A Guide to Sizing a Stormwater Quality Manufactured Treatment Device

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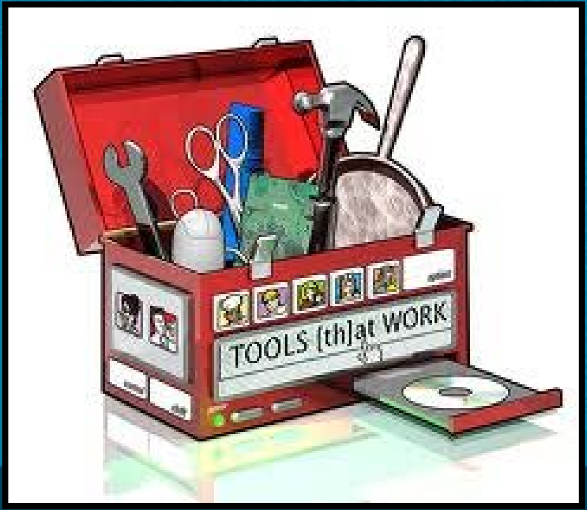
Your BMP Toolbox

One of the leading topics today in stormwater management is a drive for sustainability, green infrastructure and Low Impact Development (LID) practices.

Let's reach into our "BMP toolbox" to consider Manufactured Treatment Devices (MTDs) in LID designs and how to properly size them for long term water quality performance.



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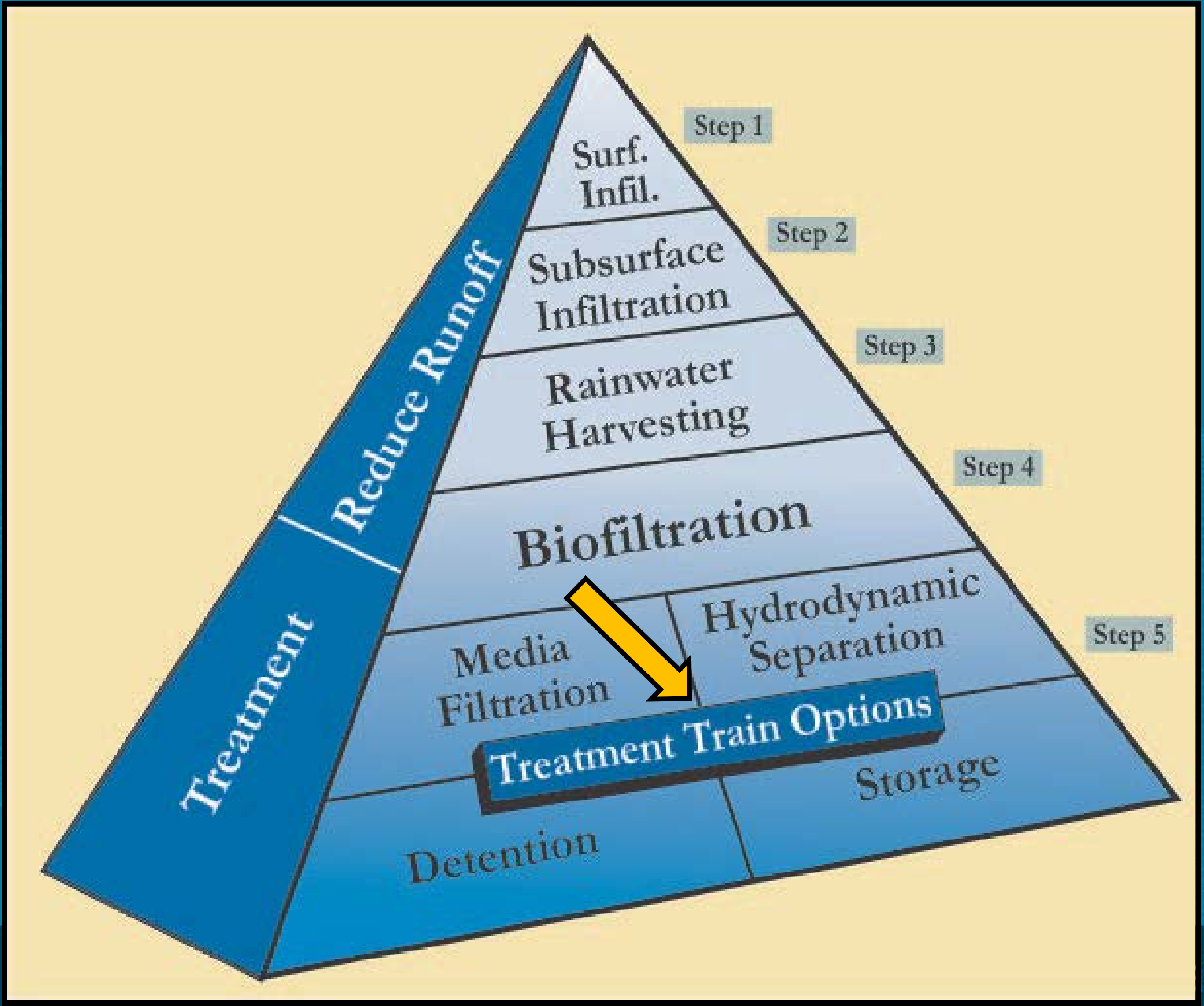
Low Impact Development (LID) Technology Selection Pyramid



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LID Benefits & Technologies

Technology	LID Benefits				
	Capture Rainfall	Reduce Peak Flows	Reduce Runoff Volumes	Enhance Infiltration	Filter Out Pollutants
Surface Infiltration	X	X	X	X	X
Underground Infiltration	X	X	X	X	X
Rainwater Harvesting & Storage	X	X	X		
Biofiltration	X	X	X	X	X
Media Filtration					X

Hydrodynamic Separation can be used for Pretreatment for Underground Infiltration and Detention

