Evaluating Self Cleansing in Existing Sewers Using the Tractive Force Method

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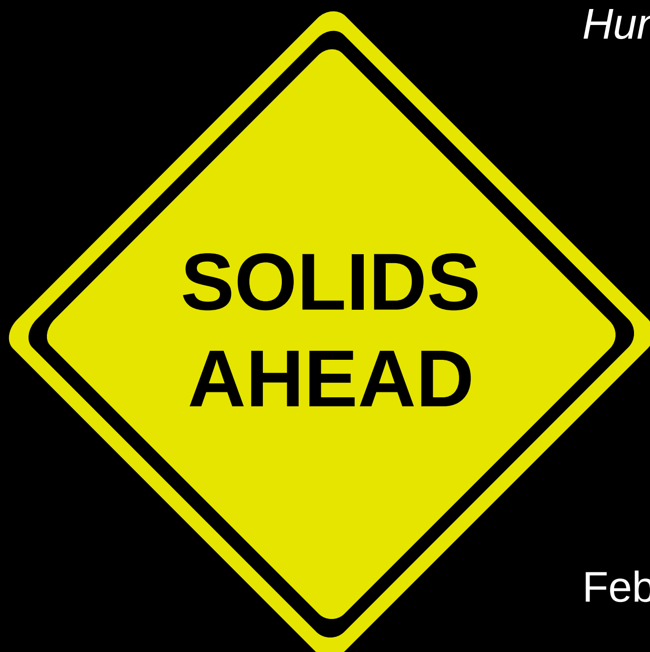


February 16, 2011

Background

Gravity Sanitary Sewer Design and Contruction, 2nd Ed. 2007

Joint publication: ASCE Manual No.60 / WEF MOP FD-5

Previous Editions:

1982

1962

1935

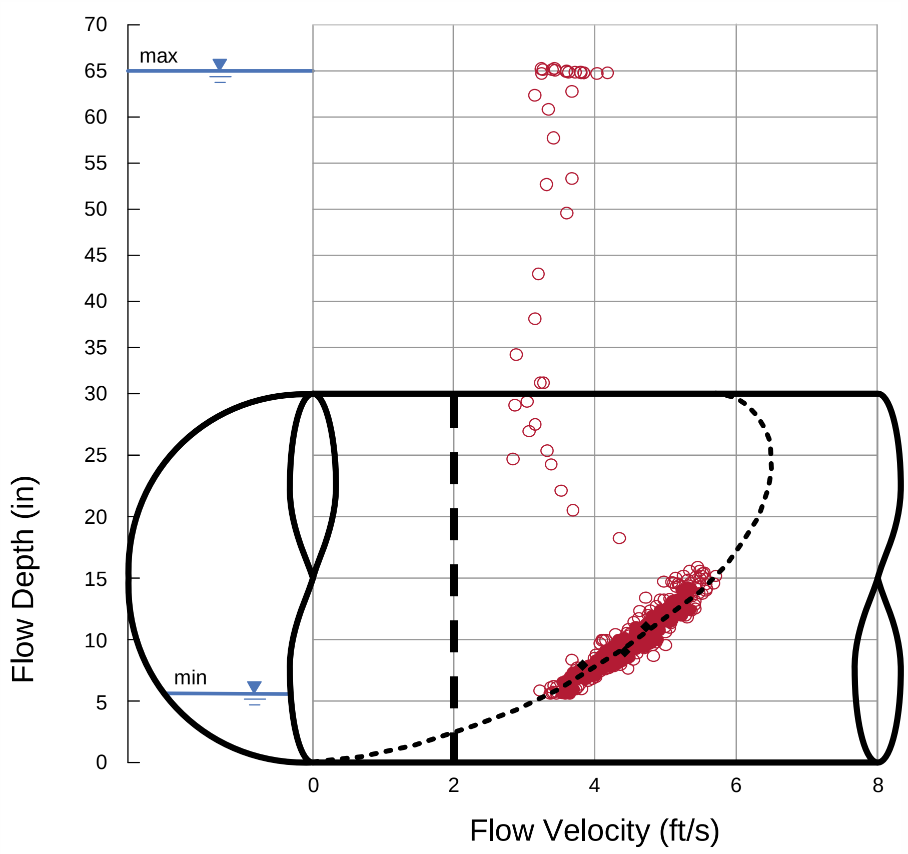
Self Cleansing Information History

2007 – 18 pages

1982 – 1.5 pages

What is a Scattergraph?

$$v = \frac{1.486}{n} R^{2/3} S^{1/2}$$



Enfinger, K.L. and Keefe, P.N. (2004). "Scattergraph Principles and Practice – Building a Better View of Flow Monitor Data," KY-TN Water Environment Association Water Professionals Conference; Nashville, TN.

