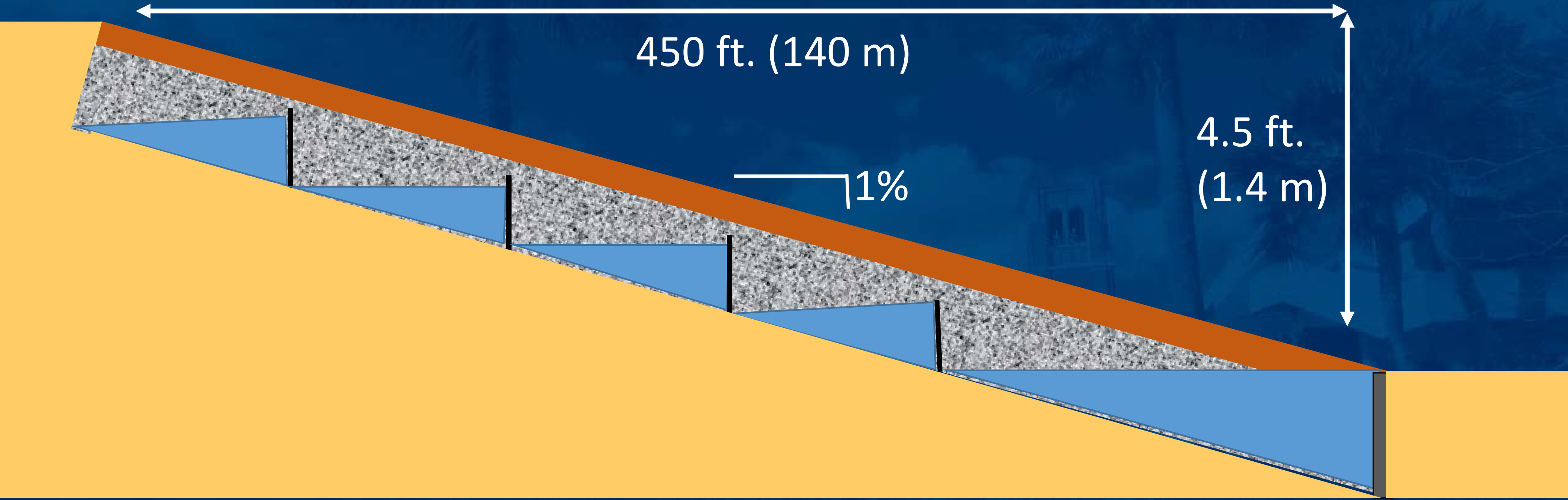
2. Storage Recovery
    - Soil and Water Table Characteristics
    - Overflow or Bypass
    - 72 Hours or Less