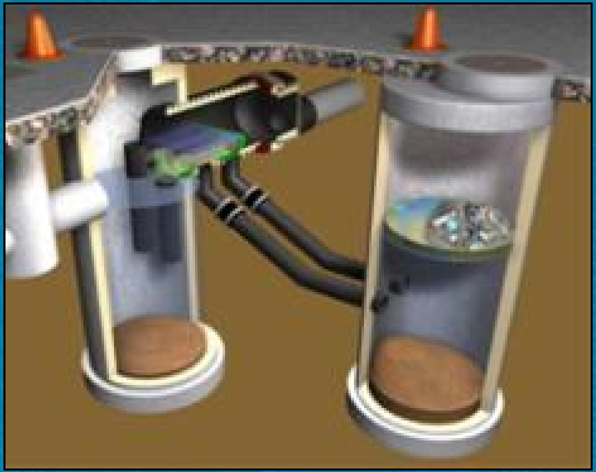
HDS Pretreatment

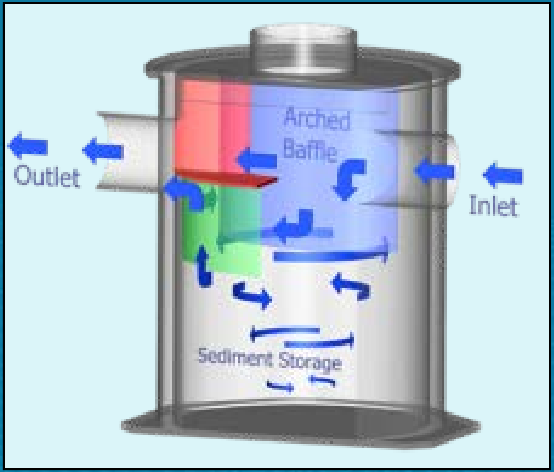
Harvesting

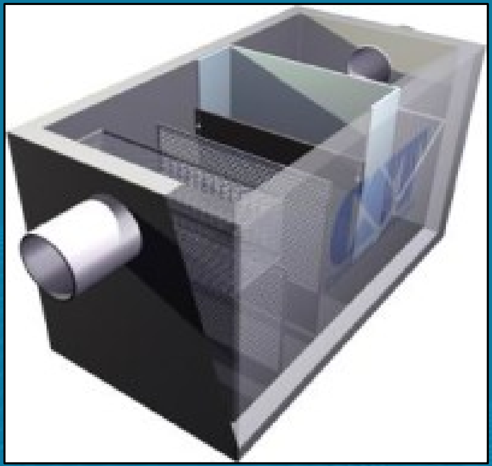
Above ground storage

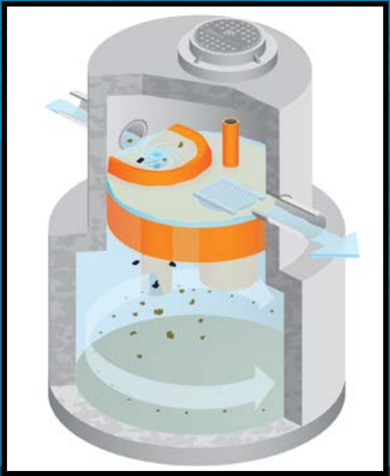
Underground storage and infiltration

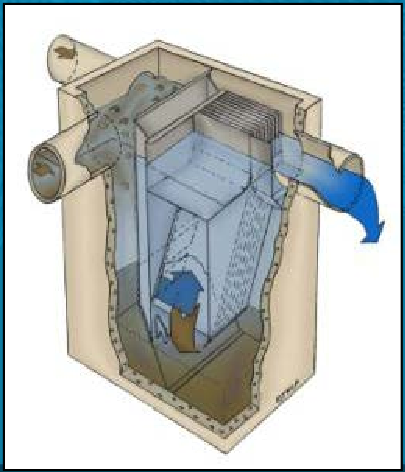
Hydrodynamic Separators (HDSs)

