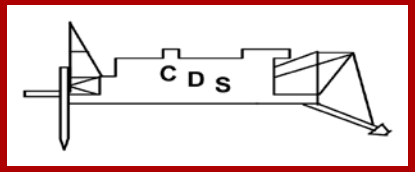
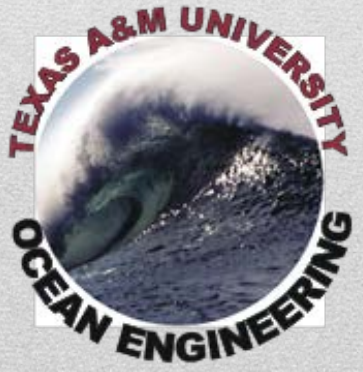


Experimental Measurement of a Model Pipeline Dredge Entrance Loss Coefficient

J. A. Girani and R. E. Randall

TEES Center for Dredging Studies

Texas A&M University



Acknowledgements

- John Reed, Laboratory Manager/Technician
- Yuanzhe “George” Zhi, Graduate Student
- Sara Clark, Keaton Savoie, Jake Triska, Colton Wylie; Haynes Lab Undergraduate Students

Overview

- Objectives
- Experimental methods
- Haynes Coastal Engineering Laboratory
- Experimental testing
- Data analysis
- Entrance loss of screen
- Conclusions and recommendations

Objectives

- Conduct experimental measurements to determine the minor loss coefficient (K) of the model cutter suction dredge intake screen
- Model effects according to specific gravity and velocity

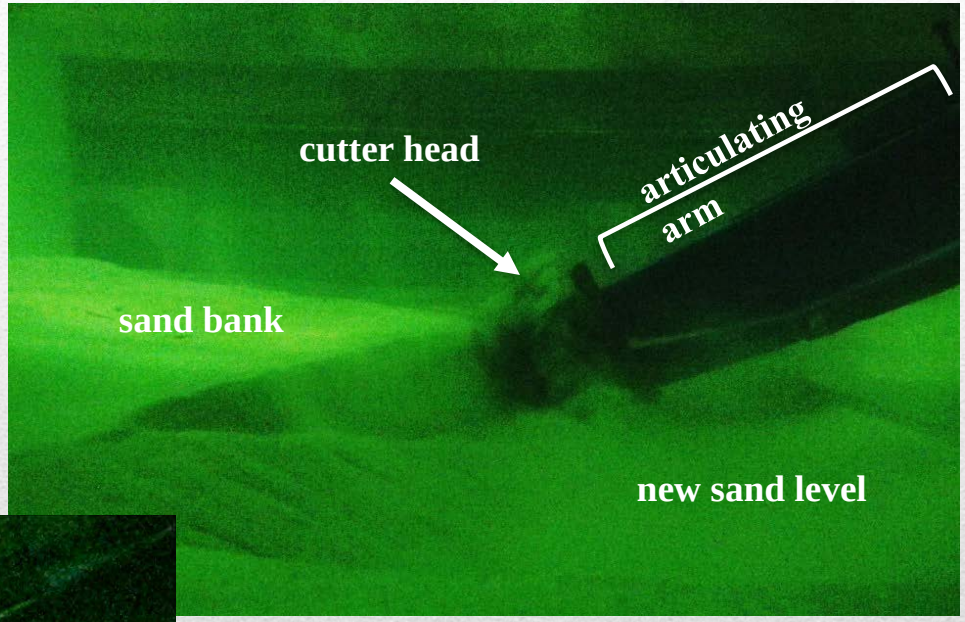
Energy Equation

- Energy equation for steady incompressible flow
  - Modified for slurry flow and applied to the suction line
  - Pressure changes are proportional to the square of the velocity
  - Pressure is proportional to specific gravity