PICP: 10,800 sq. ft.
Asphalt: 16,000 sq. ft.
Impervious to Pervious Ratio: 1.5

In-Pavement Well



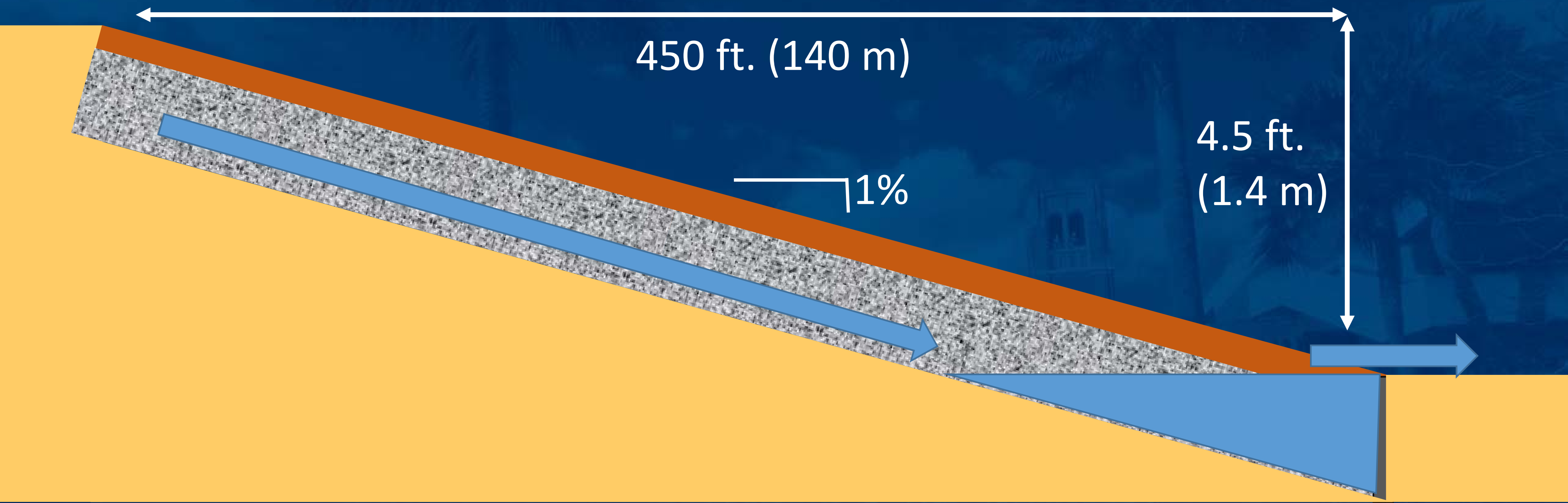
Sloped Permeable Pavement



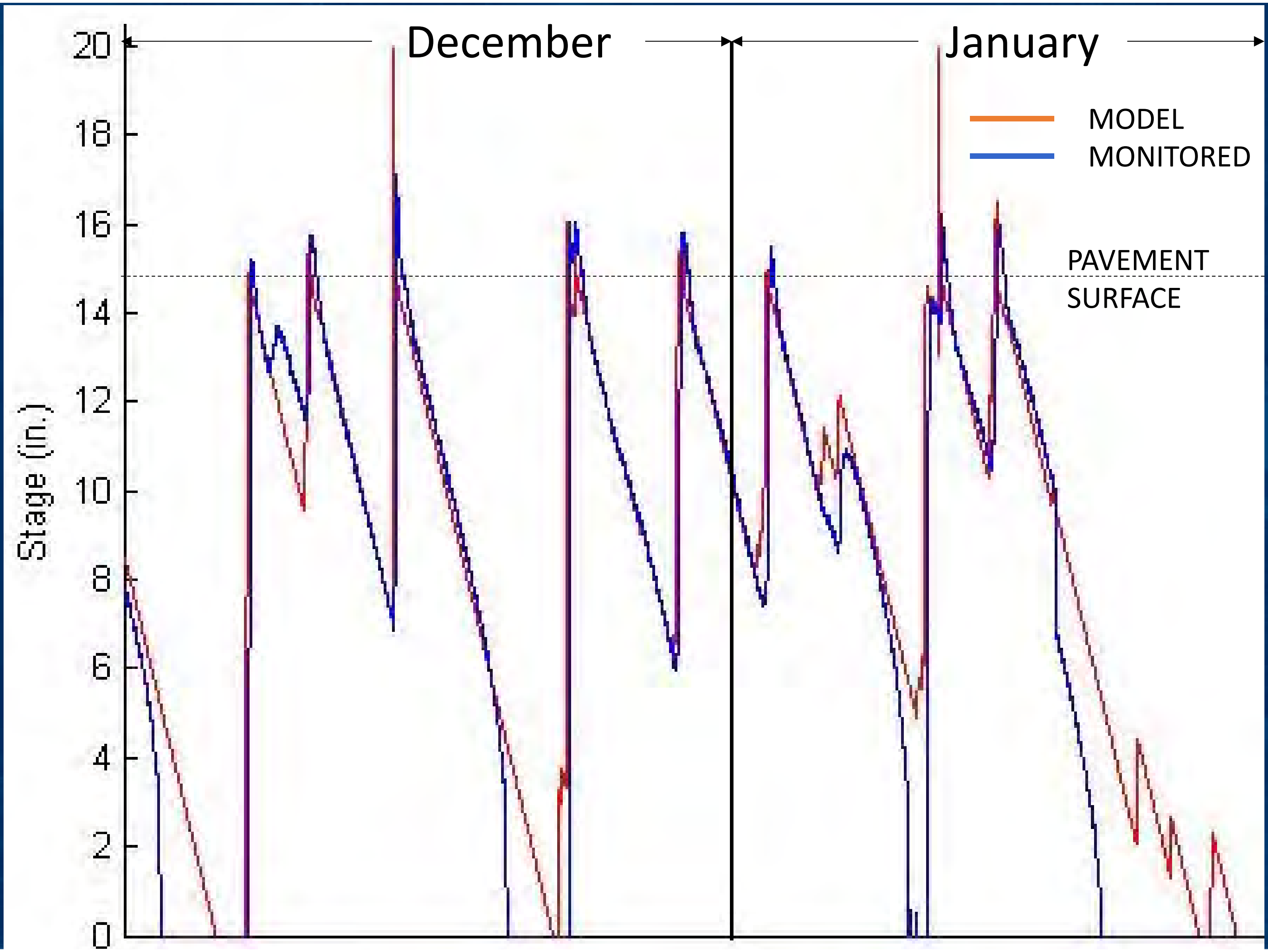
Storage: ~2.0 in. (50 mm)