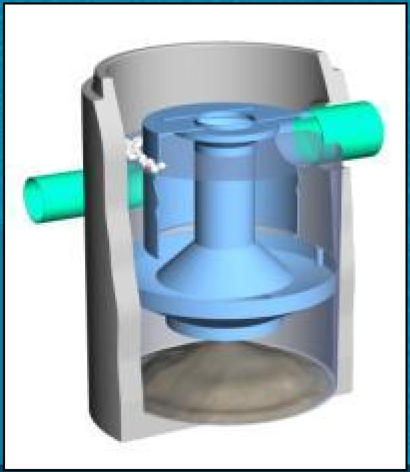








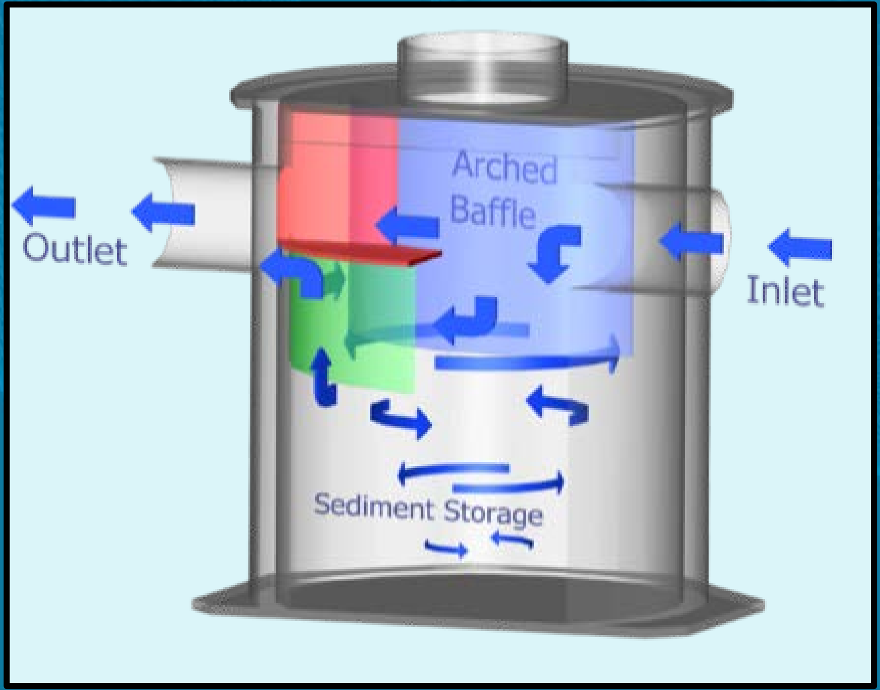




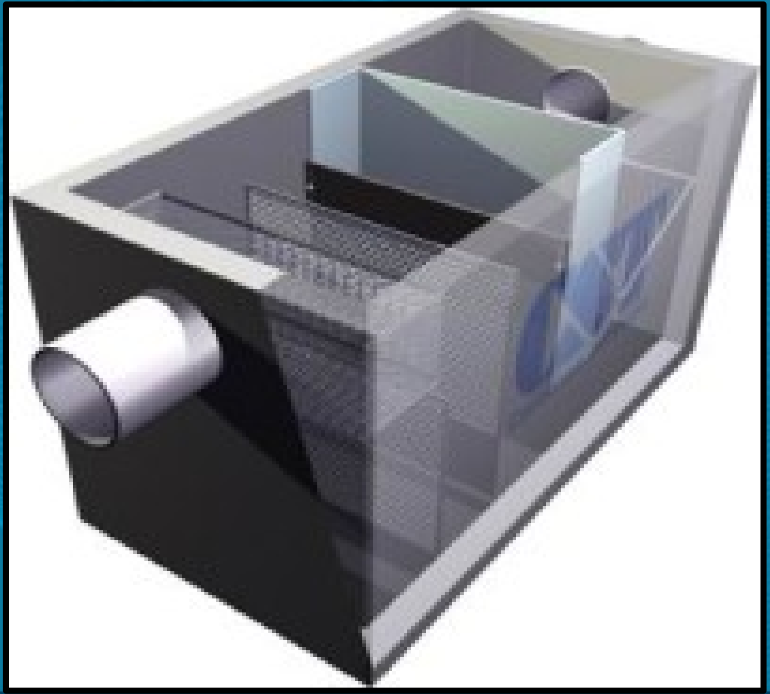
Types of HDSs

Captures sediment, debris, floatables, oil

Vortex type = Gravitational & Centrifugal Forces



Vault type = Gravitational Forces



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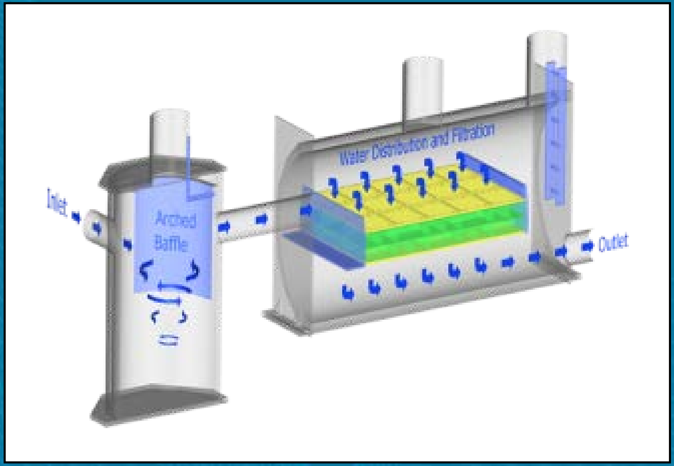
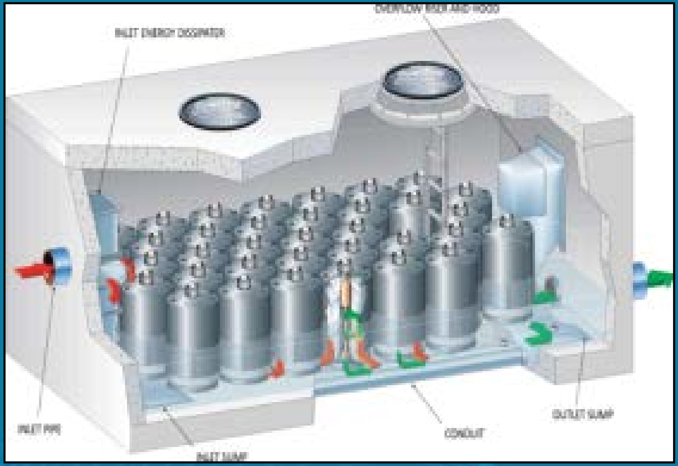
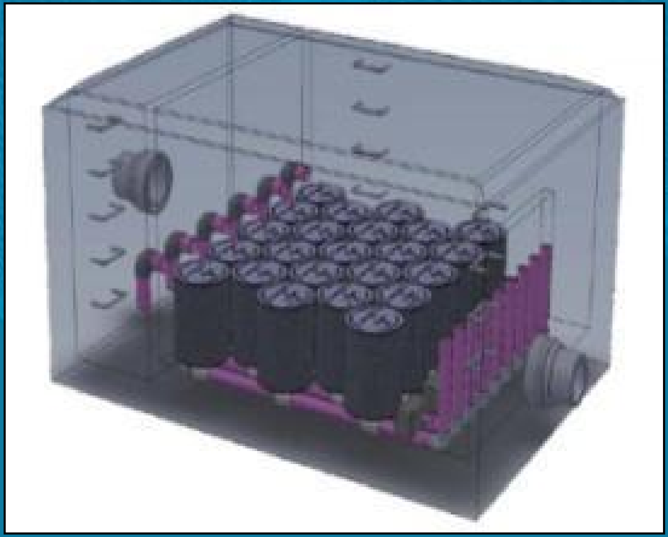
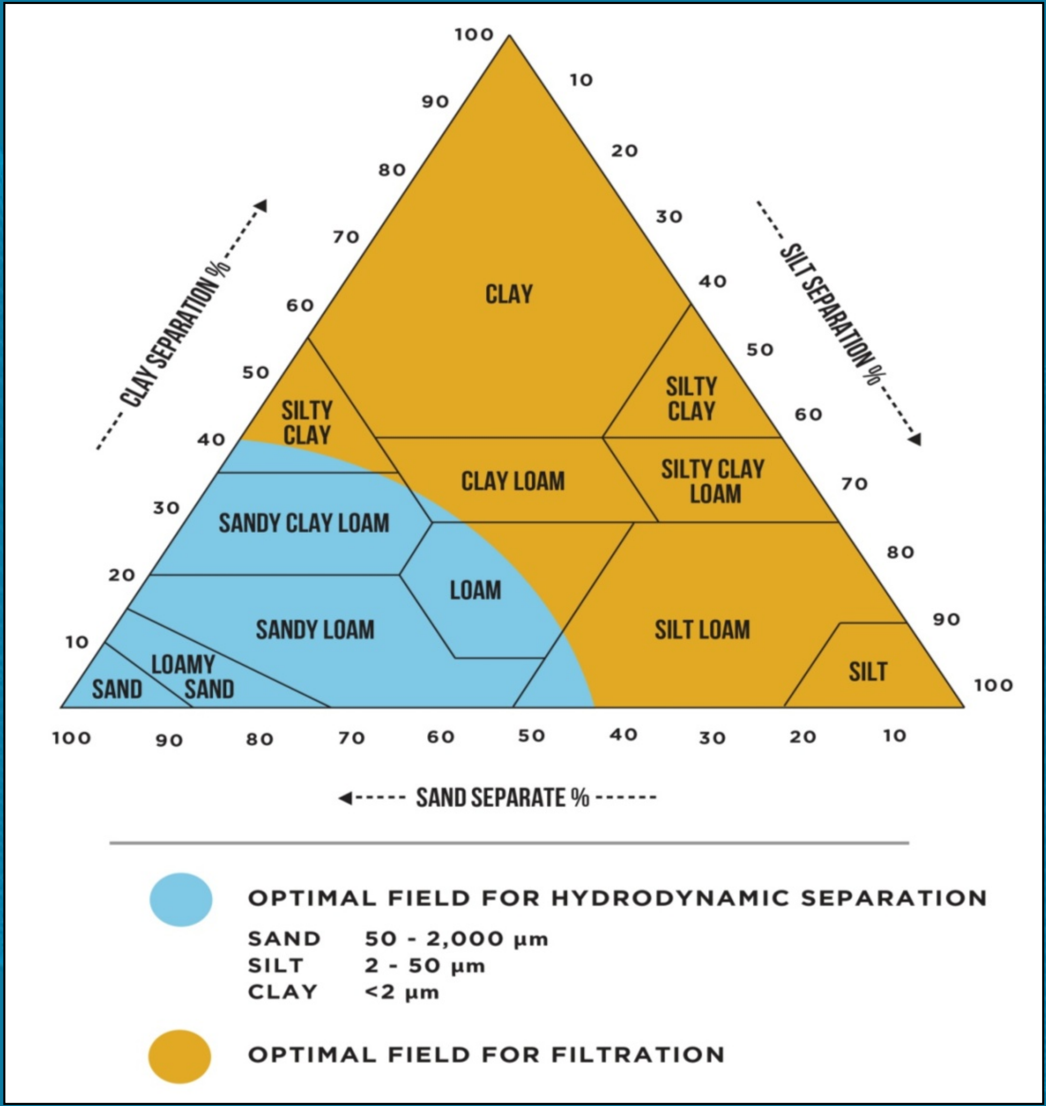
Media Filtration







HDSs & Filters vs. Soil Types



HDSs ≥ 50 µm,
Challenged <40-50 µm

Filters < 75 µm,
challenged <15-20 µm

5 Facility Design Elements for MTD Sizing

You need to know…

1. *Water Quality Flow Rate (Q in cfs) that the MTD is to treat*.