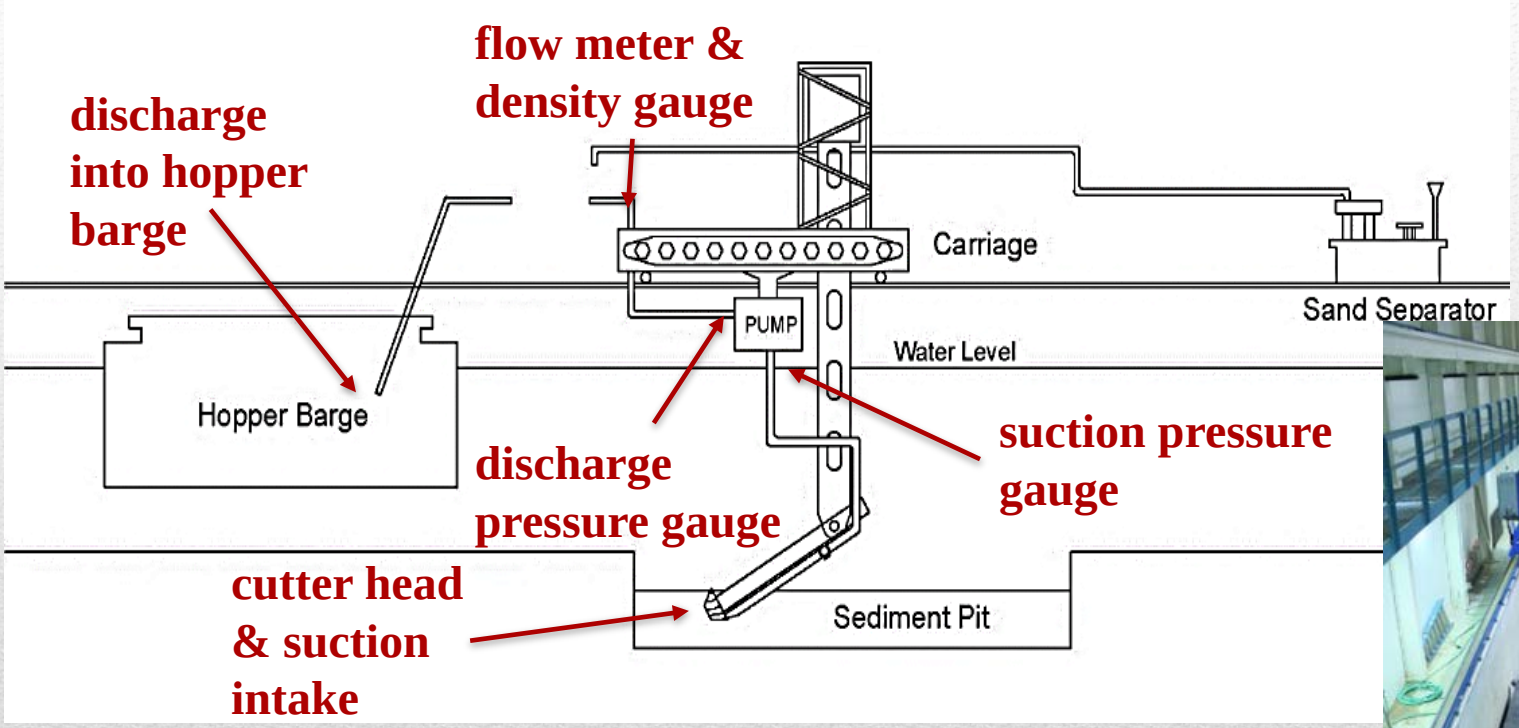
$$\frac{p_1}{\gamma_m} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma_m} + \frac{V_2^2}{2g} + z_2 - h_p + h_l$$

