Assessment of Standard Sumps for Stormwater Treatment

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UNIVERSITY OF MINNESOTA

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Outline

- Background
- 6’ and 4’ Sump Setup
- 6’ and 4’ Sump Results
- SAFL Baffle Retrofit
- Conclusion

Background

- 1987 Amendments to Clean Water Act created a market for underground proprietary stormwater treatment devices
- Mn/DOT search for other cost effective stormwater treatment BMPs
- Standard Sump (Manhole) already in common use
  - Location for pipe junctions
  - Maintenance access
  - Detention time for removal of some particulate and trash

Smith 2001

Background

- Two Important Questions
  - How well does the device remove particulate from influent?
    - Performance testing
  - How well does the device retain the captured sediment under high flows?
    - Retention testing

Background

- Removal efficiency
  - Mass of retained sediment divided by mass of sediment input
- Explain removal efficiency as a function of dimensionless number
  - Peclet number
    - Pe= Vs*h*d/Q
    - Vs= Particle Settling Velocity, h=Water Column Depth, d=Device Diameter, Q=Flowrate

Background

- Performance Continued
  - Data interpretation
    - Three parameter nonlinear model provides a performance function

$$\eta = \left(\frac{1}{R^b} + \frac{1}{(a * Pe)^b} \right)^{-\frac{1}{b}}$$

      - η=removal efficiency, R=removal efficiency as Pe approaches infinity, a=initial slope of the curve at Pe=0, b=measure of the curvature in the function at Pe=R/a, Pe=Peclet number
      - Allows for comparison of various settling devices

Wilson 2009

Background

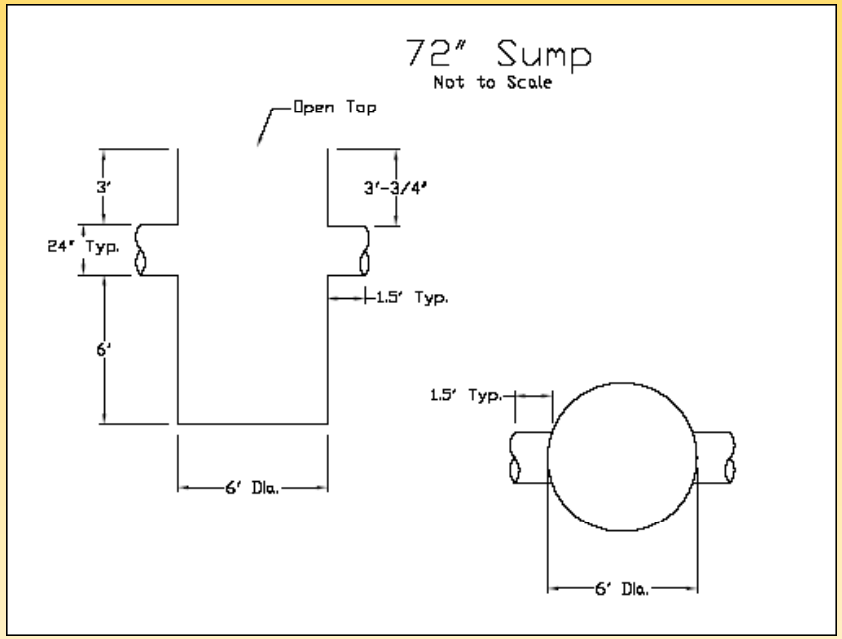
- Model Uncertainty Analysis
  - No model or measurement is completely accurate
  - Nonlinear with non-normal residual distribution
  - Pointwise confidence intervals using bootstrap
    - Create a distribution from resampling
  - CI's show uncertainty in the *model*
    - i.e. 95% of the fitted models will be within the CI

Kline 1985, Carpenter 2000

Background

- Assessment of particle resuspension
  - Simple test involving calculation of mass removed from pre-loaded sump
  - A descriptive relationship for scour has not yet been developed
    - Comparison between devices thus based on effluent concentration

6’ by 6’ Experimental Setup



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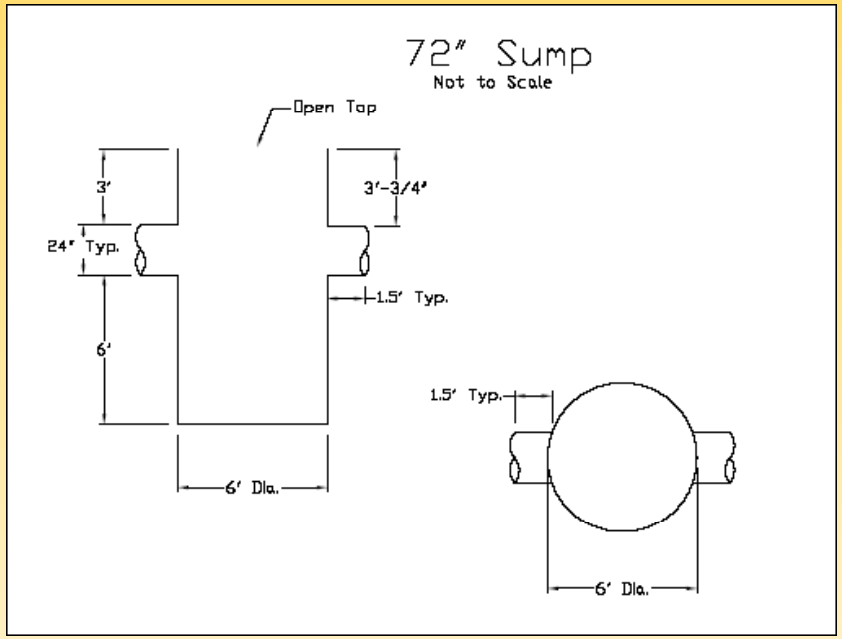

