Proposed Scaling relations for manufactured stormwater BMPs

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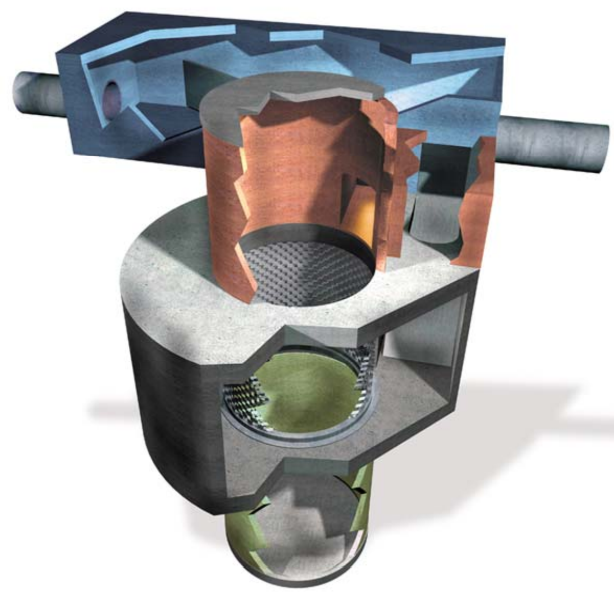
Guidelines for Certification of Manufactured Stormwater BMPs Task Committee

EWRI Stormwater Infrastructure Committee

Outline

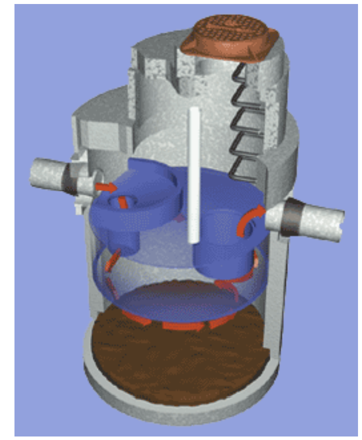
- Use of Manufactured Devices
- Need for Scaling Criteria
- Relevant Dimensionless Numbers
- Hydrodynamic Separators
- Filters
- Future needs
- Conclusions



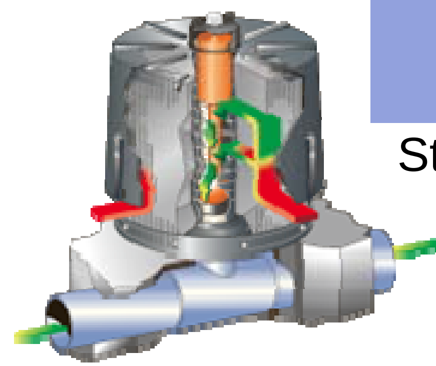
CDS Separator

Use of Manufactured Devices

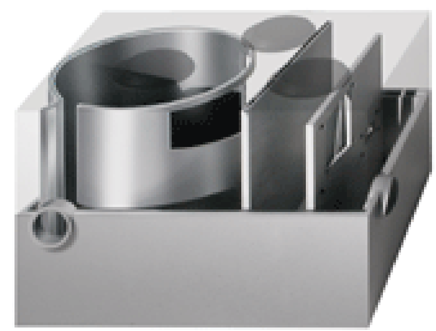
- Hydrodynamic separation remove sand and some coarse silt particles
- Filtration is used to remove organic particles as well as silt and clay.
- Floatables chamber designed to remove floatables, or particles that are lighter than water.



Stormceptor



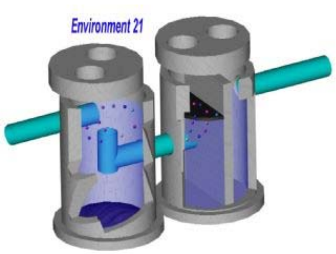
StormFilter



Vortechs System

Need for Scaling Criteria

- The numerous designs and multiple sizes suggest the *need for scaling criteria to size and apply designs in the field.*
- Geometric similarity is assumed.