For example, using the Rational Method:

Q = CIA, where:
C = Runoff coefficient (ex.: 0.9 impervious)
I = Intensity (in/hr, regulated or derived)
A = Inflow drainage area, acres

5 Facility Design Elements for MTD Sizing

2. *Peak flow rate that exceeds the water quality flow rate (Q).*

3. *Conveyance piping network and pipe diameters for Q and peak flows.*

4. *Conveyance piping elevations & slopes. MTD must fit into facility conditions.*

These elements lead to…

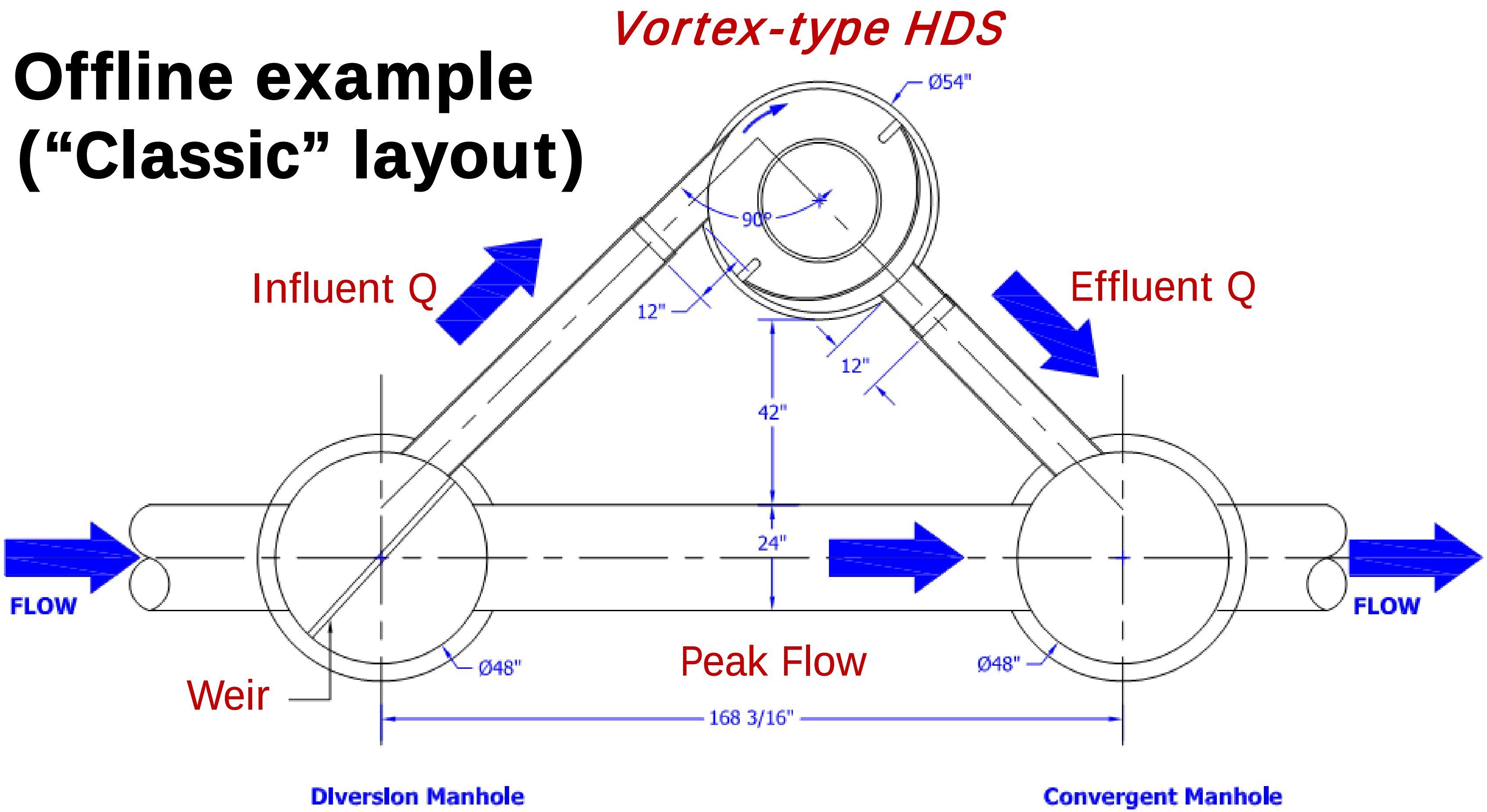
5 Facility Design Elements for MTD Sizing

5. *MTD layout in either offline or online (inline) configuration.*

Offline MTDs

- ✓ **Some MTD internal components may differ between offline or online applications. Check with manufacturer.**
- ✓ **Offline MTDs convey up to Q only, flow >Q bypasses MTD.**
- ✓ **Offline MTDs use diversion and convergent flow structures.**
- ✓ **Offline MTD pipe diameters < peak flow pipe diameters.**
- ✓ **Some regulations only allow offline MTDs since online units may be, or perceived to be, more susceptible to scouring (re-suspension) of previously captured sediment.**
- ✓ **Offline layouts usually > footprint than online layouts.**
- ✓ **Offline layouts not always >>$$ than online layouts.**

Offline example ("Classic" layout)



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5 Facility Design Elements for MTD Sizing

5. MTD layout in either offline or online (inline) configuration.

Online MTDs

- ✓ Online MTD treats Q and internally conveys untreated bypass flows >Q (no external piping).
- ✓ Online MTD footprint usually < offline MTD footprint, favorable for retrofits if online allowed.
- ✓ Online MTDs pipe diameters > offline Q pipe diameters since online designs must convey all flows.
- ✓ Some regulations prohibit online MTD designs.
- ✓ Scour (re-suspension) testing data usually required to allow for online MTD installation (NJDEP).
- ✓ Online layouts not always << $$ than offline layouts.

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Consequences of PSD Specification

Undersizing

- Potential for diminished performance and increased potential for scouring, especially for online.

- Concern for runoff conveyance (tailwater backup, upstream flooding) due to potentially undersized piping associated with the MTD (offline or online).

- Leads to increased maintenance frequency due to decreased storage capacity and long term functionality which increase operational costs.

Consequences of PSD Specification

Oversizing

- Increases footprint, can be a problem for tight spaces and/or retrofits.
- Increases project costs from a properly sized device.
- Conservative TSS removal efficiency.
- Pollutant loading will ultimately dictate maintenance frequency and cost.

Trash Only

If PSD specification is too coarse, maximum hydraulic capacity may be exceeded causing catastrophic failure.

80% removal of what?

Many stormwater manuals require 80% TSS removal using non-structural and/or structural BMPs. However, manuals often fail to specify the *particle size distribution (PSD)* that is to be removed. Let's take a look at how different PSDs impact performance curves and *sizing* of HDSs.