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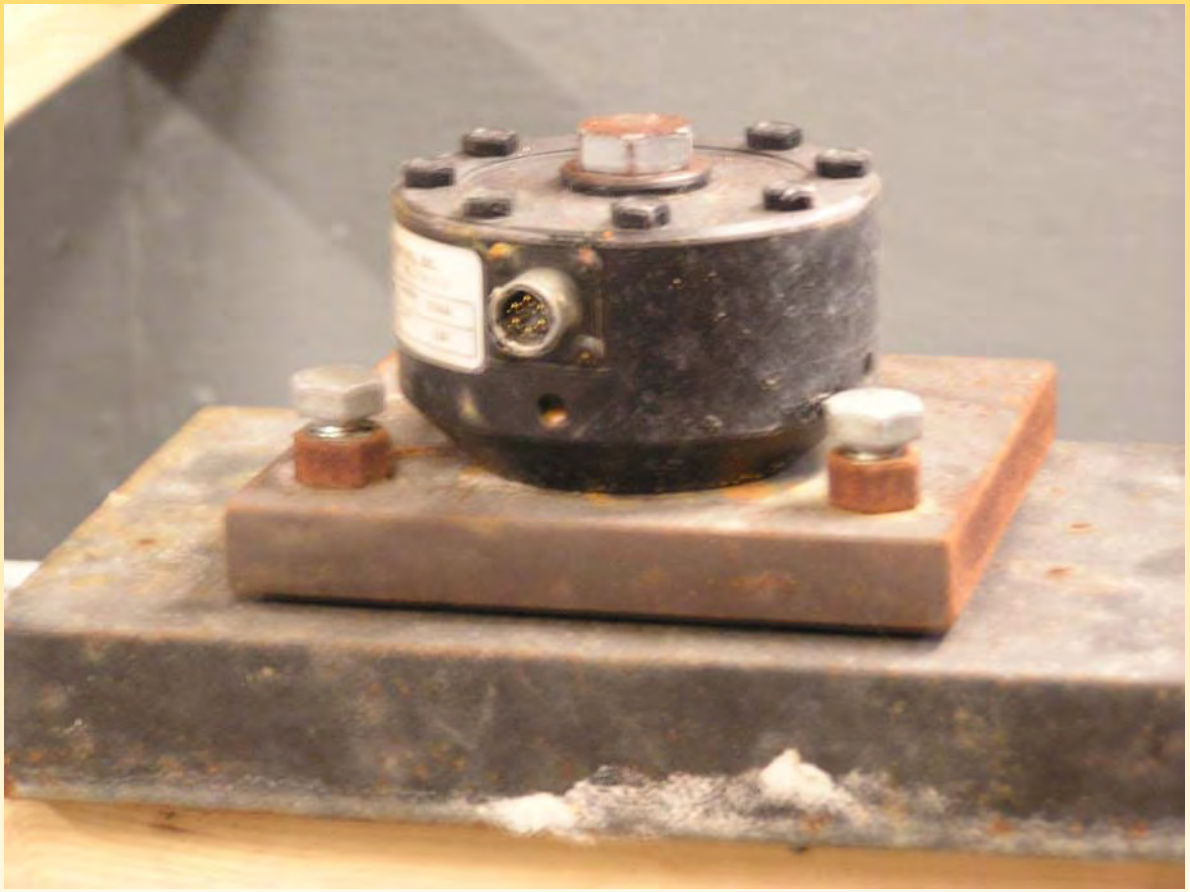
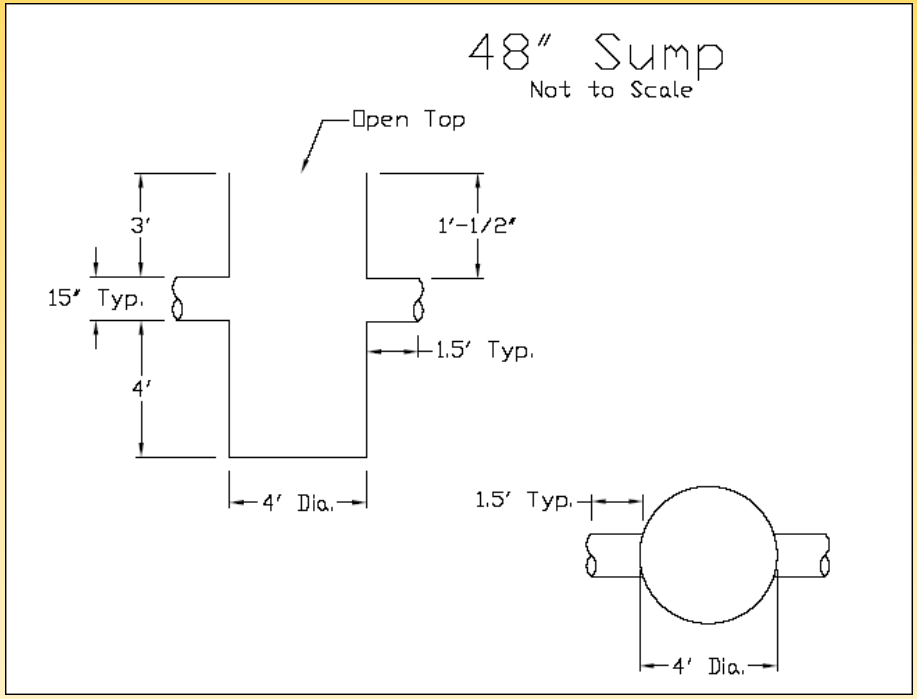


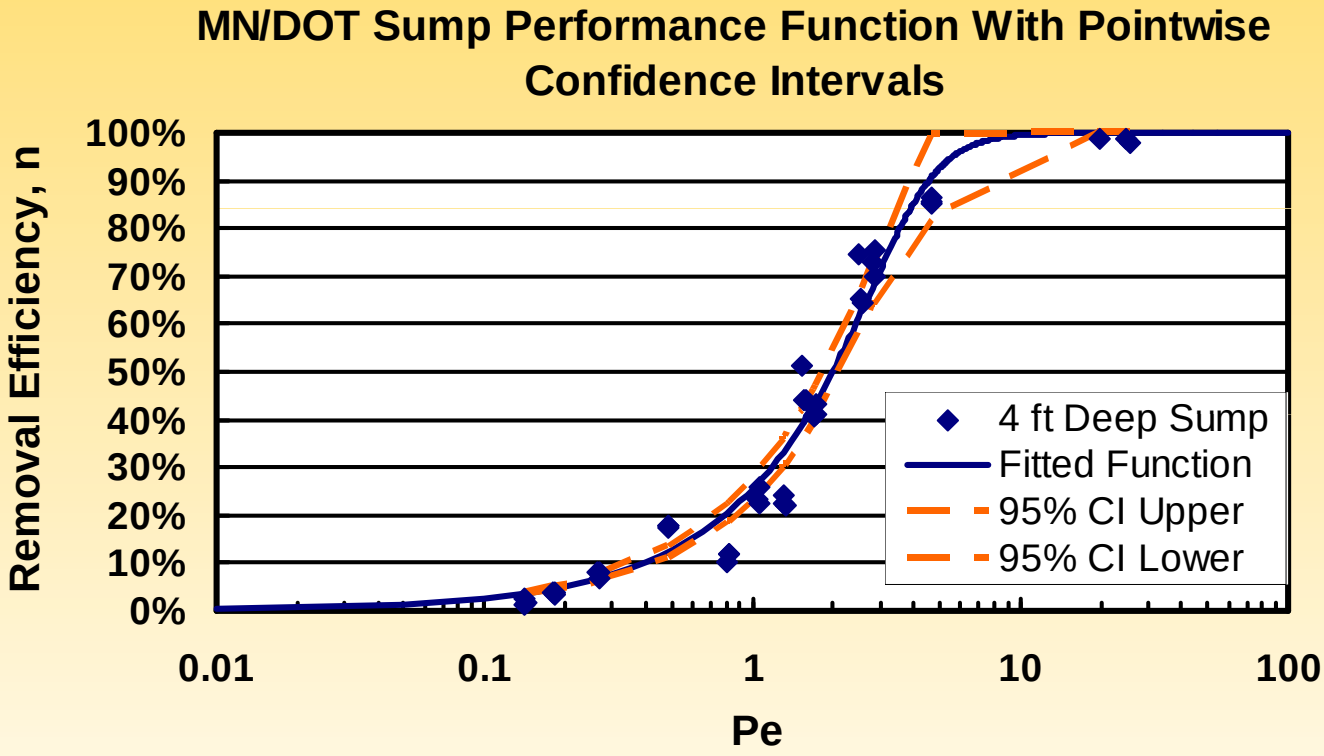
4’ by 4’ Experiment Setup



6’ by 6’ Sump Performance

- Initially Clean Sump
- Three Distinct Particle Size Ranges
  - 89-125*u*m
  - 251-420*u*m
  - 500-589*u*m
- 100 and 200 mg/L Influent Concentration
- Multiple Flowrates
  - Three Repeat Tests for 1.8, 3.5, 5.3, and 7cfs
    - 7 cfs is the 1yr design storm of 2.4in over 24hrs for the Minneapolis, MN
  - One test each at 0.3, 0.4, and 0.5 cfs with the largest particle size