Shear Stress

Self-cleansing conditions within a sewer are directly related to **shear stress**. As wastewater flows within a sewer, it exerts an average shear stress, or tractive force, on the sewer as shown below.

$$\tau = \gamma RS$$

where:	τ	= average shear stress, lb/ft^2
	γ	= specific weight of water, lb/ft^3
	R	= hydraulic radius, ft
	S	= slope of the energy gradient, ft/ft

Flow conditions are classified as self-cleansing when the actual shear stress (τ) is greater than or equal to a specified critical shear stress (τ_c) at a defined frequency of occurrence.

American Society of Civil Engineers (2007). *Gravity Sanitary Sewer Design and Construction*, 2nd Edition, ASCE Manuals and Reports on Engineering Practice No. 60, American Society of Civil Engineers: Reston, VA.

Wastewater Solids Characteristics in the United Kingdom

Solids Type	Transport Mode	Median Size d_{50} mm			Specific Gravity		
		Low	········	High	Low	········	High
Sanitary	Suspension	0 01	0 04	0 06	´ 01	´ 40	´ 60
Storm Water	Suspension	0 02	0 06	0 10	´ 10	2 00	2 50
Grit	Bedload	0 30	0 75	´ 00	2 30	2 60	2 70

Butler, D., May, R.W.P., and Ackers, J.C. (1996). "Sediment Transport in Sewers – Part 1: Background," Proceedings of the Institution of Civil Engineers, *Water, Maritime, and Energy*, Volume 118, Page 103-112.

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design particle = 1.0-mm grit particle with specific gravity of 2.70

American Society of Civil Engineers (2007). *Gravity Sanitary Sewer Design and Construction*, 2nd Edition, ASCE Manuals and Reports on Engineering Practice No. 60, American Society of Civil Engineers: Reston, VA.

Critical Shear Stress

Raths and McCauley have previously investigated the **critical shear stress** needed to transport grit particles of various sizes as bedload within a sewer. Their results are presented in equation form as shown below.

$$\tau_c = 0.0181(D_p)^{0.277}$$

where: τ_c = critical shear stress, lb/ft^2
D_p = particle size, mm

Based on the selected design particle, a critical shear stress of 0.0181 lb/ft^2 is needed to achieve self-cleansing conditions.

Walski, T.M., Barnard, T.E., Harold, E., Merritt, L.B., Walker, N., & Whitman, B.E. (2004). *Wastewater Collection System Modeling and Design*, Haestad Press, Waterbury, CT.