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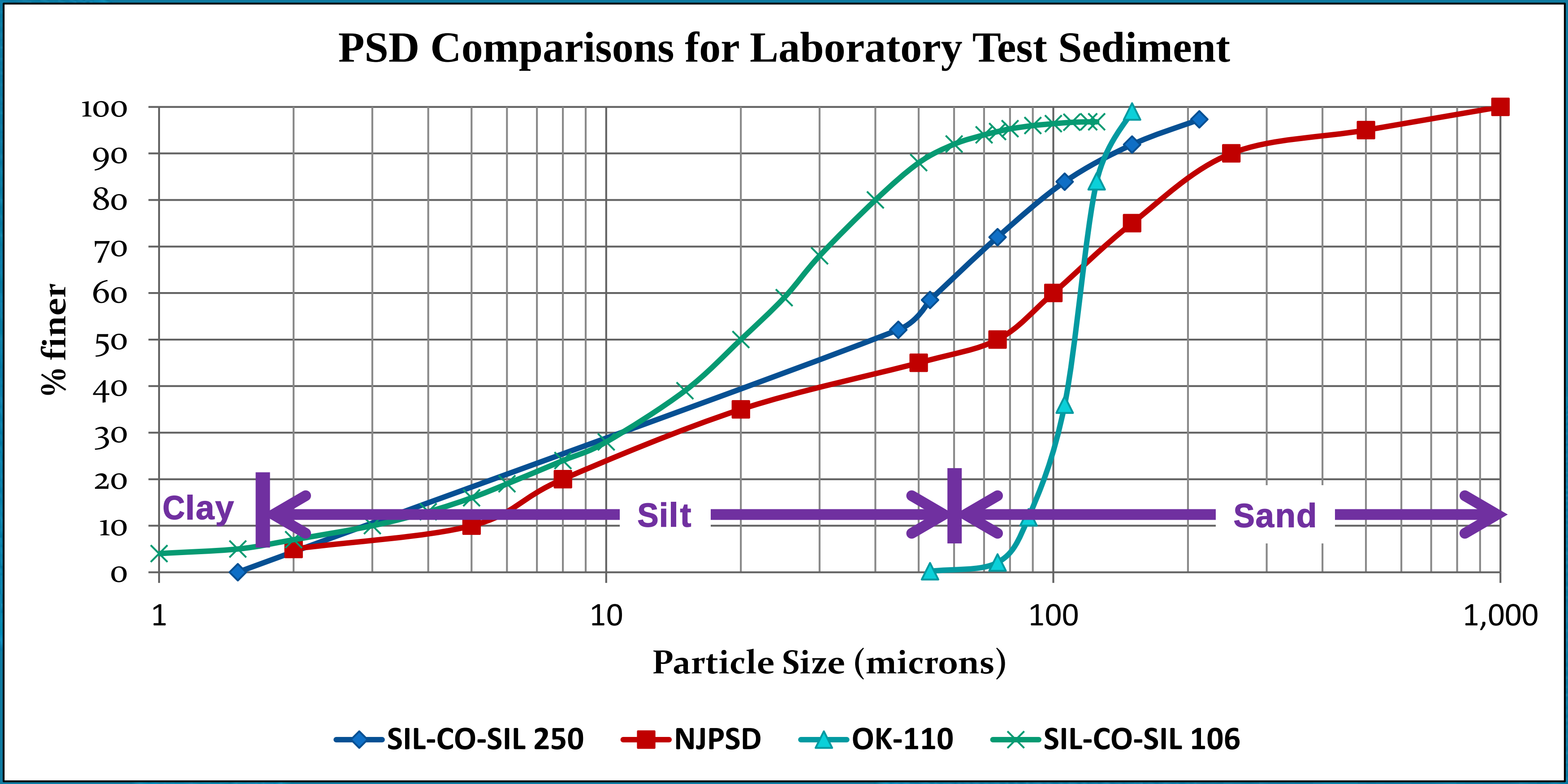
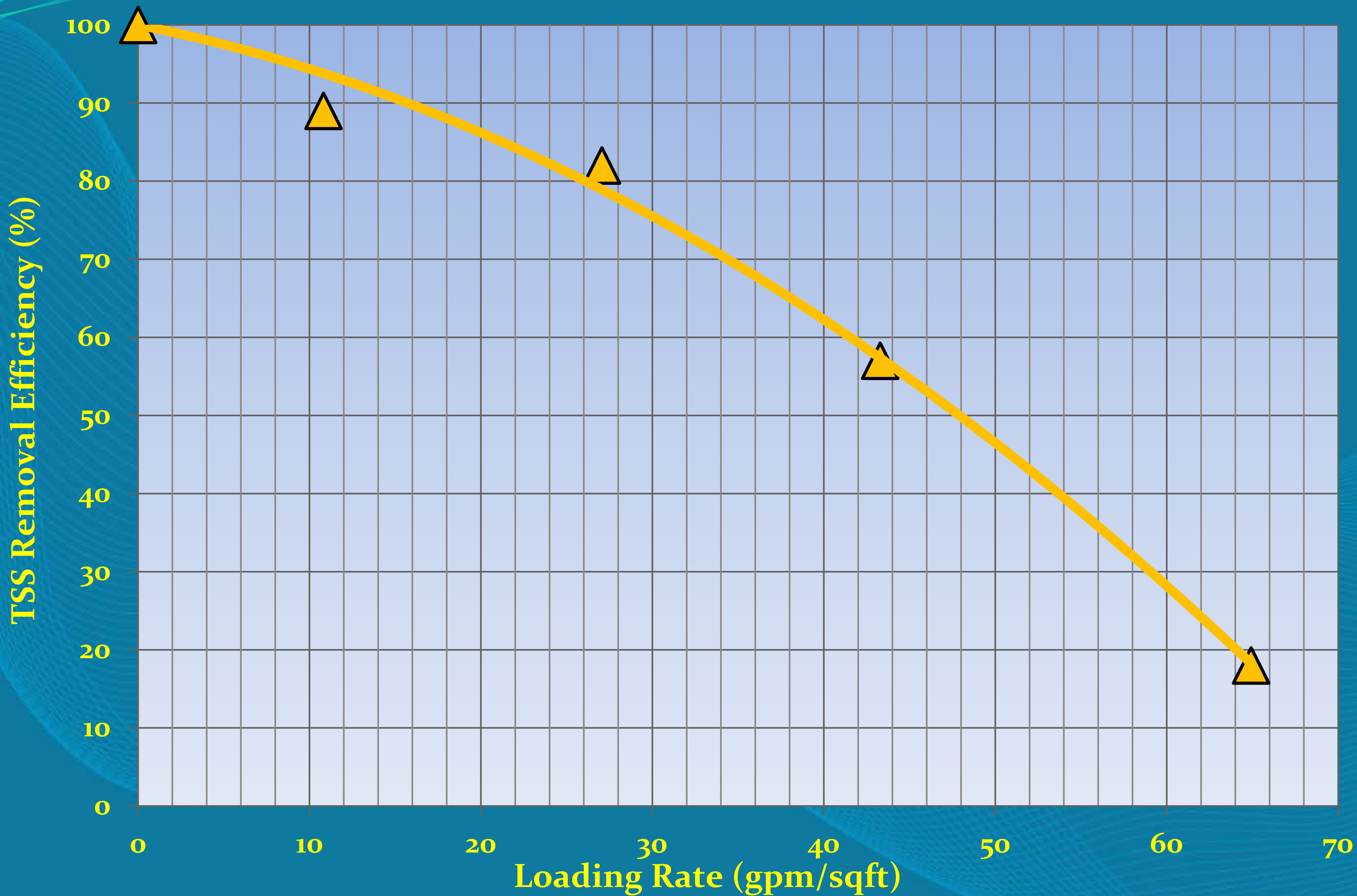
What is Particle Size Distribution?



So, which PSD is your basis for MTD sizing?

HDS Performance Curve: OK-110 Test Sediment



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Where I got the idea to use Peclet Number

University of Minnesota
ST. ANTHONY FALLS LABORATORY
Engineering, Environmental and Geophysical Fluid Dynamics

Project Report No. 494

Performance Assessment of Underground Stormwater Treatment Devices

By

Matthew A. Wilson, John S. Gulliver, Omid Mohseni, and Ray M. Hozalski

Prepared for
Local Road Research Board
and
Twin Cities Metropolitan Council

July 2007
Minneapolis, Minnesota

What's the Peclet Number?

- Provides a simple means to predict HDS performance using a different particle size than that of the test sediment.
- Allows for HDS sizing charts for different PSDs.
- Performance curves from different HDSs having different test sediment PSDs can be compared.