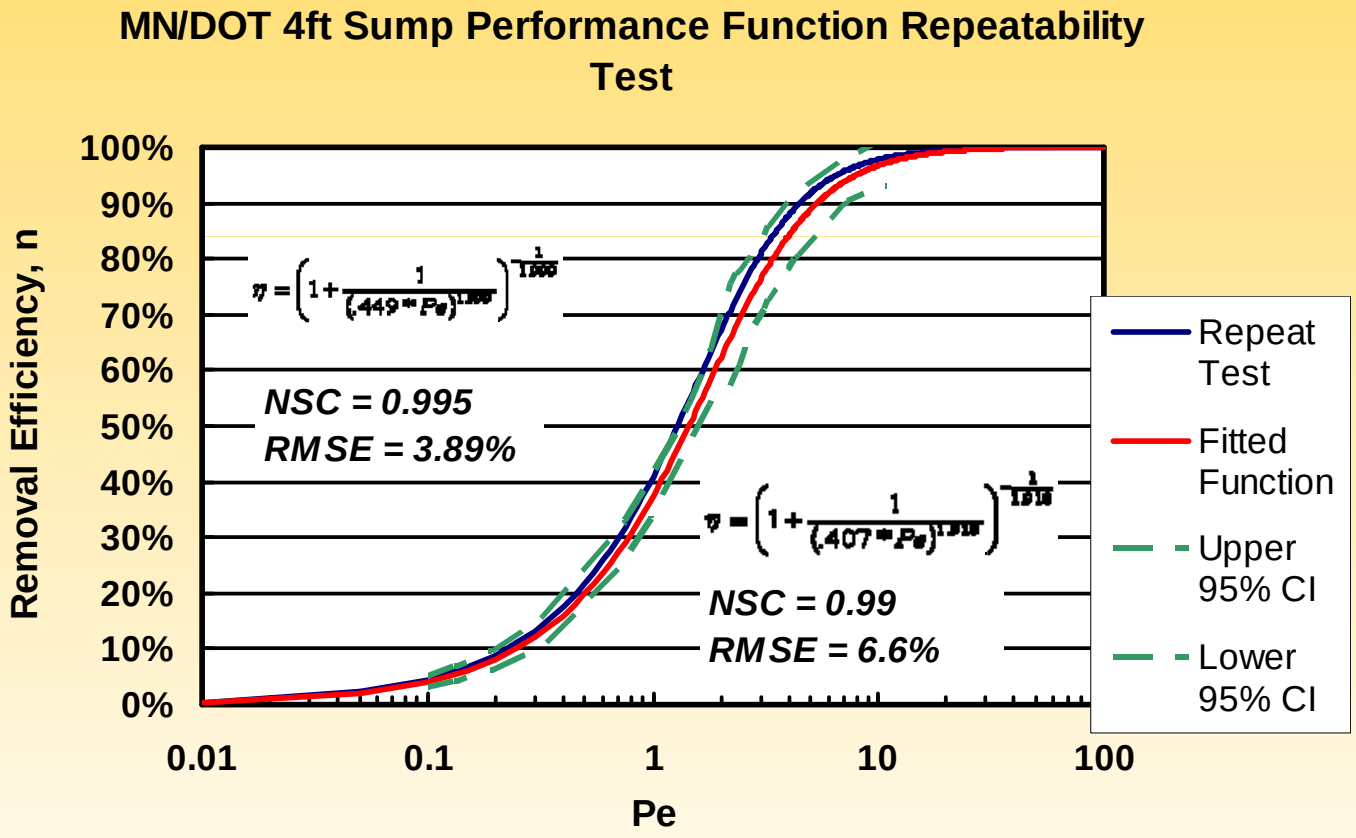
6’ by 6’ Sump Performance



4’ Deep Sump Performance

- Initially Clean Sump
- Three Distinct Particle Size Ranges
  - 89-125*u*m
  - 251-420*u*m
  - 500-589*u*m
- 200 mg/L Influent Concentration
- Multiple Flowrates
  - Three Repeat Tests for 0.6, 1.2, 1.8, and 2.4cfs
    - 2.4 cfs is the 1yr design storm of 2.4in over 24hrs for the Minneapolis, MN
  - One test each at 0.3, 0.4, and 0.5 cfs with the largest particle size