Critical Shear Stress Translated to Flow Velocity

$$\tau = \gamma RS \rightarrow S = \frac{\tau_c}{\gamma R}$$

$$\downarrow$$

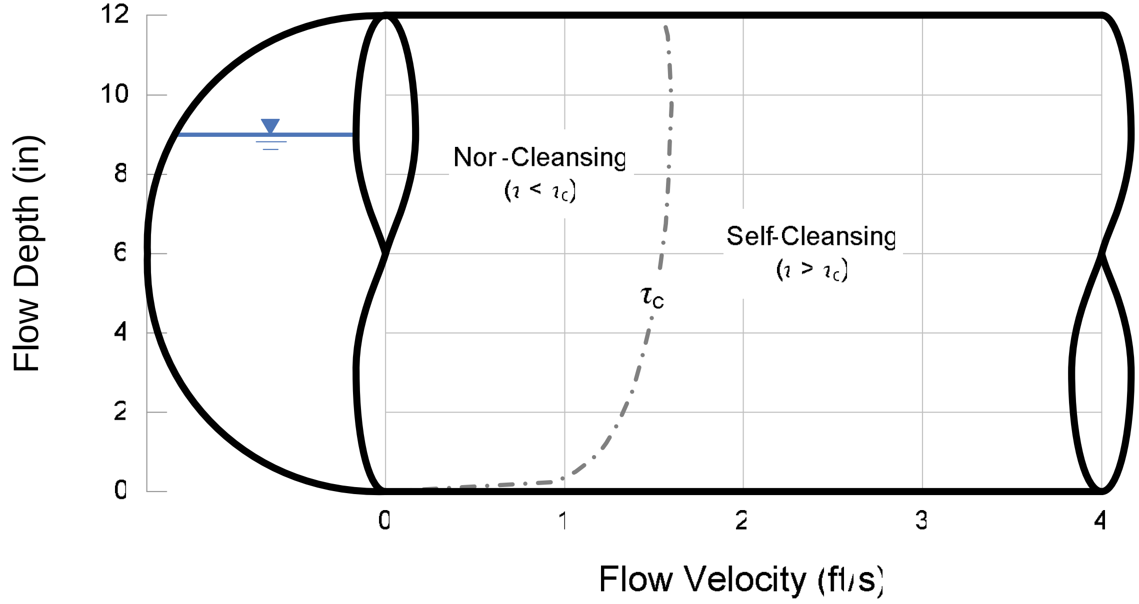
$$v = \frac{1.486}{n} R^{2/3} S^{1/2} \rightarrow v_{sc} = \frac{1.486}{n} R^{1/6} \left(\frac{\tau_c}{\gamma} \right)^{1/2}$$

where:

v_{sc} = self-cleansing flow velocity, ft/s
n = roughness coefficient
R = hydraulic radius, ft
τ_c = average shear stress, lb/ft^2
γ = specific weight of water, lb/ft^3

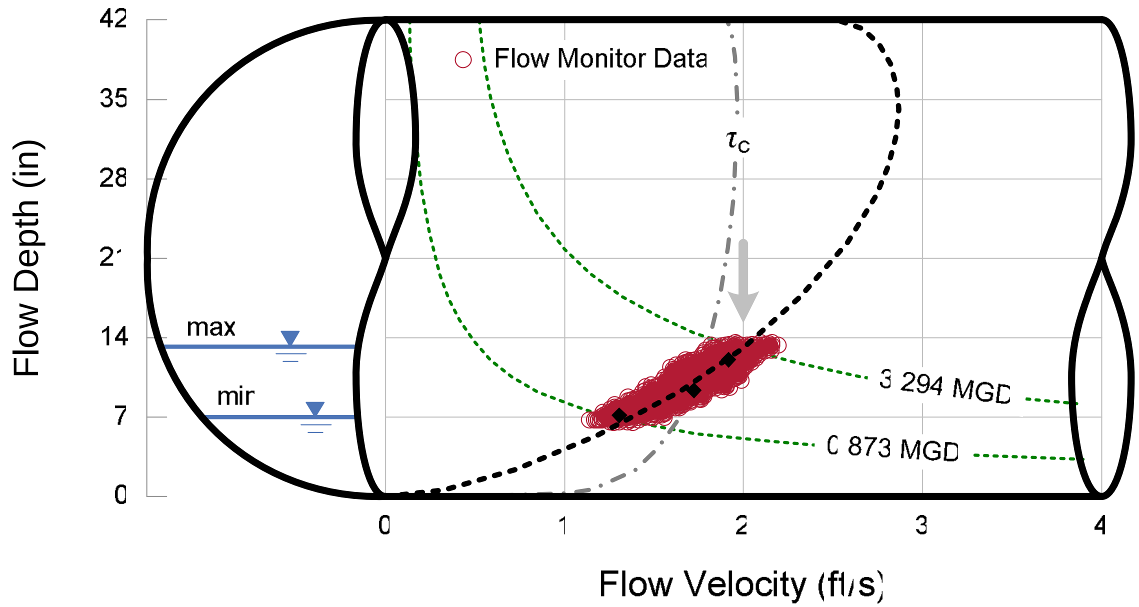
Critical Shear Stress Displayed Graphically