1 yr, 6-hr: 2.25 in. (58 mm)

Sloped Permeable Pavement

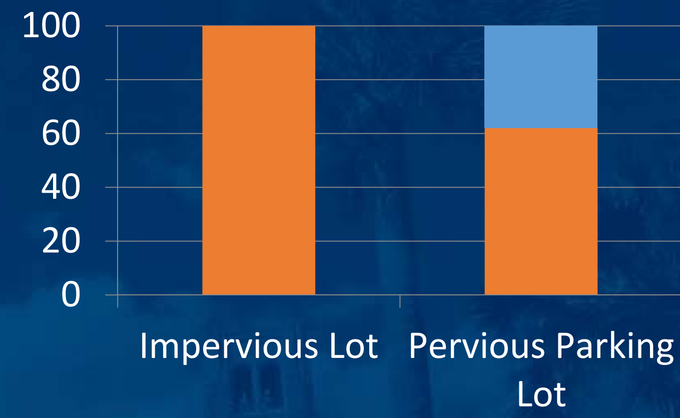


Storage: ~0.4 in. (10 mm)



December
January
MODEL
MONITORED
PAVEMENT SURFACE
Stage (in.)
0
2
4
6
8
10
12
14
16
18
20

Pavement Performance



March 2013 – April 2014

Totals

Rainfall: 64.6 in.
(15% above normal)

Runoff: 38.4 in. (60%)

Infiltration: 26.1 in. (40%)

Storms:

101 events > 0.1 in.

15 events > 1.00 in.

Max: 3.84 in. (2-yr, 24 h)