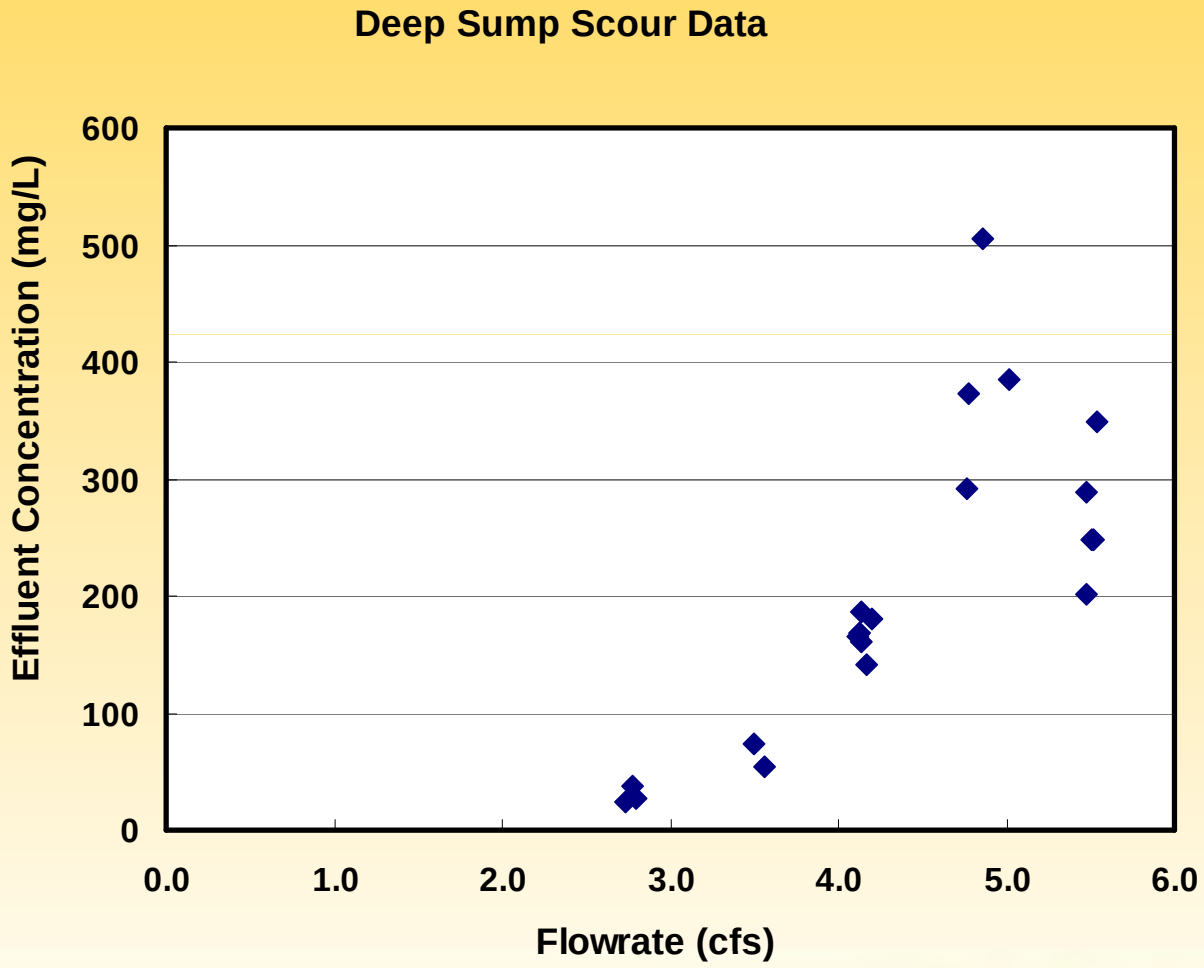
4’ Deep Sump Performance



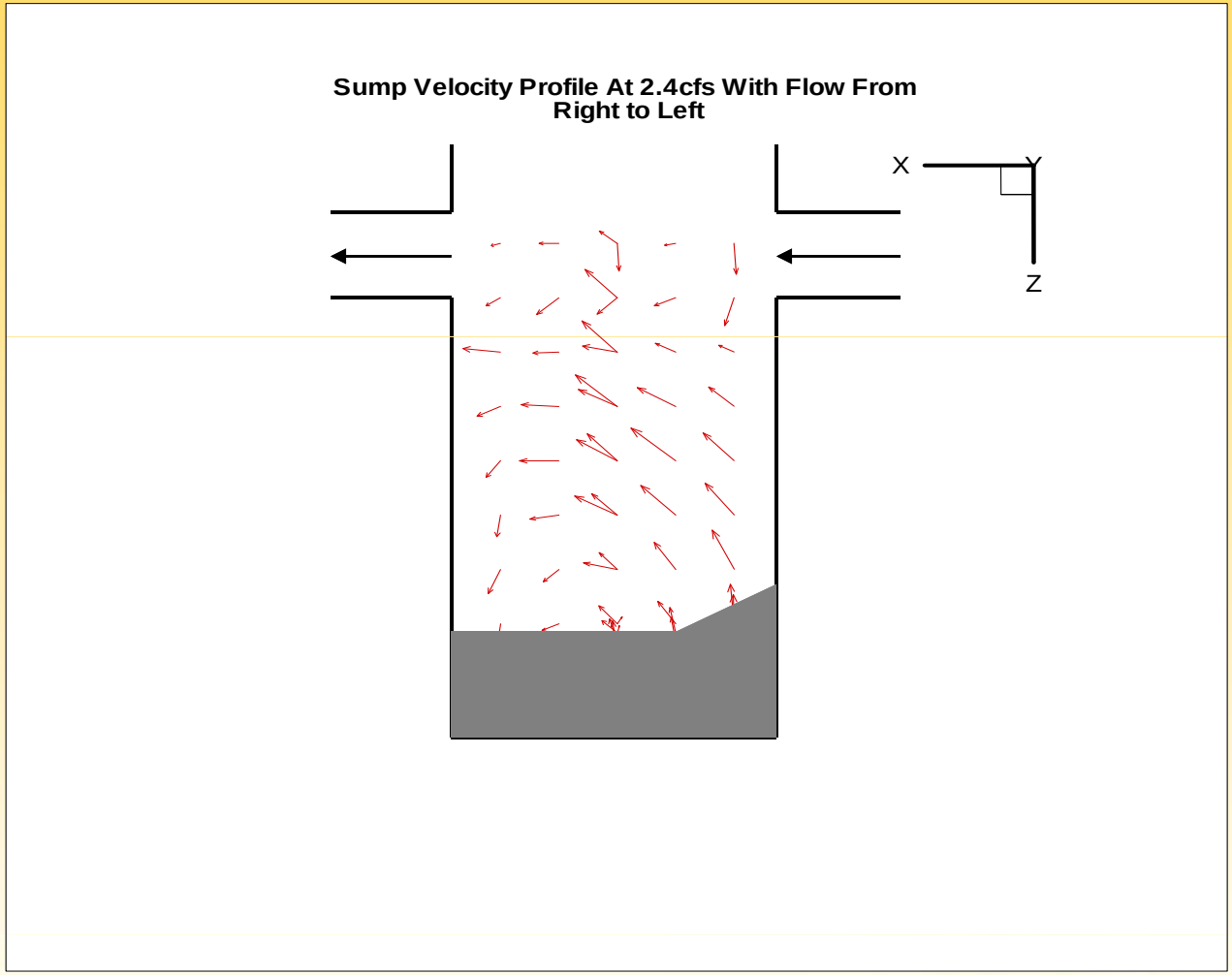
4’ Deep Sump Retention

- Preload 1300lbs (1ft depth) of Sediment
- U.S. Silica F-110
  - Median particle diameter of 110*u*m
- Multiple flowrates from 2.8 cfs to 5.5 cfs
  - 5.5 cfs is the 10 year design storm of 4.2 in over 24 hours for Minneapolis, MN
- 2 Hour Duration
- Effluent Concentration Determined Using Load Cells and Checked Using Depth Measurement

4’ Deep Sump Retention



4’ Deep Sump Retention

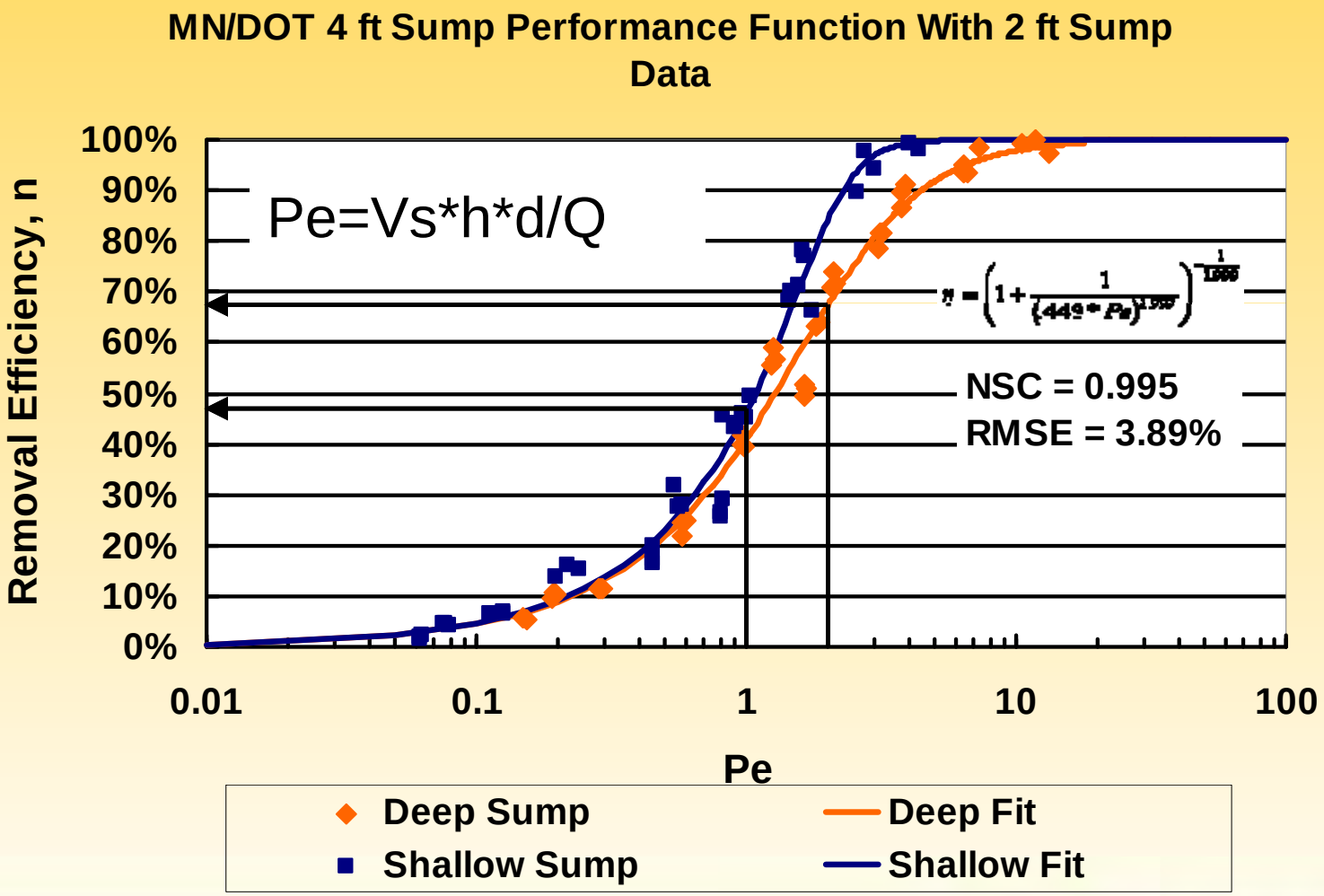


4’ Deep Sump Retention

4’ Shallow Sump Performance

- 2’ Deep False Floor Added to Sump
- Same Test Series As Before
  - 0.3, 0.4, 0.5, 0.6, 1.2, 1.8, and 2.4 cfs flowrates
  - 89-125, 251-420, and 500-589 *u*m particle sizes
  - 200 mg/L influent concentration