Model Cutter Suction Dredge

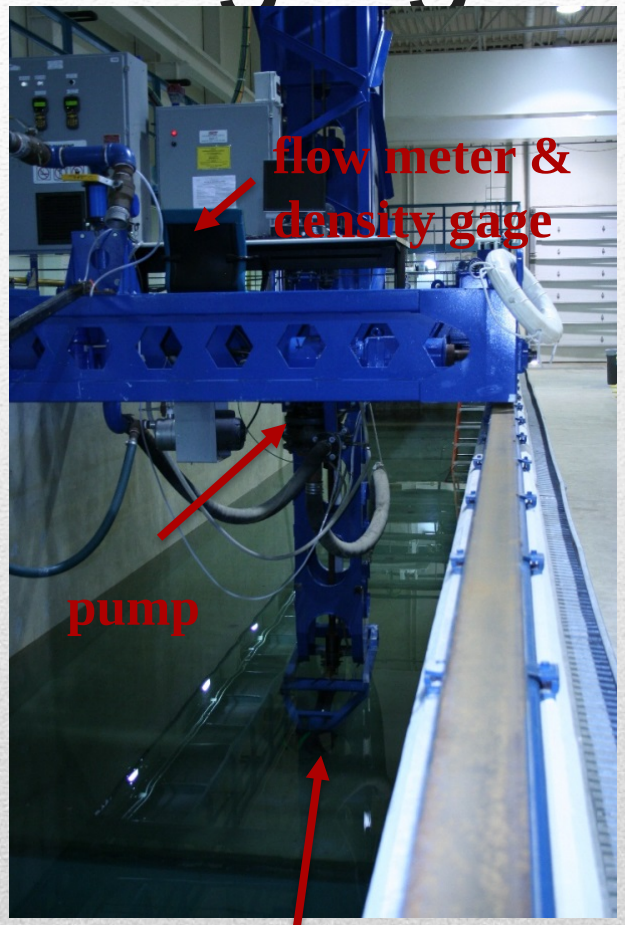
- Rotating cutter moves across top layer of sand
- Slurry moved through suction intake and into suction line
- Mixture passes through centrifugal pump and into discharge line
- Sediment discharges into the laboratory hopper barge