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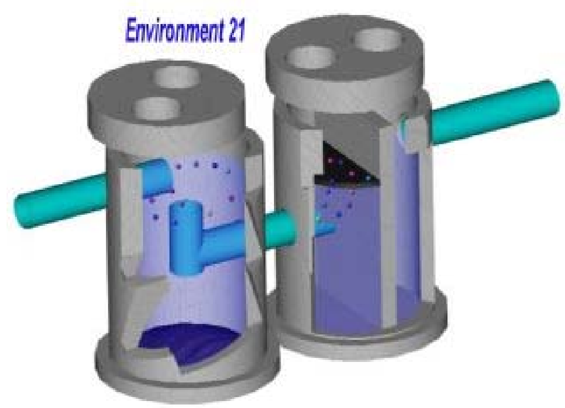

Relevant Dimensionless Numbers

- Critical numbers $$\mathbf{Re} = \frac{Q}{\nu L} \geq \mathbf{Re_c} \qquad \mathbf{We} = \frac{\rho Q^2}{\sigma L^3} \geq We_C$$
- Discharge $$\mathrm{Fr} = \frac{Q}{\sqrt{gL^5}}$$
- Friction $$f \sim \left(\frac{u_* L^2}{Q} \right)^2$$
- Pressure $$\mathrm{Eu} = \frac{\Delta P L^4}{\rho Q^2}$$

Q = discharge through the device
= kinematic viscosity
= density of the liquid
= liquid surface tension
P = pressure difference
f = friction factor
*U** = shear velocity
L = smaller of the important length scales in the flow field, such as the diameter of the device or depth of water.

Hydrodynamic Separators

- Three simultaneous processes
  - Vertical velocity of particles relative to water causes separation

Hydrodynamic Separators, Cont'd

- **Settling** $\text{Ha} = \dfrac{d^2 V_S}{Q}$
- **Mixing** $\text{Pe} = \dfrac{V_s h d}{Q}$
- **Scour: Dimensionless Shields stress**

$$\tau^* = \frac{u_*^{\,2}}{gRd_P} = \frac{fQ^2}{8gRd_P d^4}$$

Q = discharge through the device
Vs = settling velocity
f = friction factor
*U** = shear velocity
g = acceleration of gravity
R = specific gravity in water
d_p = particle diameter
d = diameter of the device
h = height of the water

Hydrodynamic Separators, Cont'd

- **Settling Performance: Hazen and Peclet numbers give:**

$$\frac{Q_p}{Q_m} = \frac{V_{Sp}}{V_{Sm}} \left(\frac{L_p}{L_m} \right)^2$$

Q = discharge through the device
Vs = settling velocity
L = length scale
m = model
p = prototype

Hydrodynamic Separators, Cont'd

- **Scour: Dimensionless Shields stress gives:**

$$\frac{Q_p}{Q_m} = \sqrt{\frac{f_m d_{pp} R_p}{f_p d_{pm} R_m}} \left(\frac{L_p}{L_m} \right)^2$$

Q = discharge through the device
Vs = settling velocity
f = friction factor
L = length scale
R = specific gravity in water
d_p = particle diameter
C_d = Drag Coefficient on particle
m = model
p = prototype

- **During scour there is also settling, thus:**

$$V_s = \frac{gRd_p^{\ 2}}{18\nu + \left(0.75 C_D g R d_p^{\ 3}\right)^{1/2}} \Rightarrow \sqrt{\frac{gRd_p}{0.75 C_D}}$$

Hydrodynamic Separators, Cont'd

- **Simultaneous similitude of settling and scour requires:**
  - **Settling depends upon drag coefficient**
  - ***~ constant drag coefficient***

- **Therefore, we can scale:**
  - ***Large particles,*** $Re = V_s d_p/\nu > \sim 100$
  - d_p **(S.G.=2.65) > .75 mm**
  - d_p **(S.G. = 1.1) > 1.5 mm,** V_s **(S.G. = 1.1) = 7 cm/s**

    => d_p **(S.G. =2.65) >.45 mm**

Filters

- Particle trapping of a filter is well-simulated with a bench-top column test.
  - Media Reynolds number:

$$\boldsymbol{Re} = \frac{Q}{\varepsilon^{1/3} A^{1/2} \nu}$$

  - suspended solid-media size ratio,

$$L_s = \frac{d_p}{d_{med}}$$

= porosity of the filter media

dmed = equivalent spherical diameter of the filter media.

A = cross-sectional area of filter

Filters, Cont'd

However,

- Pressure differences in flow field can affect filtration rate.

$$\text{Eu} = \frac{\Delta P L^4}{\rho Q^2} \qquad f \sim \left(\frac{u_* L^2}{Q}\right)^2 \qquad \text{Fr} = \frac{Q}{\sqrt{g L^5}}$$

- Many filters are partially self-cleaning, utilizing turbulence in the flow field to remove caked material.

Future Needs

- Scour in hydrodynamic separators
- Influence of fluid flow on pressure difference in filters
- Influence of fluid flow on fowling in filters

Conclusions

- Have made progress with Ha or Pe scaling for removal of hydrodynamic separators.
- Scour is the next challenge.
  - Will need data and empirical relationships
- Need a methodology to develop scaling criteria for filters.
  - Well calibrated and verified CFD codes could help in this process.

Thank you! / Questions?