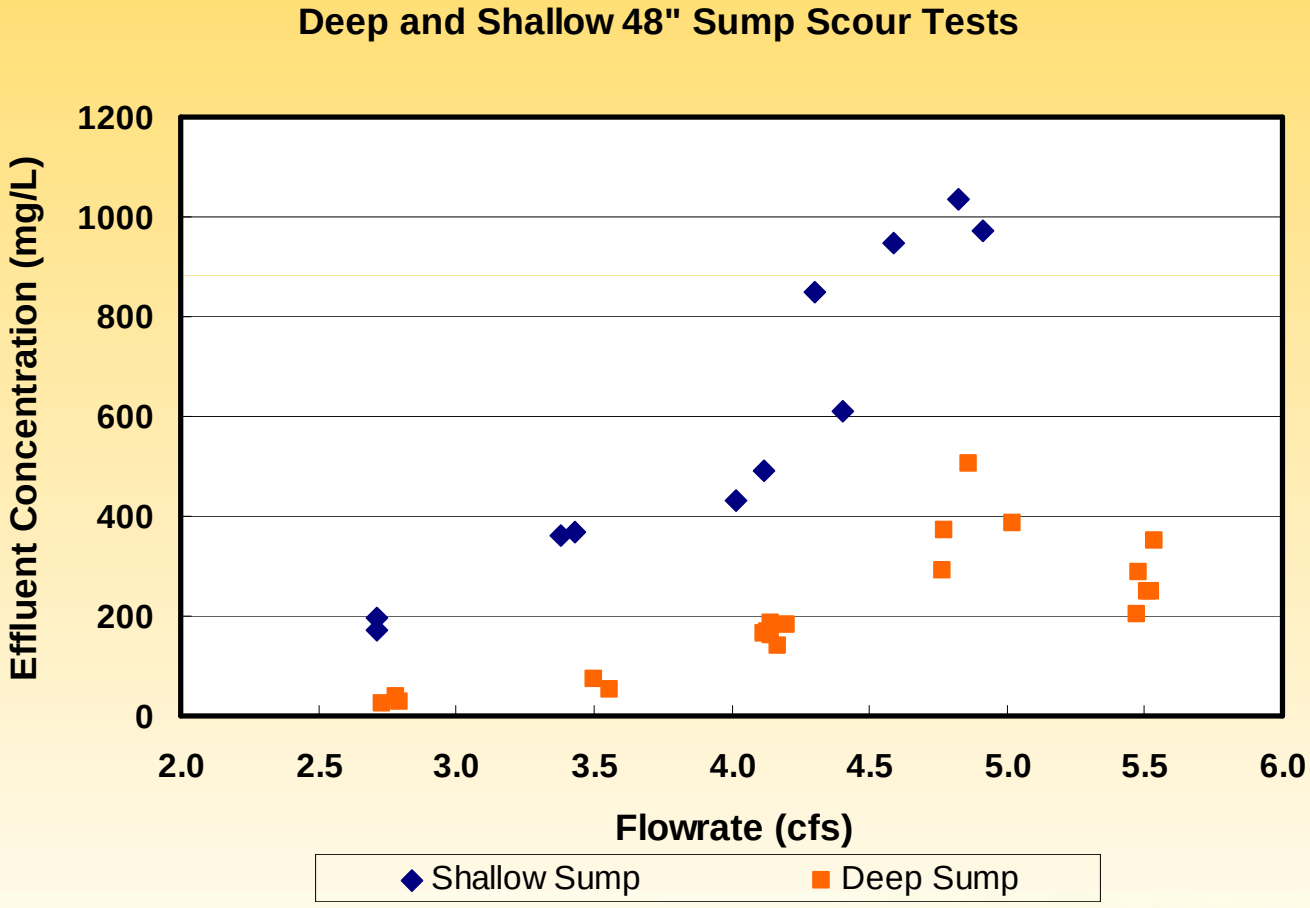
4’ Shallow Sump Performance



4’ Shallow Sump Retention

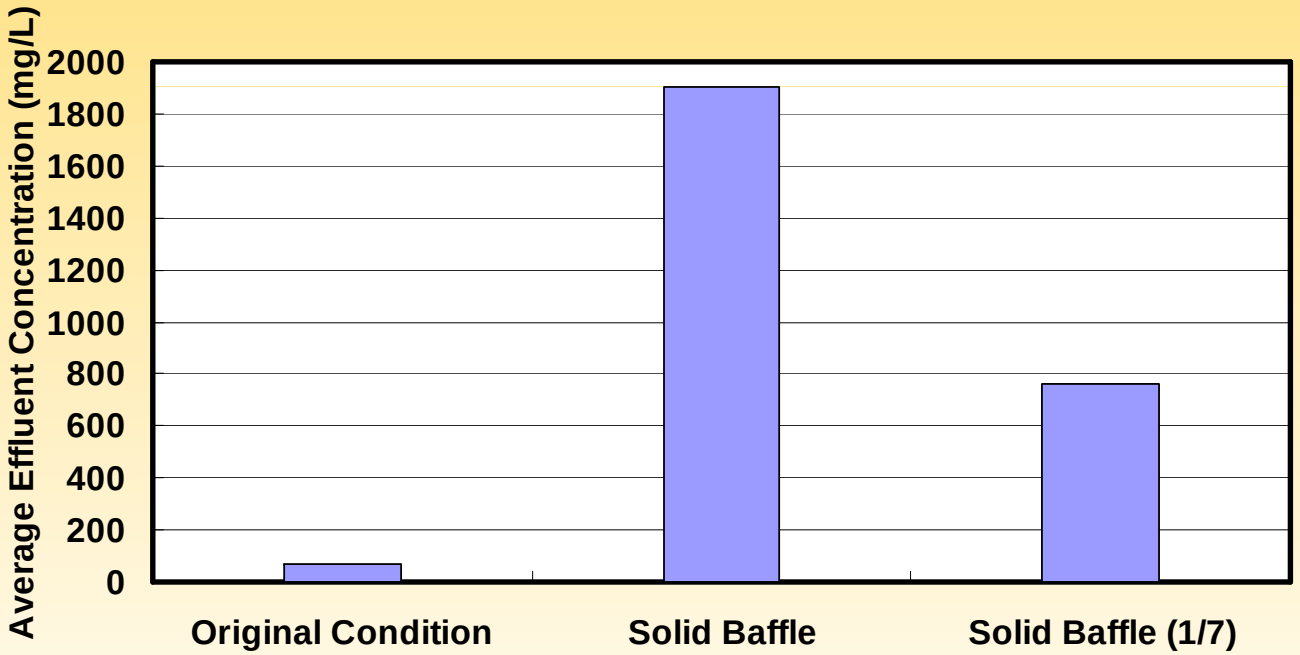
- Similar Sediment and Flowrates as Before
  - 2.8cfs to 5.0cfs
  - 1 foot of U.S. Silica F-110 pre-loaded
- Duration Decreased Due to Increased Scour
  - New variable if floor becomes exposed
  - Durations from 12 to 72 minutes