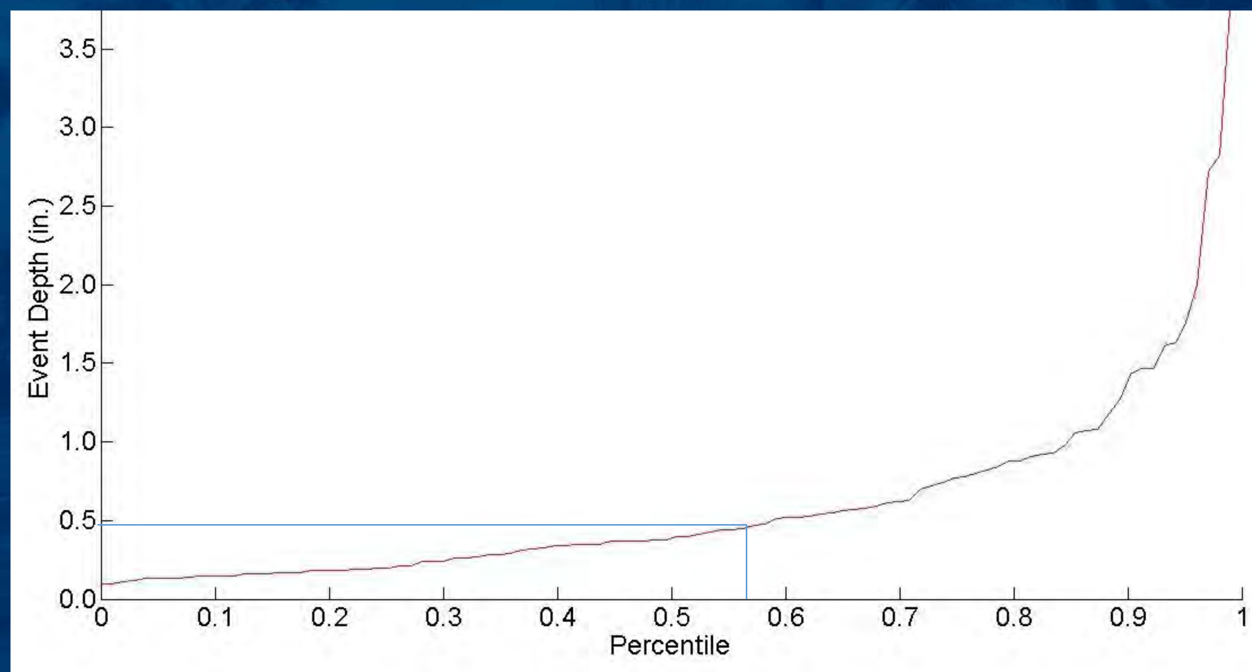


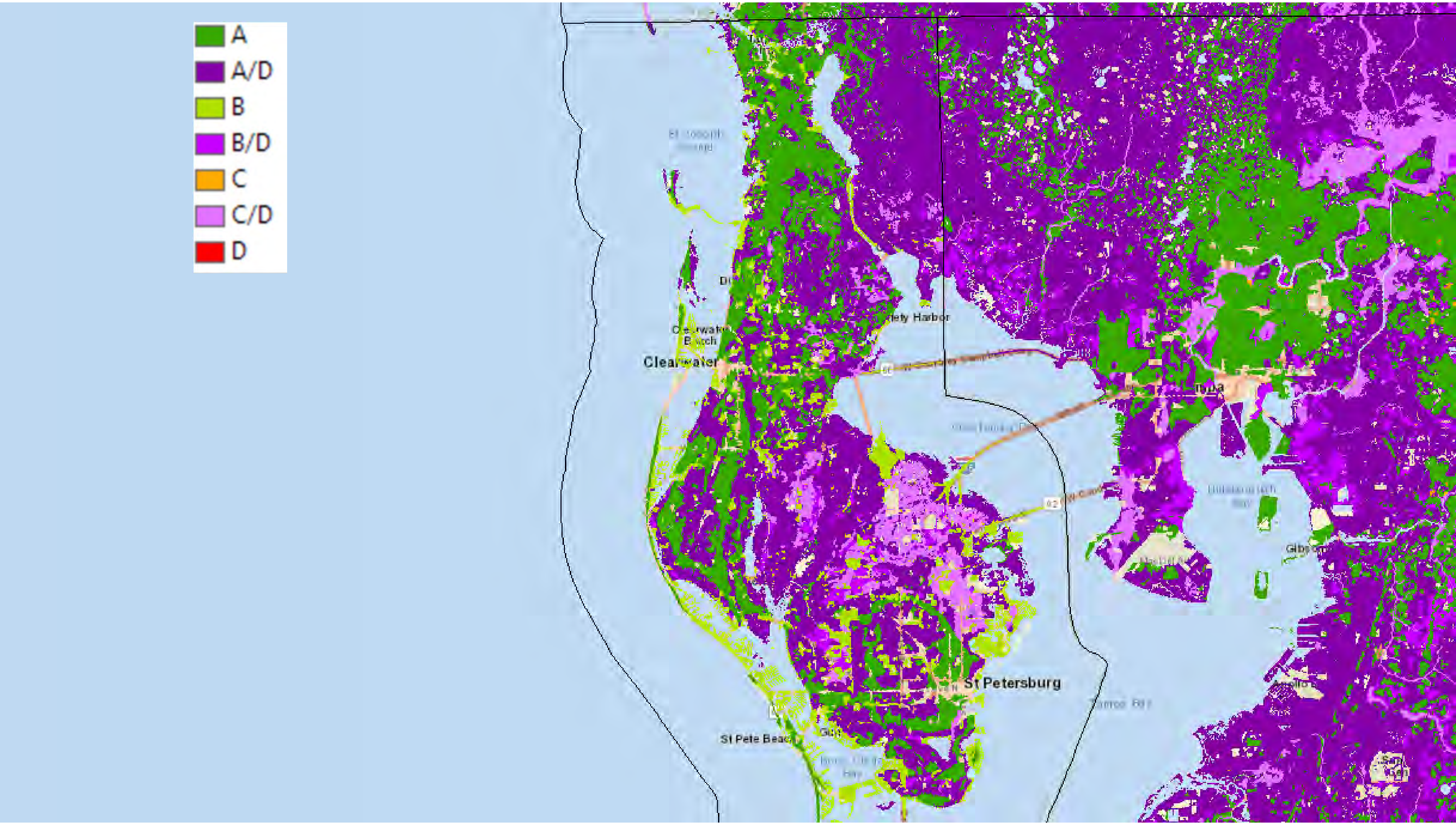
TABLE 6-1

REQUIRED RETENTION DEPTHS TO ACHIEVE AN ANNUAL REMOVAL EFFICIENCY OF 80%

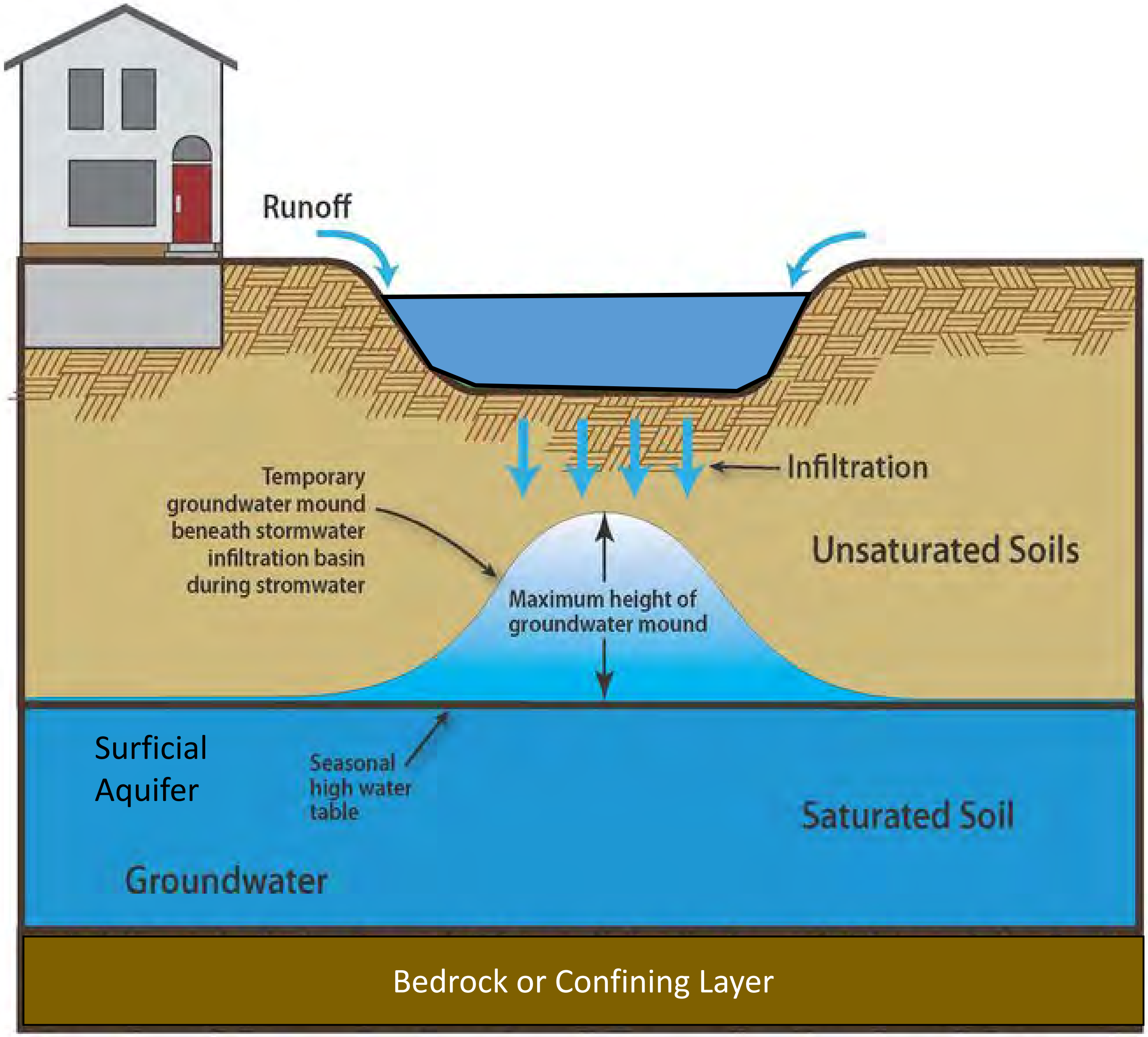
State-Wide Average

NDCIA CN	Percent DCIA																		
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	0.24	0.28	0.37	0.45	0.51	0.59	0.67	0.75	0.82	0.90	0.98	1.05	1.13	1.21	1.29	1.37	1.44	1.52	1.60
35	0.26	0.30	0.39	0.46	0.53	0.60	0.68	0.75	0.83	0.91	0.98	1.06	1.14	1.21	1.29	1.37	1.45	1.52	1.60
40	0.29	0.33	0.41	0.48	0.54	0.62	0.69	0.77	0.84	0.92	0.99	1.07	1.14	1.22	1.30	1.37	1.45	1.52	1.60