$$v_{sc} = \frac{1.486}{n} R^{1/6} \left(\frac{\tau_c}{\gamma} \right)^{1/2}$$

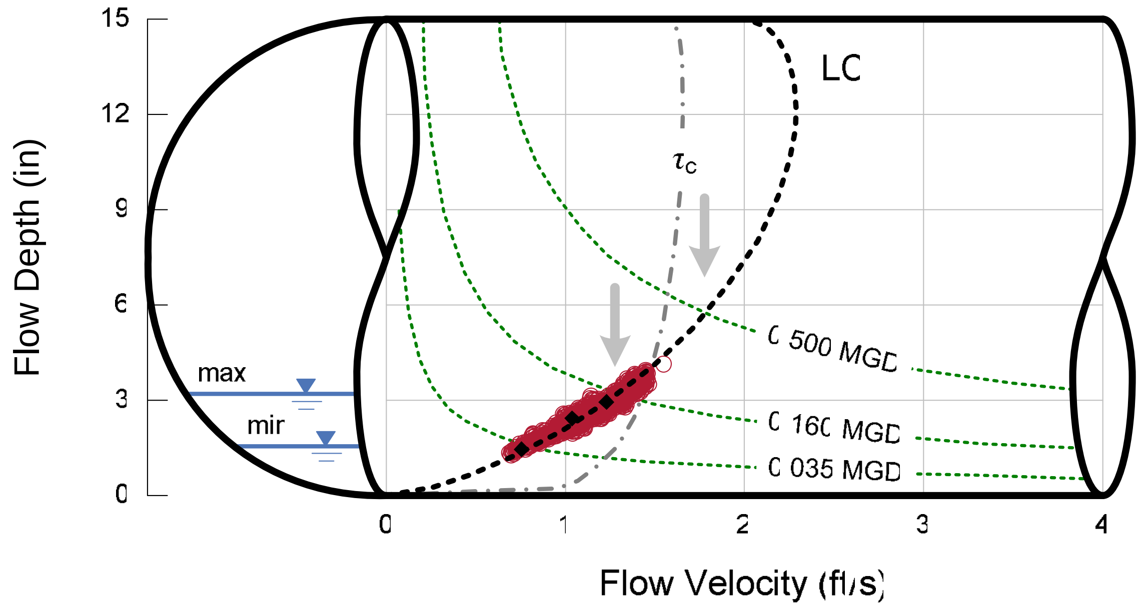


Moraitis, P. (1999). "Development of Gravity Flow Pipe Design Charts." Unpublished Undergraduate Project for Professor David Butler. Imperial College, Department of Civil and Environmental Engineering, London.