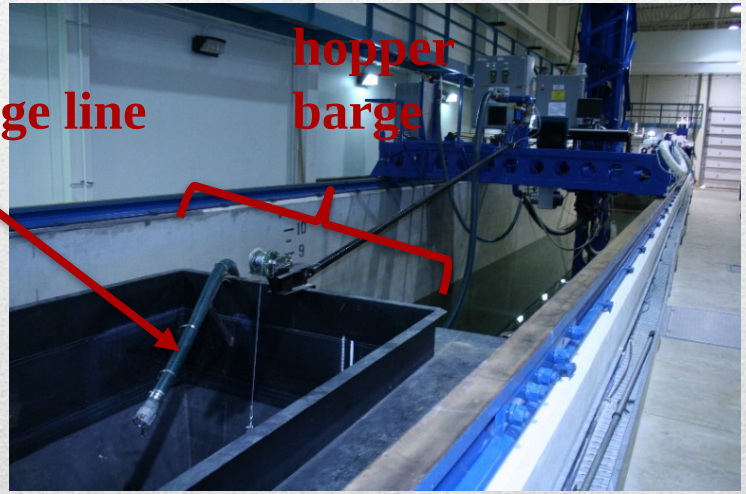


Laboratory System



Dredging Setup





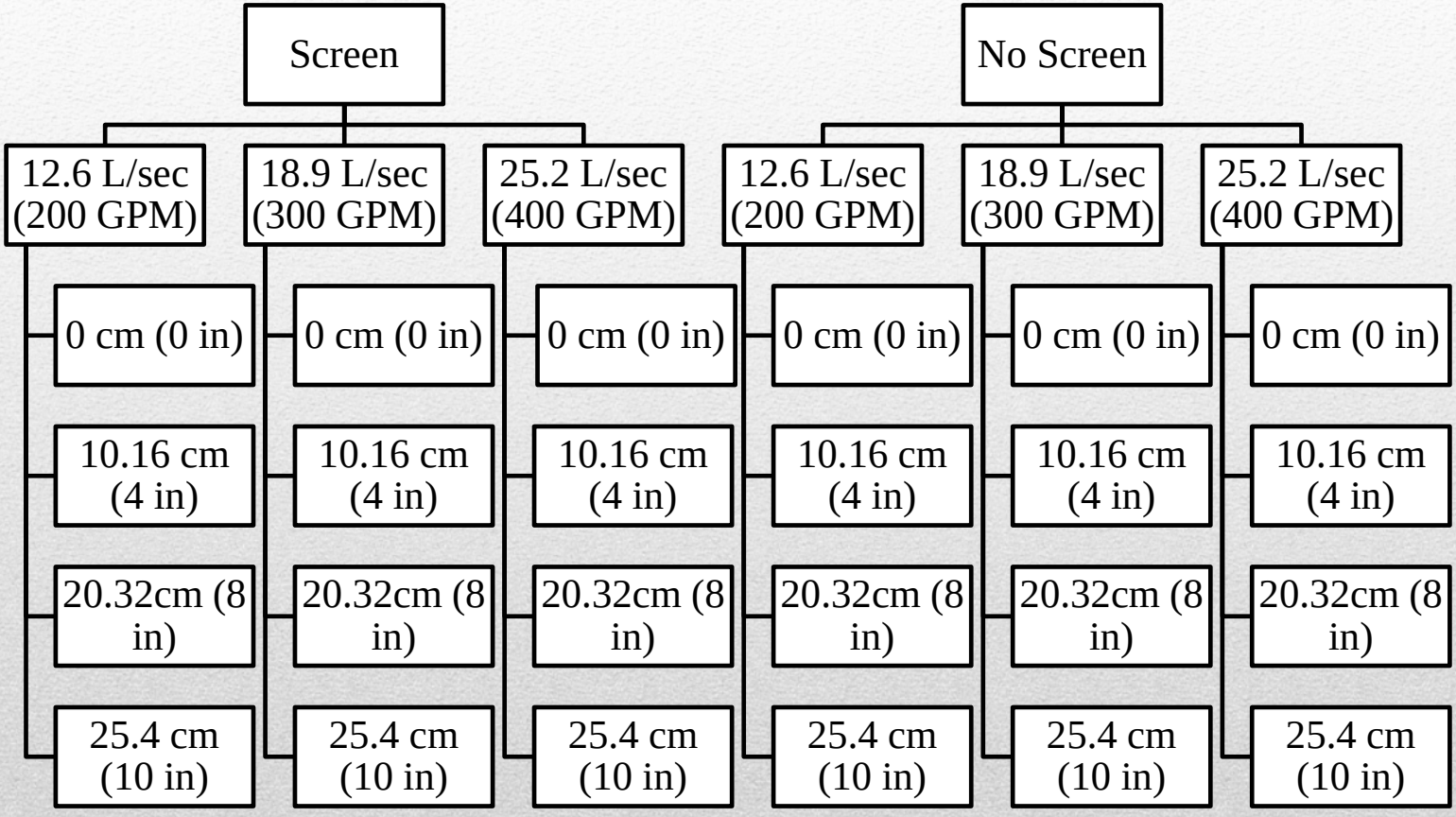
Dredging Configuration

- 12 in (0.3 m) laboratory model cutter
- 4 in (108 mm) suction line
  - Approximately a 1:10 model to prototype scale
- Suction intake can be outfitted with or without entrance screen
- Testing flow rates were 200, 300, and 400 GPM
- Specific gravities were between 1.0 and 1.2