45	0.34	0.37	0.44	0.50	0.56	0.64	0.71	0.78	0.85	0.93	1.00	1.08	1.15	1.23	1.30	1.38	1.45	1.53	1.60
50	0.43	0.44	0.48	0.53	0.59	0.67	0.74	0.80	0.87	0.95	1.02	1.09	1.16	1.24	1.31	1.38	1.45	1.53	1.60
55	0.54	0.52	0.54	0.58	0.64	0.70	0.77	0.83	0.90	0.97	1.04	1.11	1.18	1.25	1.32	1.39	1.46	1.53	1.60
60	0.68	0.62	0.62	0.64	0.69	0.75	0.81	0.86	0.93	0.99	1.06	1.13	1.19	1.26	1.33	1.40	1.46	1.53	1.60
65	0.82	0.74	0.72	0.73	0.77	0.81	0.86	0.91	0.97	1.03	1.09	1.15	1.21	1.28	1.34	1.41	1.47	1.54	1.60
70	0.98	0.88	0.85	0.84	0.86	0.89	0.93	0.97	1.02	1.07	1.13	1.18	1.24	1.30	1.36	1.42	1.48	1.54	1.60
75	1.12	1.04	0.99	0.97	0.97	0.99	1.02	1.05	1.09	1.13	1.18	1.23	1.28	1.33	1.38	1.43	1.49	1.55	1.60
80	1.26	1.19	1.14	1.12	1.11	1.11	1.13	1.15	1.18	1.21	1.24	1.28	1.32	1.37	1.41	1.46	1.50	1.55	1.60
85	1.39	1.33	1.29	1.26	1.25	1.25	1.25	1.26	1.28	1.30	1.33	1.35	1.38	1.42	1.45	1.49	1.52	1.56	1.60
90	1.50	1.46	1.43	1.41	1.40	1.39	1.39	1.39	1.40	1.41	1.42	1.44	1.46	1.48	1.50	1.52	1.55	1.57	1.60
95	1.58	1.56	1.55	1.54	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.54	1.54	1.55	1.56	1.57	1.58	1.59	1.60
98	1.59	1.59	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.59	1.59	1.59	1.59	1.60	1.60	1.60