4’ Shallow Sump Retention



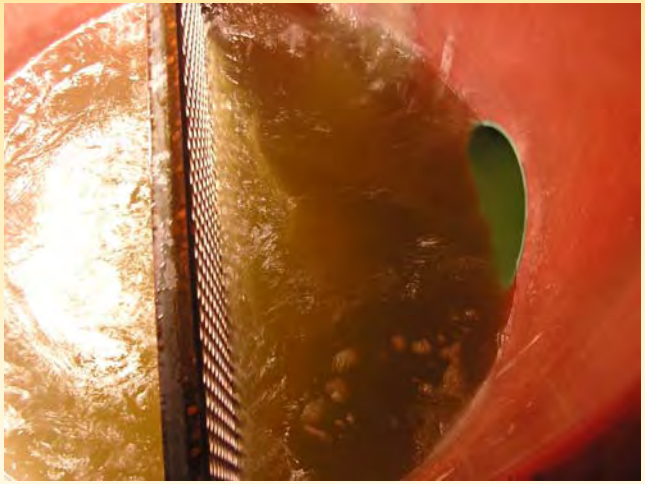
St. Anthony Falls Baffle Retrofit

- ¼ Scale Solid Baffle Testing

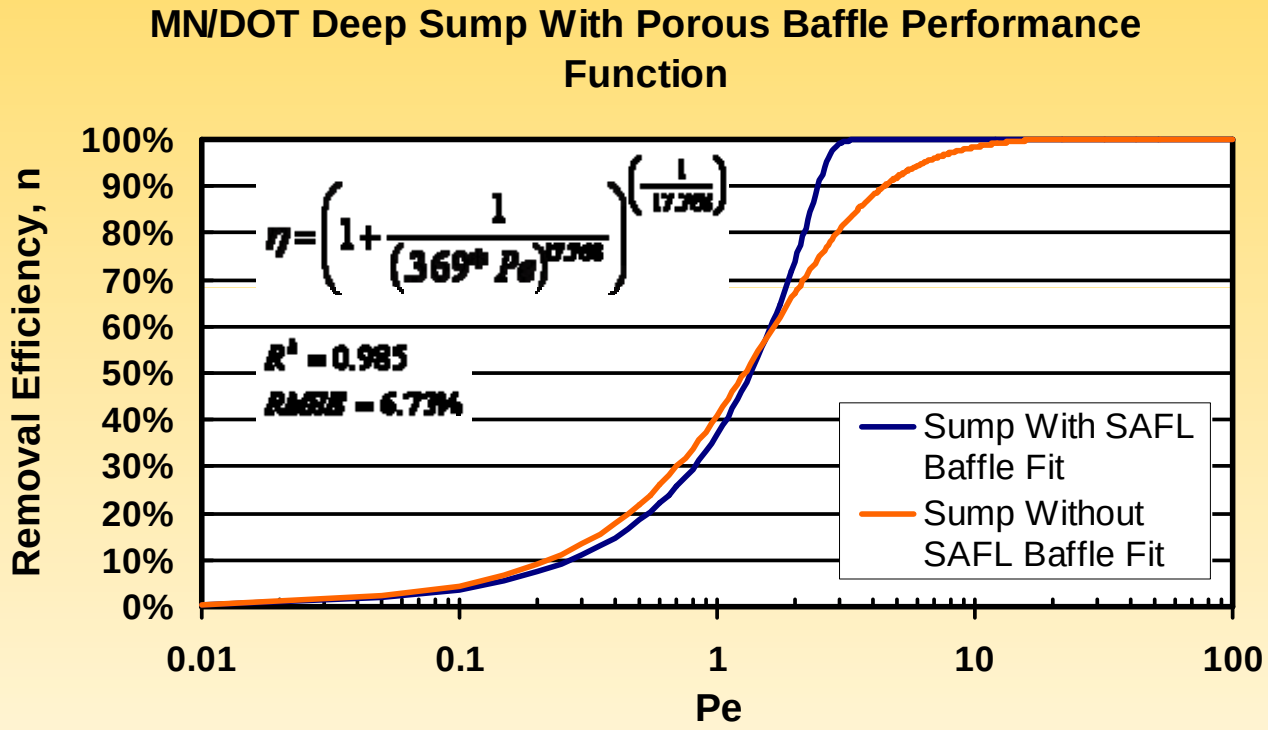


SAFL Baffle Retrofit

- ¼ Scale Porous Baffle Testing
  - Tested for various porosities and orientations
  - Tests involved both retention and performance
- Optimal Design Tested at Full Scale for Performance and Retention

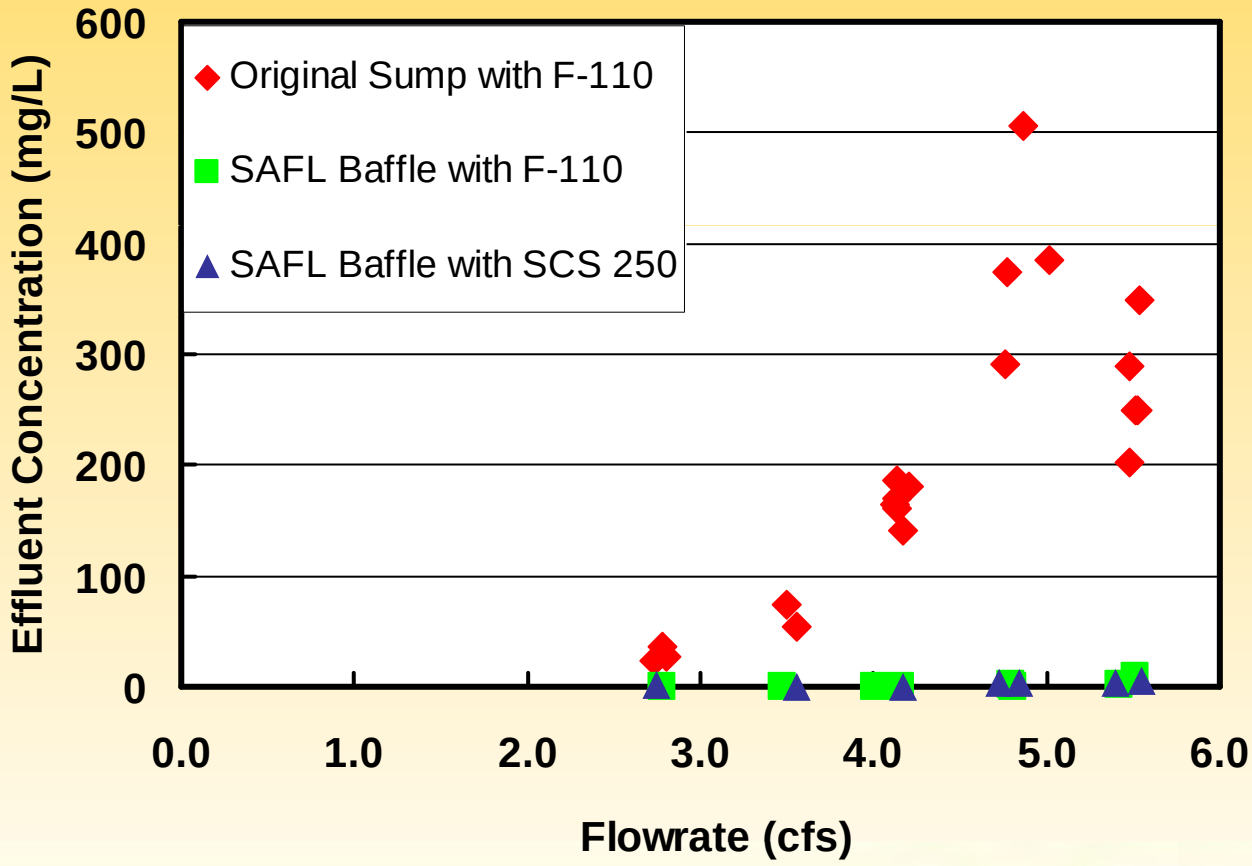


SAFL Baffle Retrofit



- Increased Performance Above Pe of 1.5
- Similar Performance as the Standard 4' Sump