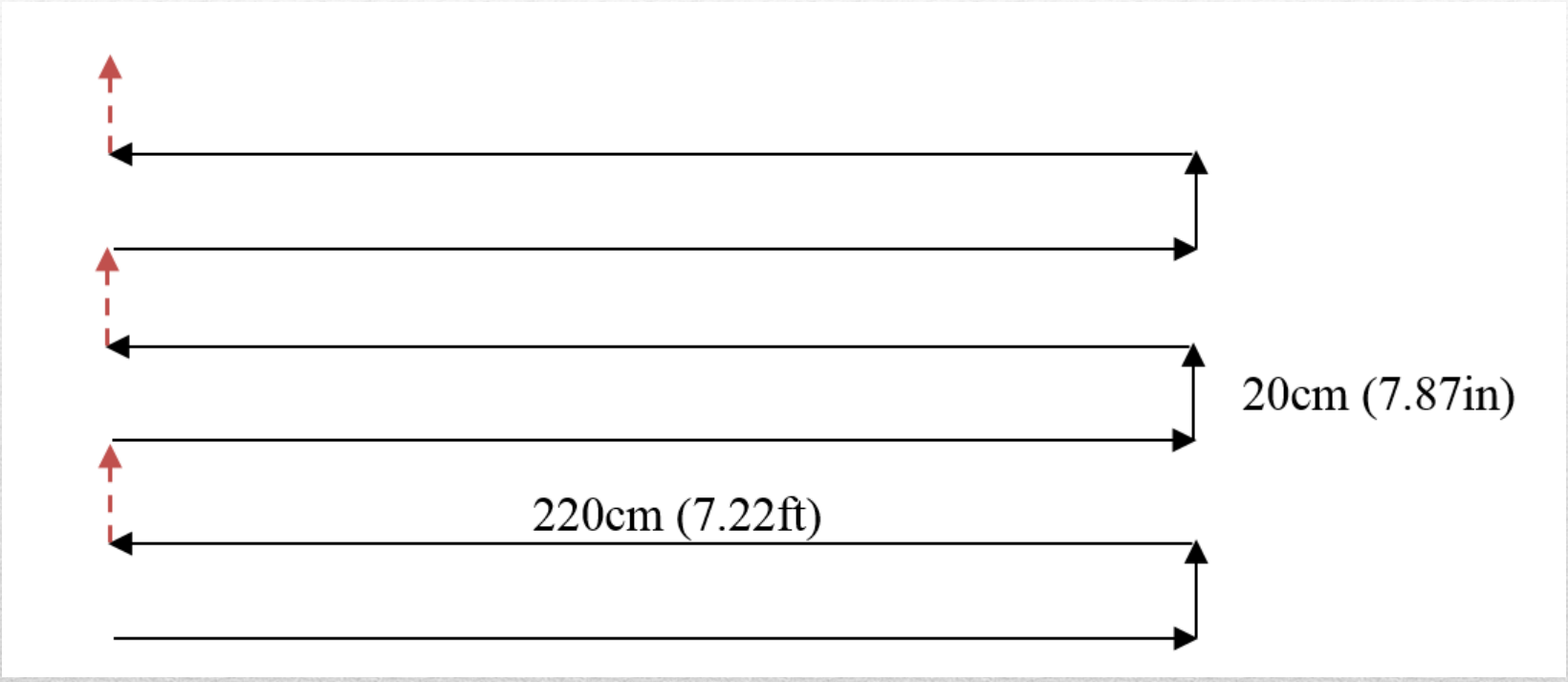
Laboratory Equipment

- Acquisition system utilizing Lookout Direct software
  - Controls x, y, and z coordinates and records specific data
    - Controller to drive system by hand
    - Automated dredge patterns using pre-programmed software
- Ohmart Vega DSG radiation based density meter
  - Accurate to 1% of the measurement span
- Two Rosemount Pressure Transmitters (Model 1151)
  - Located at the intake and discharge points of the centrifugal pump
  - Accuracy of 0.075% of the gauge range
- Krohne ICF 090 flow meter
  - Factory calibrated with maximum error of 0.3% of the measured value