Self-Cleansing Conditions

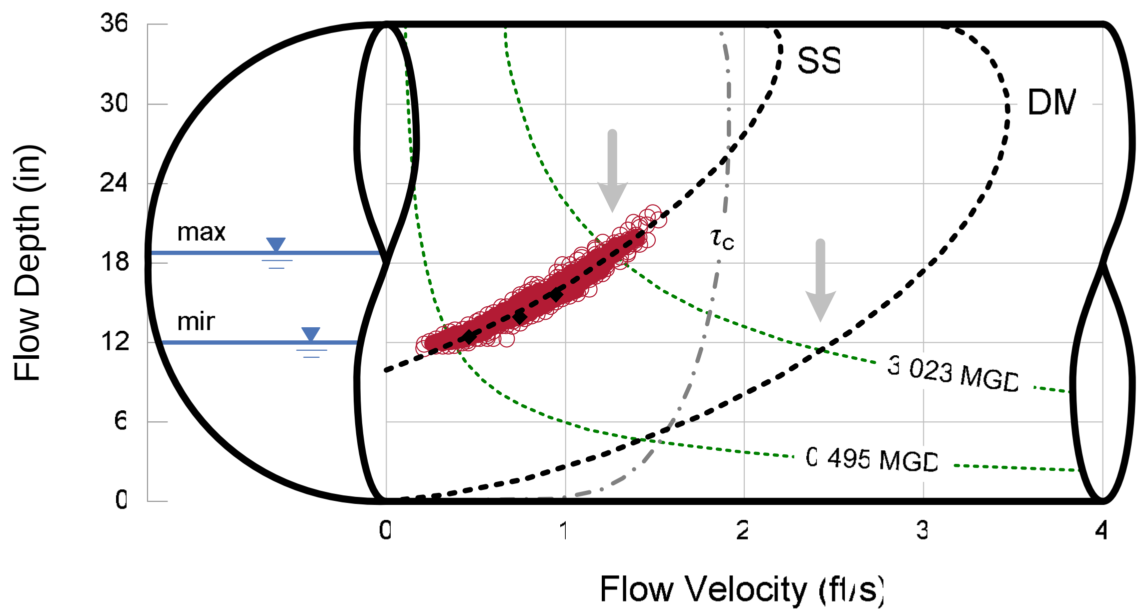


Non-Cleansing Conditions – Type I



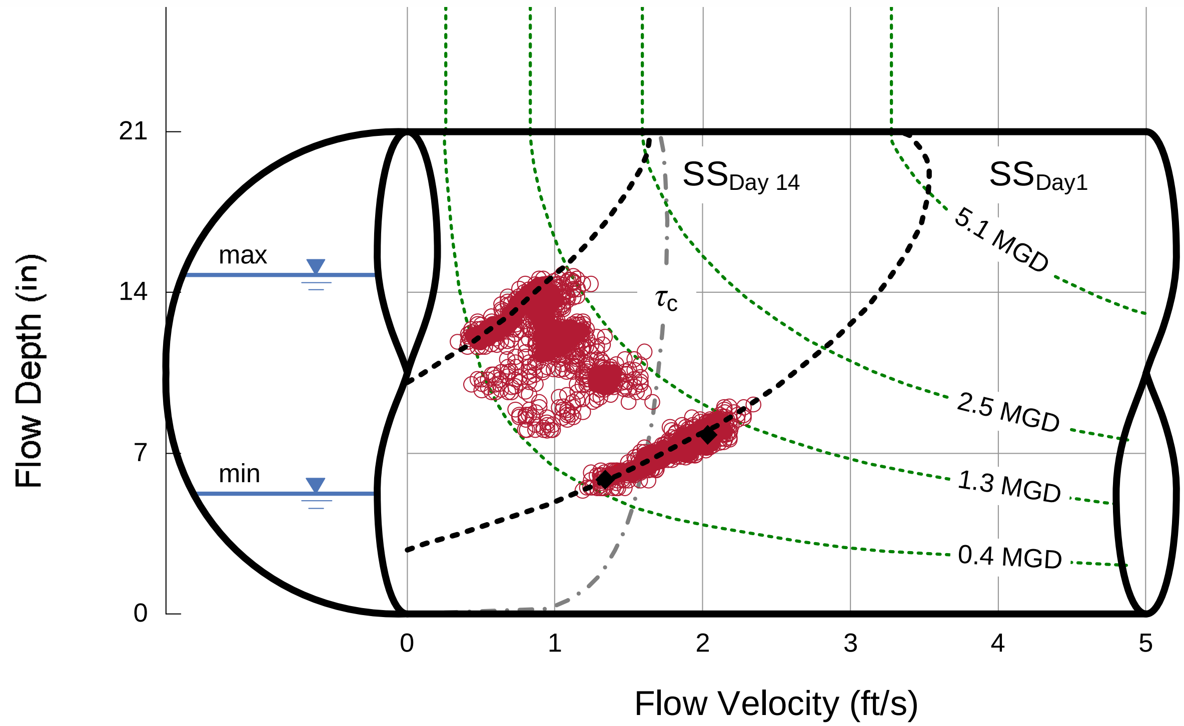
Type I non-cleansing conditions include sewers that operate under uniform flow conditions, but do not have conditions necessary to generate a shear stress in excess of the required critical shear stress.

Non-Cleansing Conditions – Type II



Type II non-cleansing conditions include sewers that operate under non-uniform flow conditions caused by backwater effects resulting from a variety of downstream obstructions, or *dead dogs*. Examples include offset joints, debris, and other related conditions.