SAFL Baffle Retrofit



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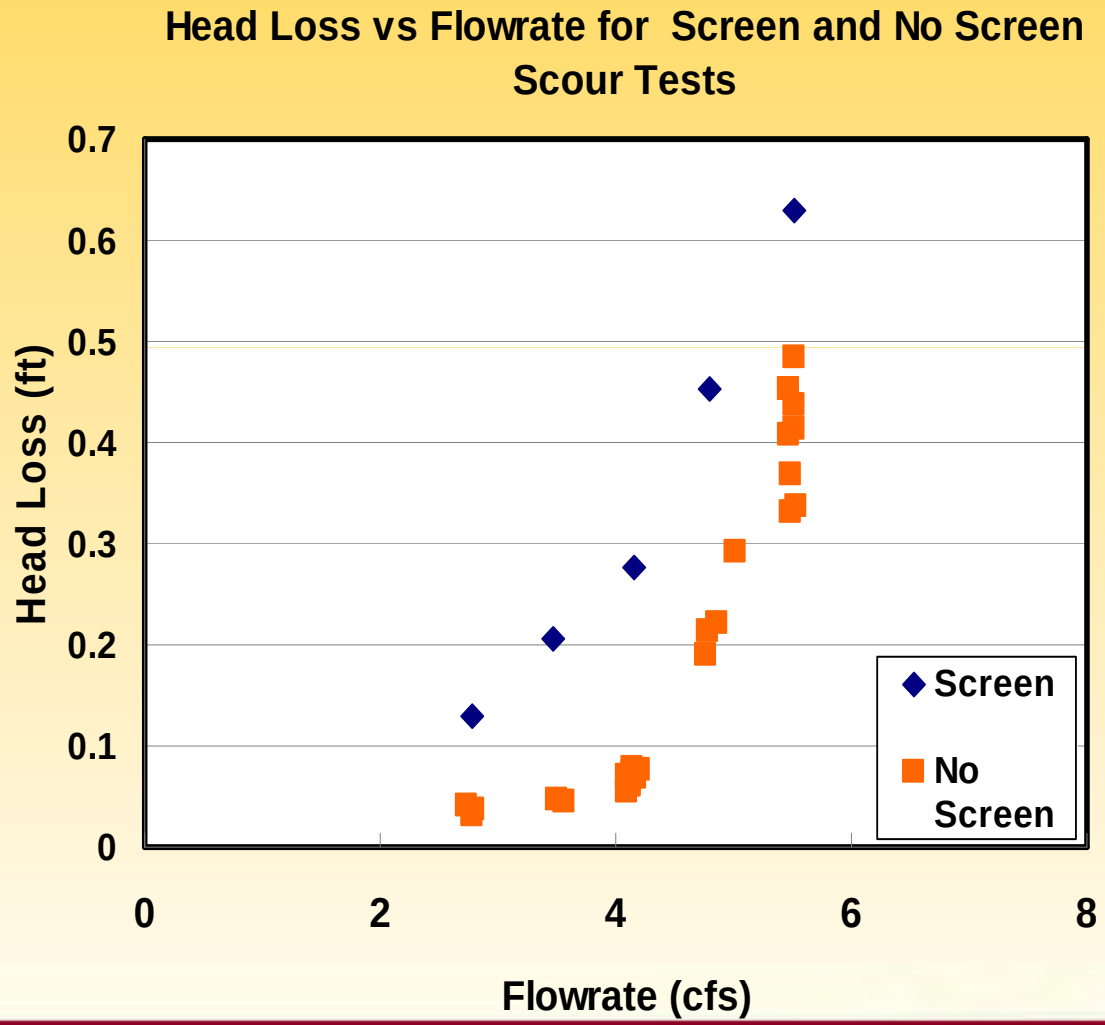

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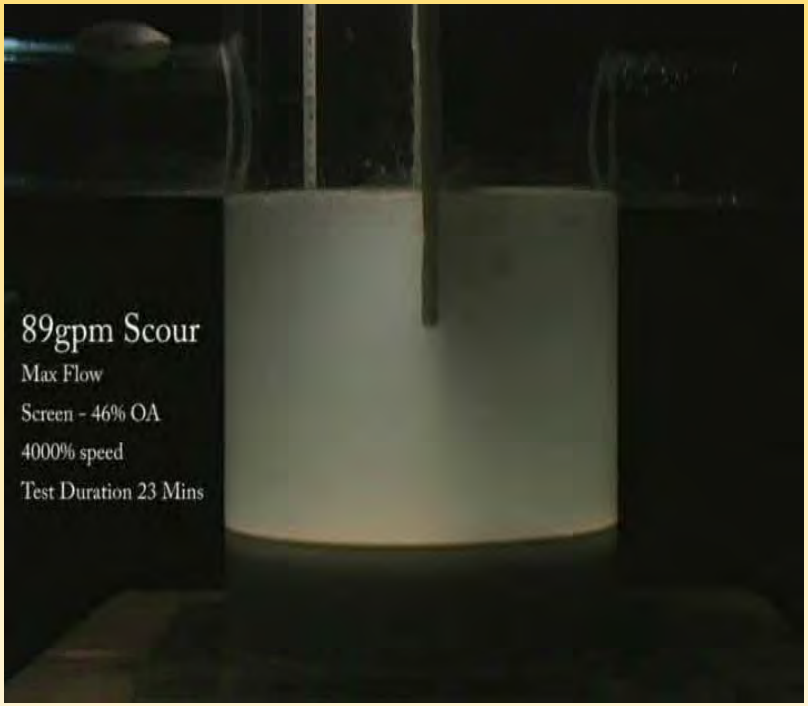

SAFL Baffle Retention Results

- Will Retain Any Particle Size Which Can Be Captured By The Sump
- Two Hour Duration
- Results Within Error of Load Cells
- Tested With Both F-110 (d50~ 110 *u*m) and SCS 250 (d50~ 45*u*m)

Conclusion

- Sump can be designed for particulate removal and provide pollution prevention credit
- High scour potential requires increased maintenance
- SAFL Baffle significantly improves performance at low flowrates
- SAFL Baffle nearly eliminates scour for any particle size which may be retained by the sump

Acknowledgements

- Funding provided by Minnesota Department of Transportation
- Andrew Fyten, Pat Brockamp, Matt Lueker, Ben Plante, Dave Saddoris, Kurt McIntire, Andrew Sander, and Teigan Gulliver from SAFL
- Julia Molony from the U of Mn Statistics Clinic

Questions?