Test Plan

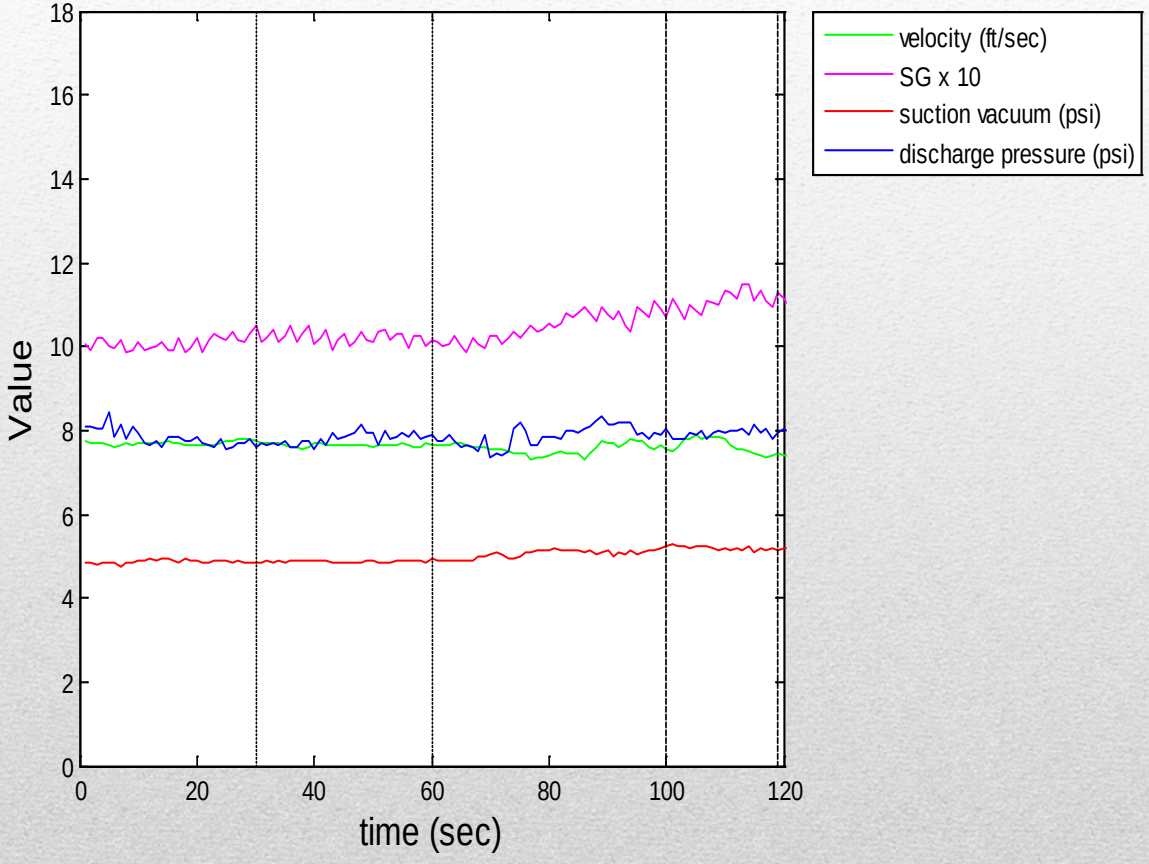

Screen
No Screen
12.6 L/sec (200 GPM)
18.9 L/sec (300 GPM)
25.2 L/sec (400 GPM)
12.6 L/sec (200 GPM)
18.9 L/sec (300 GPM)
25.2 L/sec (400 GPM)
0 cm (0 in)
10.16 cm (4 in)
20.32cm (8 in)
25.4 cm (10 in)