Peclet Number (Pe)

$$Pe = (d \cdot h \cdot Vs) / Q$$

d = Horizontal flow dimension in feet
h = Vertical flow dimension in feet
Vs = Particle settling velocity in feet/sec
Q = Flow rate in cubic feet/second

- “d” in Vortex HDS = diameter of effective treatment area
- “d” in Vault HDS = long axis of effective treatment area (parallel to flow)

Calculate Pe for Tested HDS

Test Parameters	Q (cfs)	Loading Rate (gpm/ft²)	TSS RE (%)	Pe (unitless)
d_{50} = 110 µm (OK-110)	0	0	100	NA
Vs = 0.021 ft/s	0.20	10.8	89	1.33
SG = 2.65	0.50	27.1	82	0.53
d = 3.3 ft	0.80	43.3	57	0.33
h = 3.83 ft	1.20	64.9	18	0.22

$$Pe = (d \cdot h \cdot Vs) / Q$$

Example: Q = 0.2 cfs

Pe = (3.3 ft · 3.83 ft · 0.021 ft/sec) / 0.2 cfs = 1.33

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Calculate Particle Settling Velocity (Vs)

Term	Variable	Units	Description
Gs	2.65		Specific gravity of particle
ρ_s	165.07	lb/ft^3	Density of particle
ρ_w	62.29	lb/ft^3	Density of water
g	32.20	ft/s^2	Acceleration due to gravity
T	20.00	C°	Temperature of water
T	68	F°	Temperature of water
μ	2.09E-05	$lb*s/ft^2$	Dynamic viscosity of water at given temp.
υ	1.08E-05	ft^2/s	Kinematic Viscosity of water
D	110	micron	Diameter of particle
Vs	0.024	ft/s	Settling velocity, Cheng Formula
Vs	0.02080	ft/s	Settling velocity, Stoke's Law
Vs	0.029	ft/s	Settling velocity, Ferguson & Church

Stoke's Law Particle Settling Velocities

Faster settling time

Particle Size (µm)	Vs (ft/sec)
45	0.0085
50	0.010
67	0.013
75	0.014
90	0.017
110	0.021
125	0.024

Performance Summary - 45 µm

Rearrange equation to solve for Q

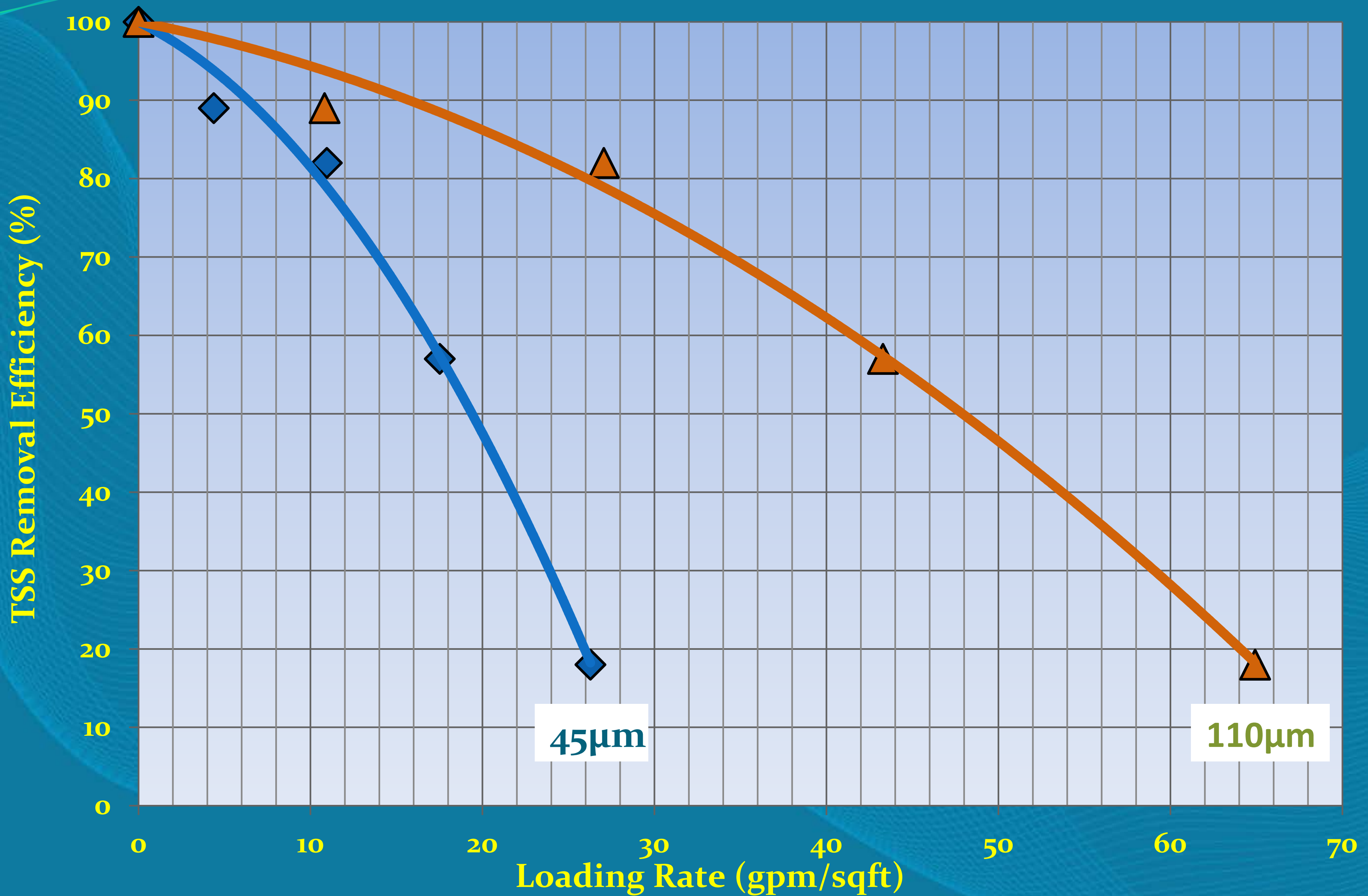
$Q = (3.3\ ft \cdot 3.83\ ft \cdot Vs) / Pe$

RE and Pe constant

Parameters	Q (cfs)	Loading Rate (gpm/ft²)	RE (%)	Pe (unitless)
d_{50} = 45 µm	0	0	100	NA
Vs = 0.0085 ft/sec	0.081	4.4	89	1.33
SG = 2.65	0.202	10.9	82	0.53
d = 3.3 ft (8.3 ft^2)	0.325	17.5	57	0.33
h = 3.83 ft	0.486	26.3	18	0.22

Loading Rate = Q cfs · 448.83 gpm / cfs / Area ft^2

HDS Performance Curves for 45 and 110 µm



50 μm				
Parameters	Q (cfs)	Loading Rate (gpm/ft^2)	RE (%)	Pe (unitless)
d_{50} = 50 μm	0	0	100	NA
Vs = 0.010 ft/sec	0.10	5.2	89	1.33
SG = 2.65	0.24	12.9	82	0.53
d = 3.3 ft	0.38	20.6	57	0.33
h = 3.83 ft	0.57	30.9	18	0.22