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6’ by 6’ Experimental Setup

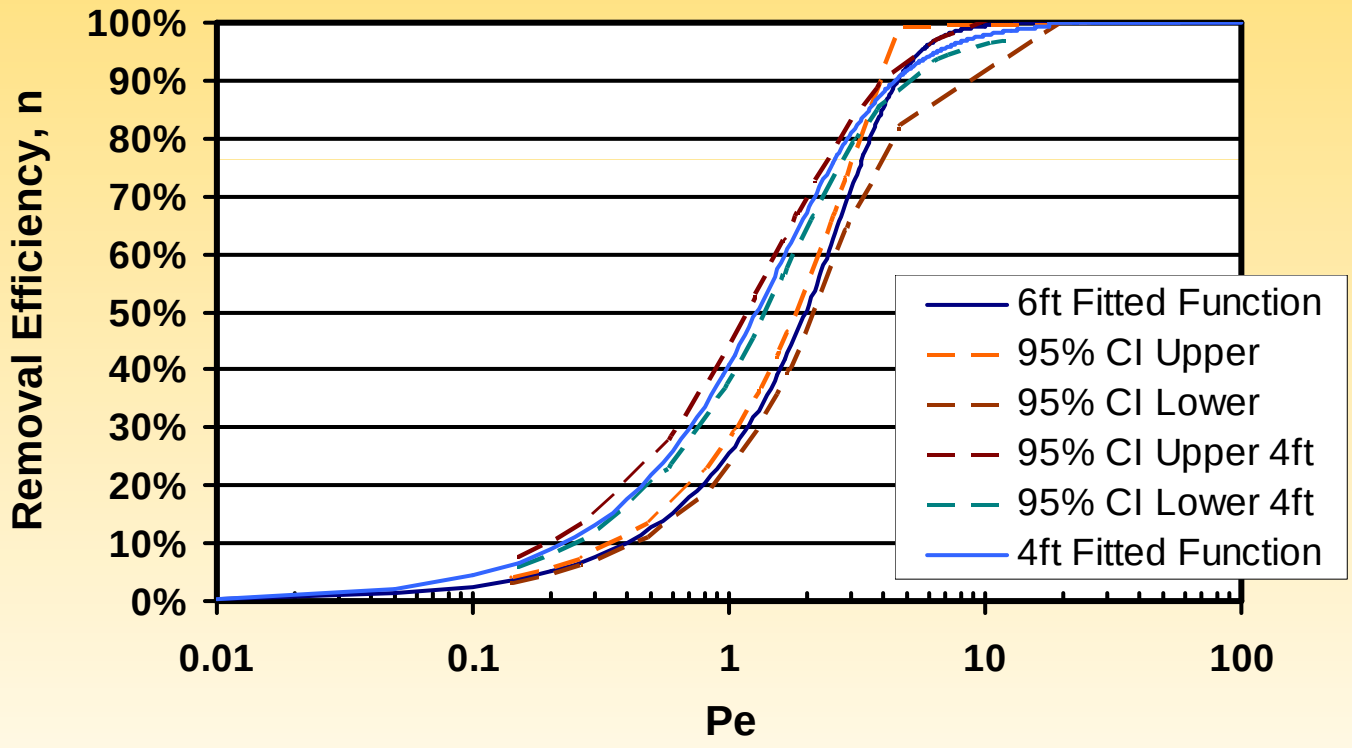
- 72 inch diameter sump with 72 inch depth below inlet invert
- Straight, unrestricted flow from inlet to outlet with 1% drop
- 24 inch diameter inlet and outlet pipes
- Connected to SAFL plumbing system by two 12 inch pipes from supply channel
- Flowrate measured using two pitot cylinders, one on each 12 inch supply pipe
- Mounted on four precision strain gauge load cells

4’ by 4’ Experimental Setup

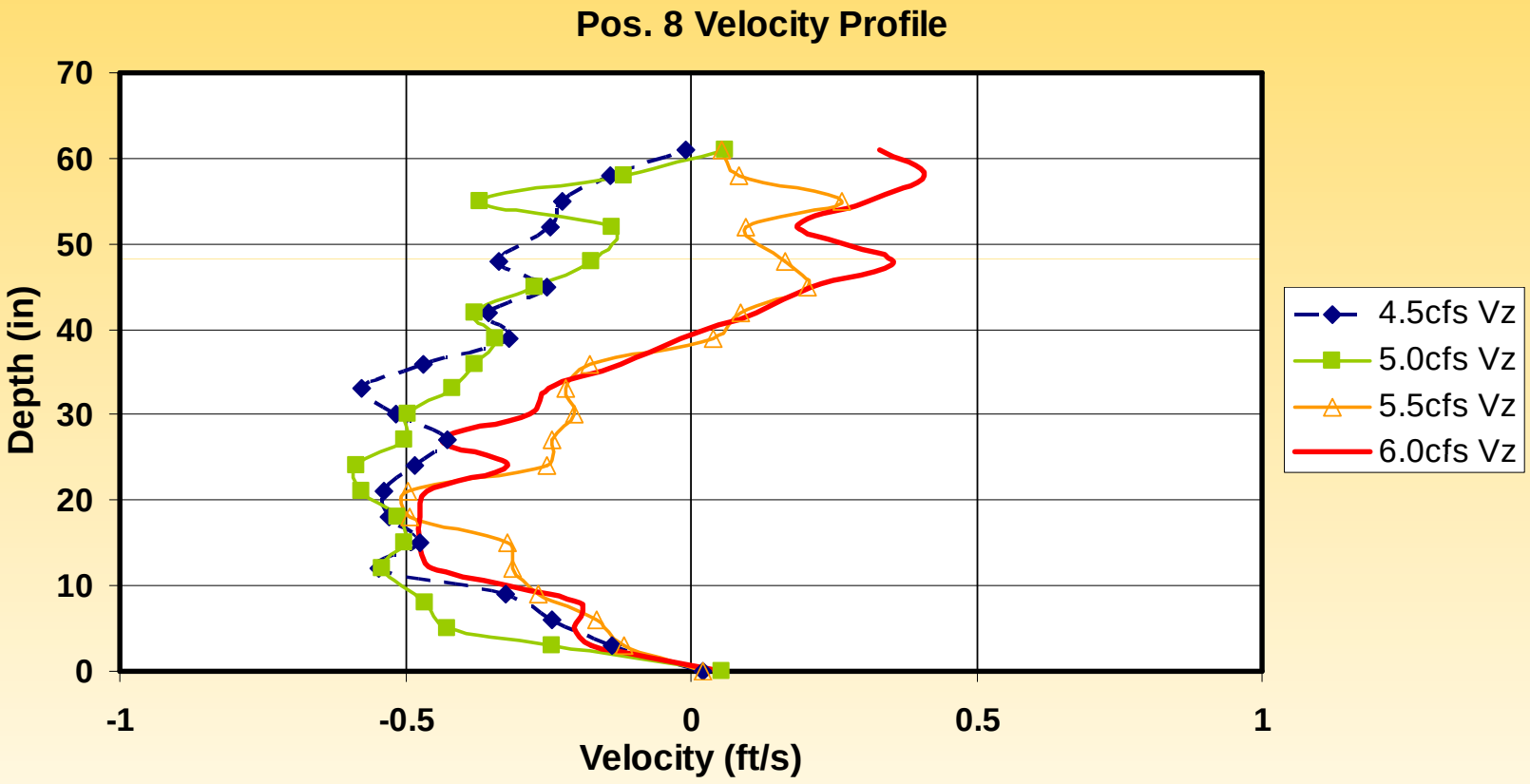
- 48 inch diameter sump with 48 inch depth below inlet invert, or 24 inch depth with false floor
- Straight, unrestricted flow from inlet to outlet with 1% drop
- 15 inch diameter inlet and outlet pipes
- Connected to SAFL plumbing system by one 12 inch pipe from supply channel
- Flowrate measured using pitot cylinder and circular weir
- Mounted on three precision strain gauge load cells

4’ x 4’ Performance Tests

MN/DOT 4ft and 6ft Sump Performance Function With Pointwise Confidence Intervals



4’ by 4’ Retention Tests



4'by 4' Retention Results

MN/DOT Deep Sump Scour Data

		Stick Measurements		Load Cells	
Test #	Flowrate (cfs)	Weight Removed (lb)	Effluent Conc. (mg/L)	Weight Removed (lb)	Effluent Conc. (mg/L)
9	2.8	39	31	33	27
10	2.8	62	50	46	37
11	2.7	33	27	29	24
18	4.1	NA	NA	299	161
19	4.2	NA	NA	342	181
20	4.2	258	138	265	141
21	4.1	NA	NA	314	169
22	4.1	NA	NA	346	186
23	4.1	251	135	306	165
25	5.5	NA	NA	617	249
26	5.5	NA	NA	496	202

SAFL Baffle Retention Results

Test #	Goal Flowrate (cfs)	Date	Weight Removed Adjust (lb)	Effluent Conc. (mg/L)
1	2.75	7/21/2009	-5	-4
2	3.5	7/22/2009	-5	-3
3	4.125	7/23/2009	-3	-2
4	4.8	7/23/2009	5	2
5	5.5	7/24/2009	21	9
6	5.5	7/28/2009	2	1
7	4.8	7/28/2009	0	0
8	4.1	7/29/2009	-4	-2
9	2.75	7/30/2009	2	2
10	3.5	7/30/2009	0	0
11	4.1	7/31/2009	-2	-1
12	4.8	7/31/2009	10	4
13	5.5	8/3/2009	9	4
14	4.8	8/3/2009	6	3
15	5.5	8/3/2009	15	6