Non-Cleansing Conditions – Type II



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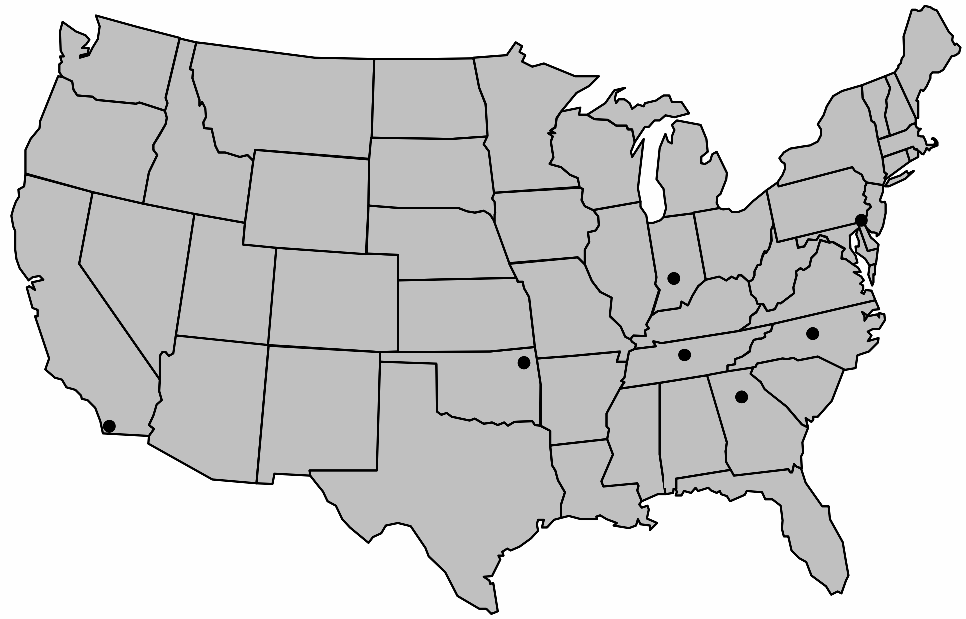
HWEA 2011

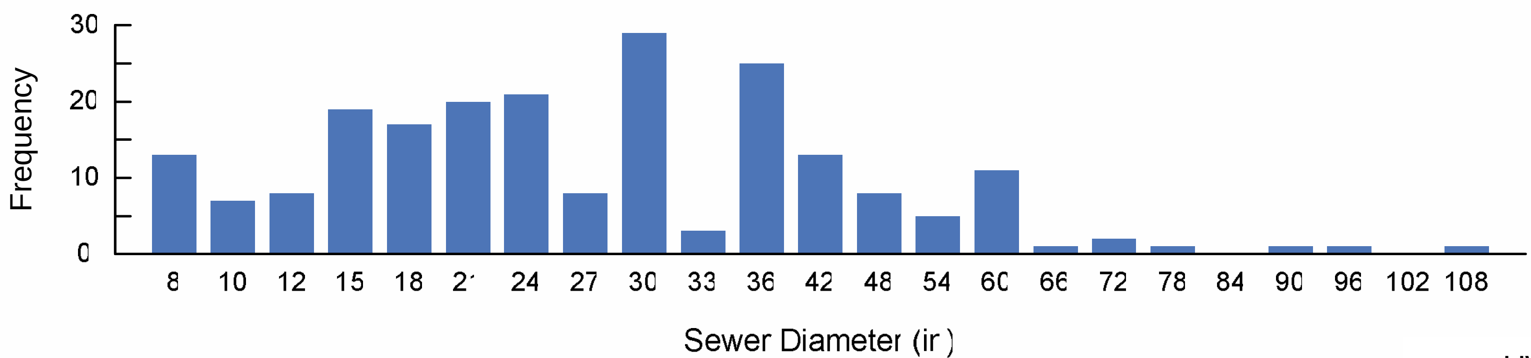
A Practical Test of the Tractive Force Method

Flow monitor data were obtained from 214 existing sewers during a 30-day evaluation period.