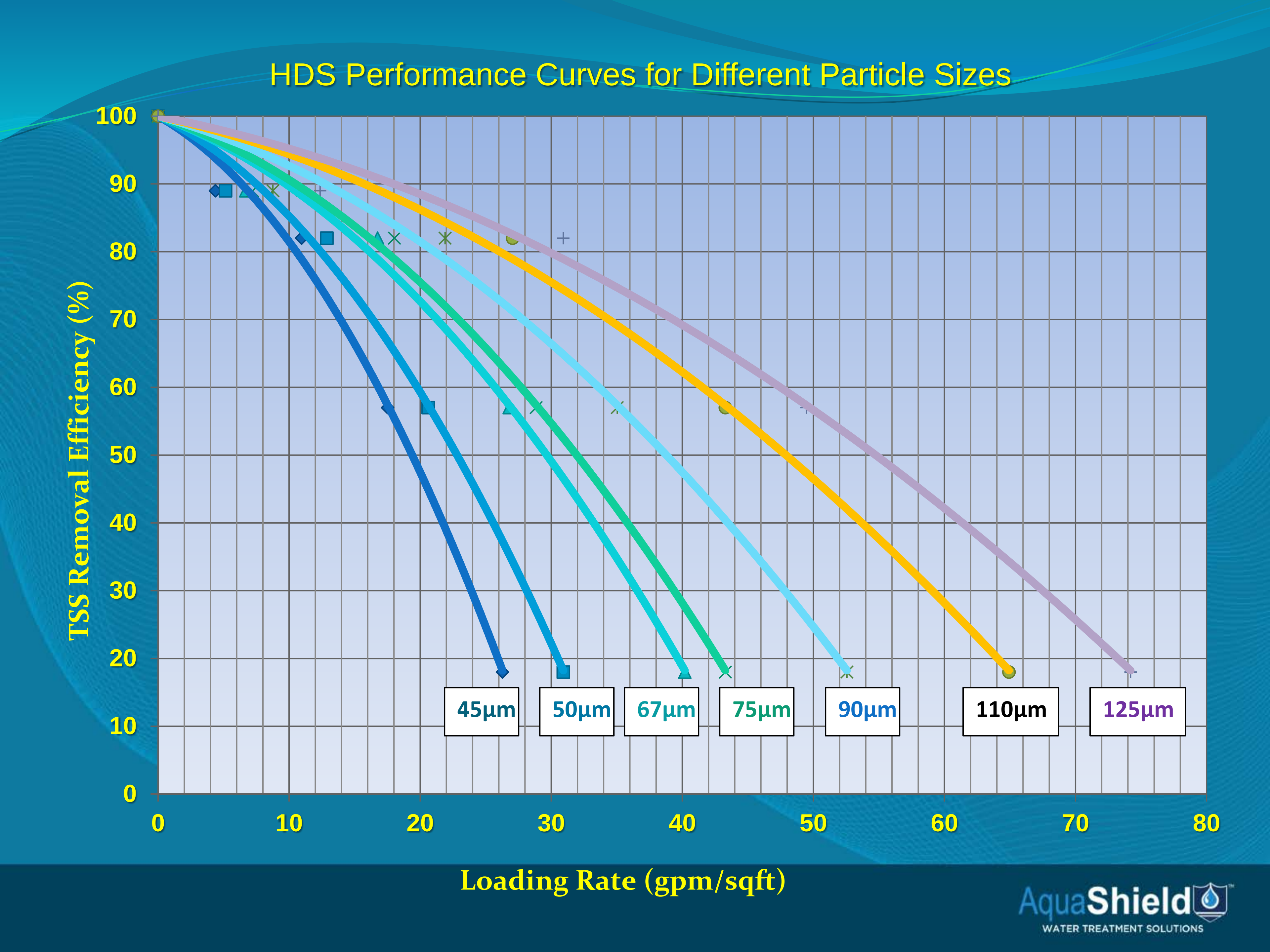
67 μm (Old d_{50} from NJDEP PSD)				
Parameters	Q (cfs)	Loading Rate (gpm/ft^2)	RE (%)	Pe (unitless)
d_{50} = 67 μm	0	0	100	NA
Vs = 0.0.013 ft/sec	0.124	6.7	89	1.33
SG = 2.65	0.310	16.7	82	0.53
d = 3.3 ft	0.495	26.8	57	0.33
h = 3.83 ft	0.743	40.2	18	0.22

75 µm				
Parameters	Q (cfs)	Loading Rate (gpm/ft²)	RE (%)	Pe (unitless)
d_{50} = 75 µm	0	0	100	NA
Vs = 0.014 ft/sec	0.133	7.2	89	1.33
SG = 2.65	0.333	18.0	82	0.53
d = 3.3 ft	0.533	28.9	57	0.33
h = 3.83 ft	0.800	43.3	18	0.22

90 µm				
Parameters	Q (cfs)	Loading Rate (gpm/ft²)	RE (%)	Pe (unitless)
d_{50} = 90 µm	0	0	100	NA
Vs = 0.017 ft/sec	0.162	8.8	89	1.33
SG = 2.65	0.405	21.9	82	0.53
d = 3.3 ft	0.648	35.0	57	0.33
h = 3.83 ft	0.971	52.6	18	0.22

110 µm				
Parameters	Q (cfs)	Loading Rate (gpm/ft^2)	RE (%)	Pe (unitless)
d_{50} = 110 µm	0	0	100	NA
Vs = 0.021 ft/sec	0.2	10.8	89	1.33
SG = 2.65	0.5	27.1	82	0.53
d = 3.3 ft	0.8	43.3	57	0.33
h = 3.83 ft	1.2	64.9	18	0.22

125 µm				
Parameters	Q (cfs)	Loading Rate (gpm/ft^2)	RE (%)	Pe (unitless)
d_{50} = 125 µm	0	0	100	NA
Vs = 0.024 ft/sec	0.229	12.4	89	1.33
SG = 2.65	0.571	30.9	82	0.53
d = 3.3 ft	0.914	49.5	57	0.33
h = 3.83 ft	1.371	74.2	18	0.22