Harper & Baker, 2007

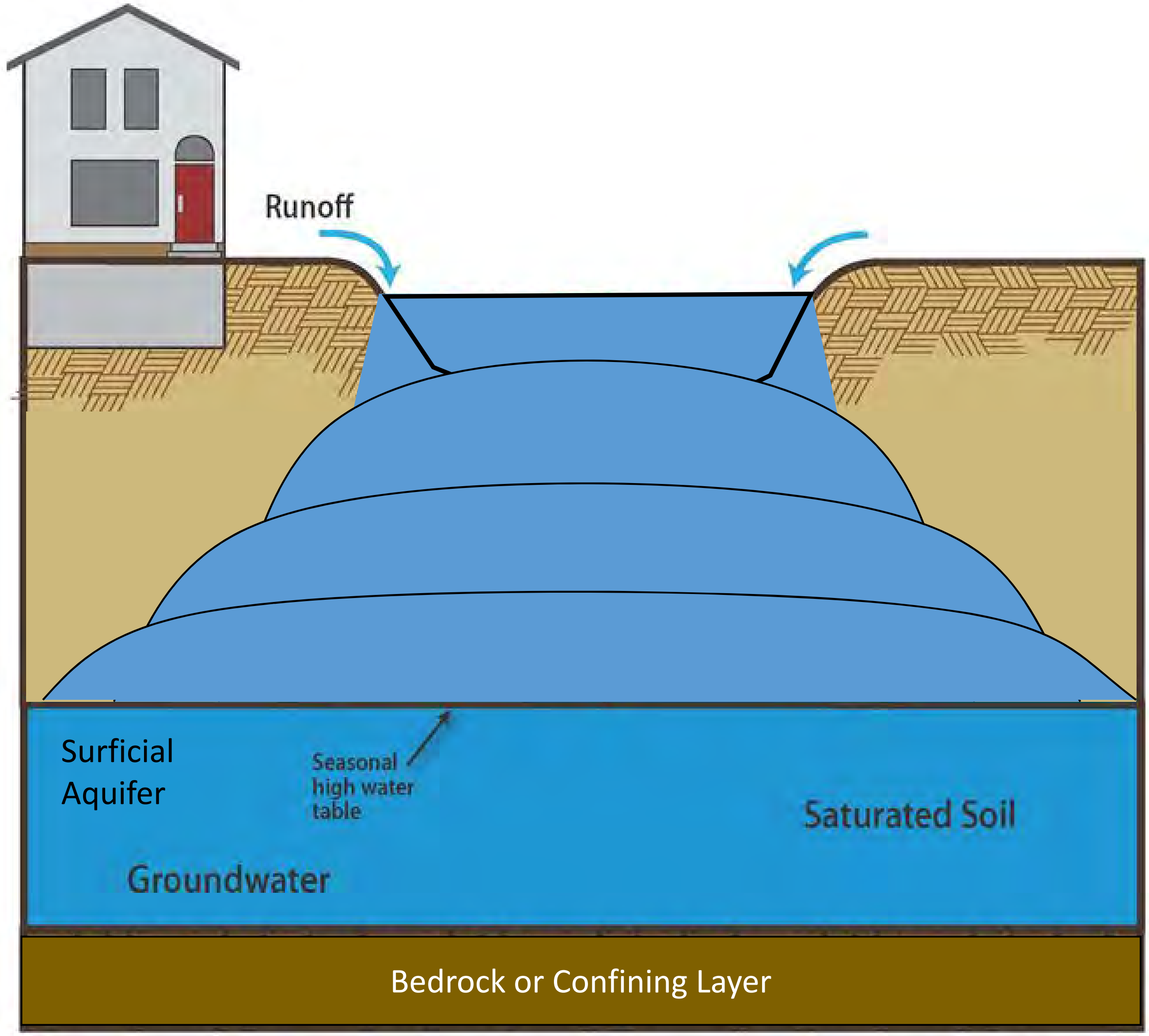


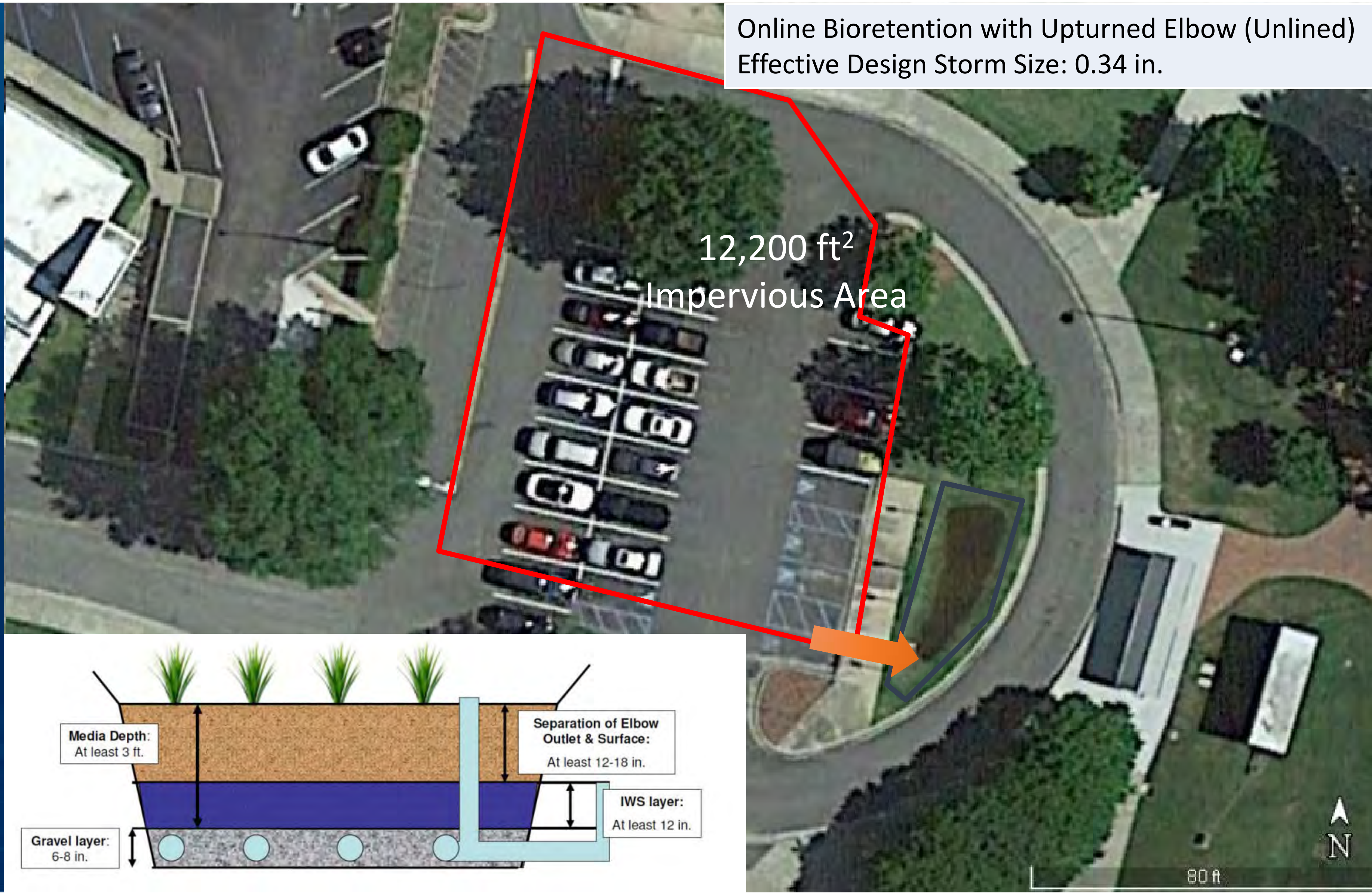
A
A/D
B
B/D
C
C/D
D
Clearwater
St Petersburg
St Pete Beach


Runoff
Infiltration
Temporary groundwater mound beneath stormwater infiltration basin during stromwater
Unsaturated Soils
Maximum height of groundwater mound
Surficial Aquifer
Seasonal high water table
Saturated Soil
Groundwater
Bedrock or Confining Layer

Groundwater Mounding

- Vertical infiltration
- Fill available porosity above water table or confining layer
- Recovers via lateral flow
- Area : Perimeter Ratio




Online Bioretention with Upturned Elbow (Unlined)
Effective Design Storm Size: 0.34 in.
12,200 ft2
Impervious Area
Media Depth:
At least 3 ft.
Separation of Elbow Outlet & Surface:
At least 12-18 in.
IWS layer:
At least 12 in.
Gravel layer:
6-8 in.
N
80 ft

Operation and Maintenance is Key

"Another flaw in the human character is that everybody wants to build and nobody wants to do maintenance."

- Kurt Vonnegut

- Filters clog
- Plants die
- Sediment accumulates

Operation and Maintenance

- Pre-treatment is a worthwhile investment
- Design can prevent excess O&M
- Recover retention storage in 72 h (ideally sooner)
- Consider the functions of the system
- Vegetation as an indicator of performance
- Water/debris lines

- Right solution to the wrong problem is not helpful

Low Impact Development Summary

- Conserve Natural Space
- Limit Impervious Cover
- Restore/Preserve Ecosystem Services to Landscape
- Manage Stormwater Close to Source
- Treatment Train
- Require Maintenance

Questions?

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AGRICULTURAL & BIOLOGICAL ENGINEERING

SUSTAINABLE HUMAN AND ECOLOGICAL DEVELOPMENT

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CLUE CENTER FOR LAND USE EFFICIENCY