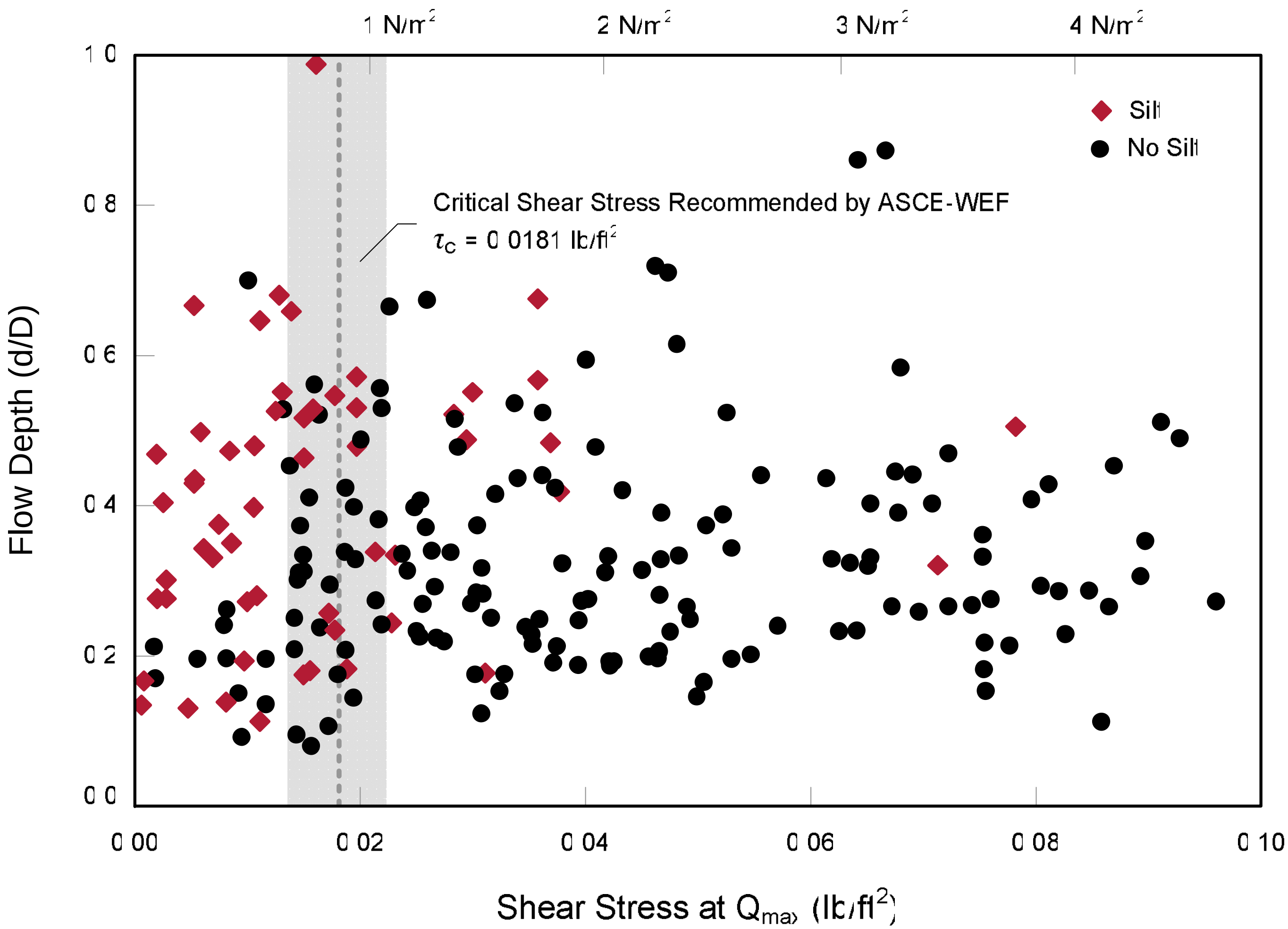
Each sewer was classified as self-cleansing or non-cleansing, based on the **Tractive Force Method**.

Independent silt measurements were then obtained over a 12-month Observation Period and compared to original predictions.





Test Case Summary



Conclusion

- Previous self cleansing design criteria result in slopes that are steeper than needed for smaller pipes (<42”) and flatter than actually needed for larger pipes.

- Existing sewers with adequate self-cleansing conditions and those with potential silt, sediment, or debris accumulation are readily identified looking at flow data scattergraphs.

- Practical application of this method to over 200 existing sewers demonstrates the general effectiveness of the tractive force approach for the self-cleansing design of sanitary sewers.

Questions or Comments?

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