HDS Performance Curves for Different Particle Sizes
TSS Removal Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
45µm
50µm
67µm
75µm
90µm
110µm
125µm
Loading Rate (gpm/sqft)
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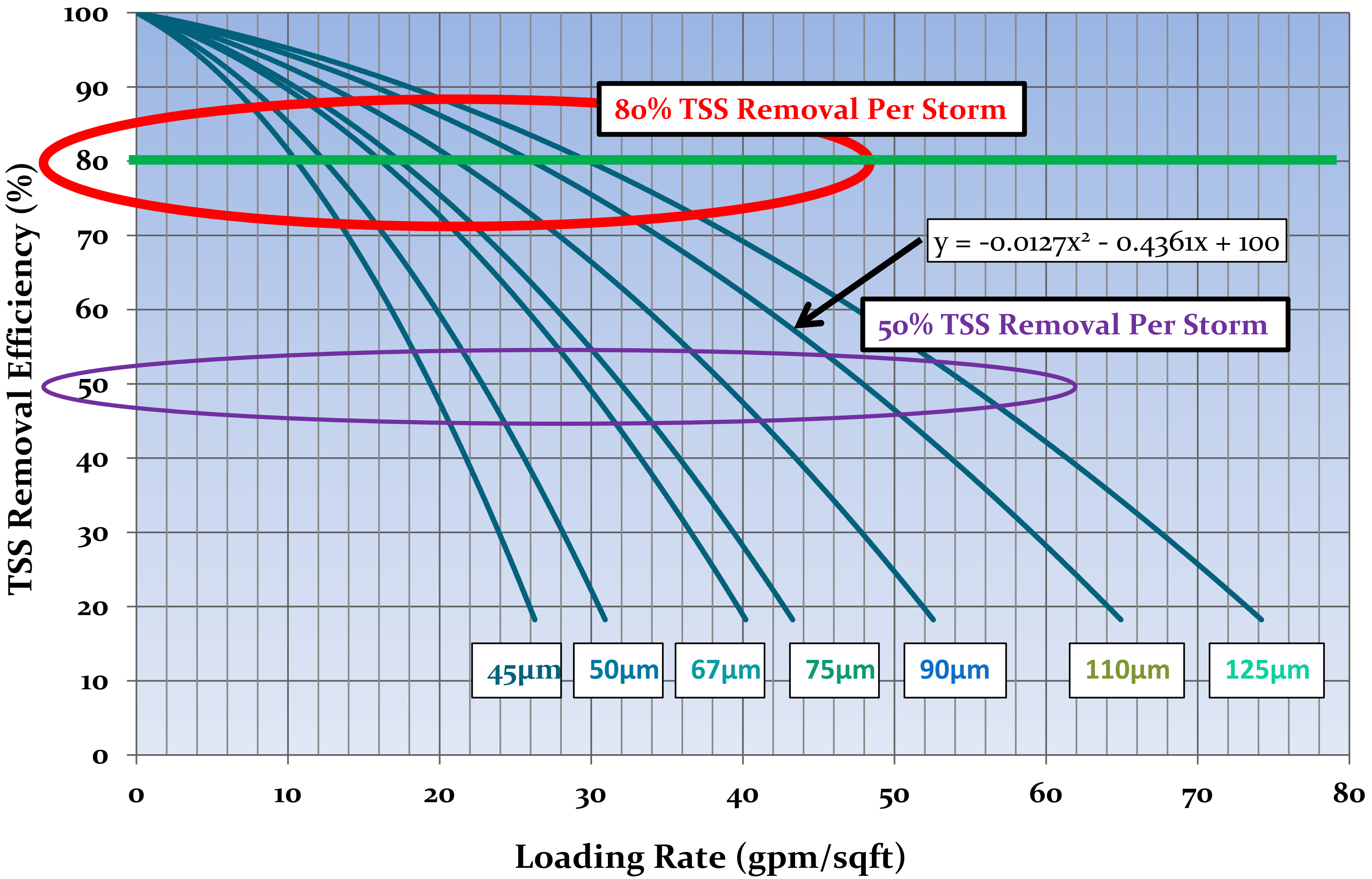
HDS 80% TSS Removal Per Storm



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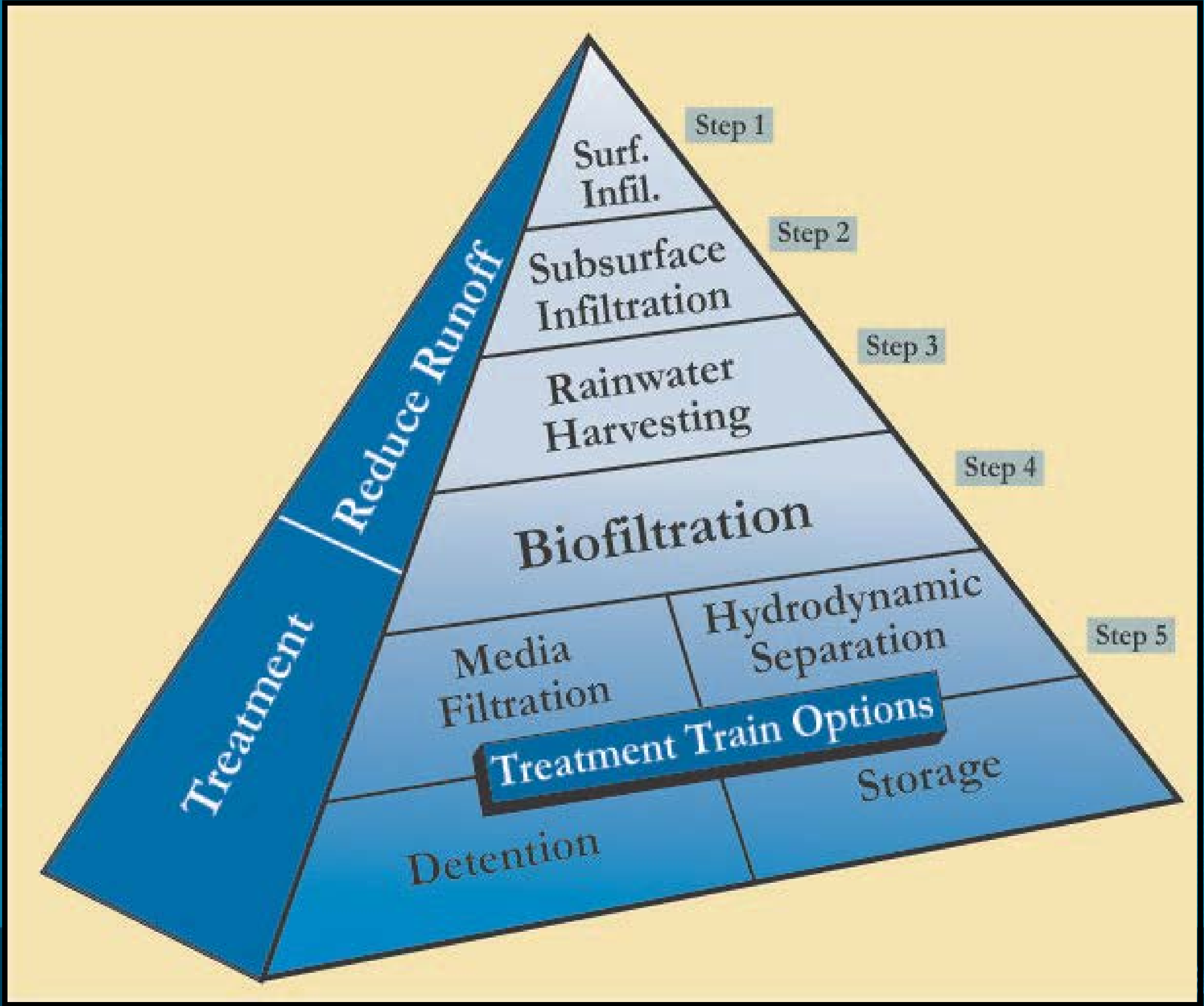
HDS Sizing Charts: 80% TSS Removal per Storm

Example HDS Model Diameter (ft)	Effective Treatment Area (ft^2)	Particle Size and Loading Rate						
		45 µm	50 µm	67 µm	75 µm	90 µm	110 µm	125 µm
		10.5 gpm/ft^2	12.2 gpm/ft^2	16.0 gpm/ft^2	17.5 gpm/ft^2	21.0 gpm/ft^2	26.0 gpm/ft^2	30.0 gpm/ft^2
		Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
4.0	12.6	0.29	0.34	0.45	0.49	0.59	0.73	0.84
5.0	19.6	0.46	0.53	0.70	0.76	0.92	1.14	1.31
6.0	28.3	0.66	0.77	1.01	1.10	1.32	1.64	1.89
8.0	50.3	1.18	1.37	1.79	1.96	2.35	2.91	3.36
10.0	78.5	1.84	2.13	2.80	3.06	3.67	4.54	5.24

Q (cfs) = (square ft · gpm / sq ft) / 448.83 gpm / cfs

Low Impact Development (LID) Technology Selection Pyramid



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It's all about good clean water…

Tennessee River, Chattanooga

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Thank you.

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