Dredge Path

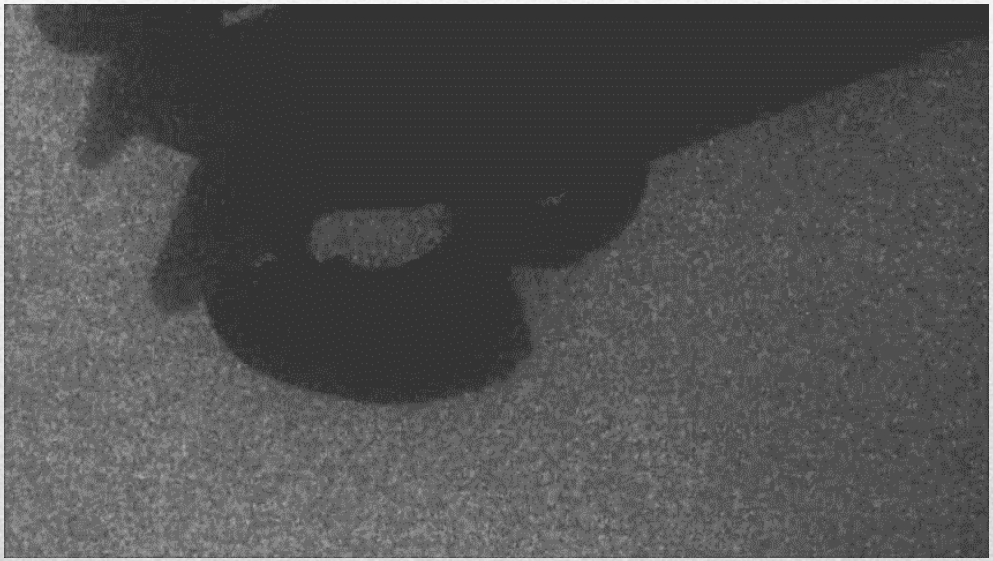


Data Review

- Test broken into segments
- Instantaneous head loss calculated for each test point (1 Hz) and averaged over analysis
- Tests separated into screen and no screen sets



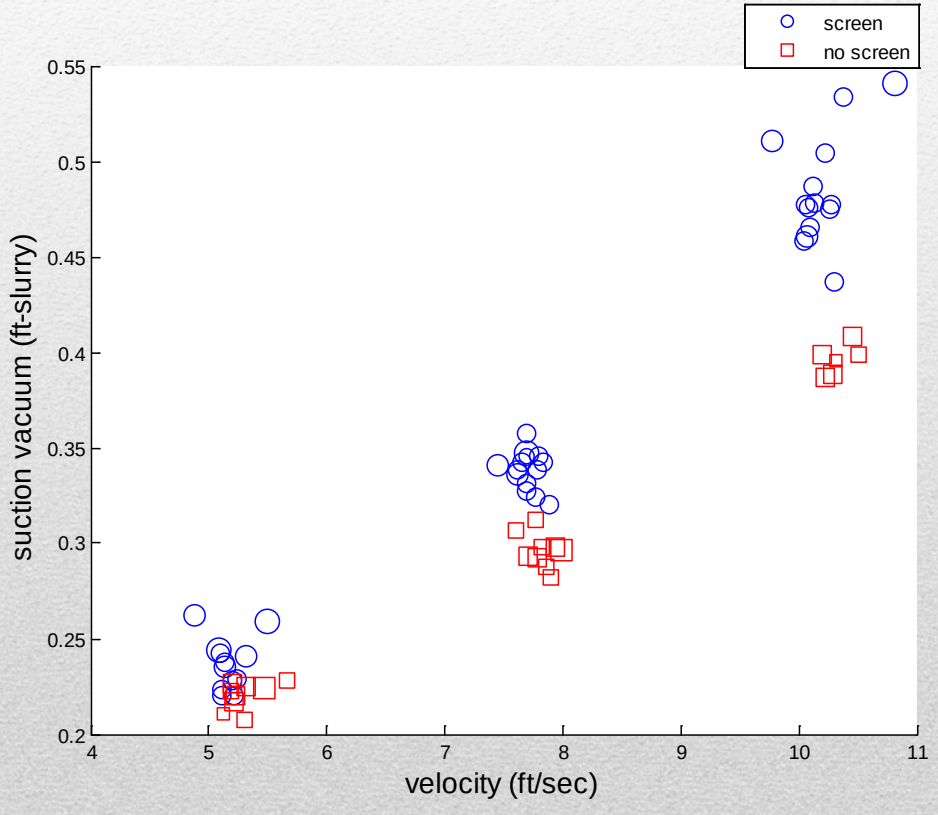
Screen Clogging

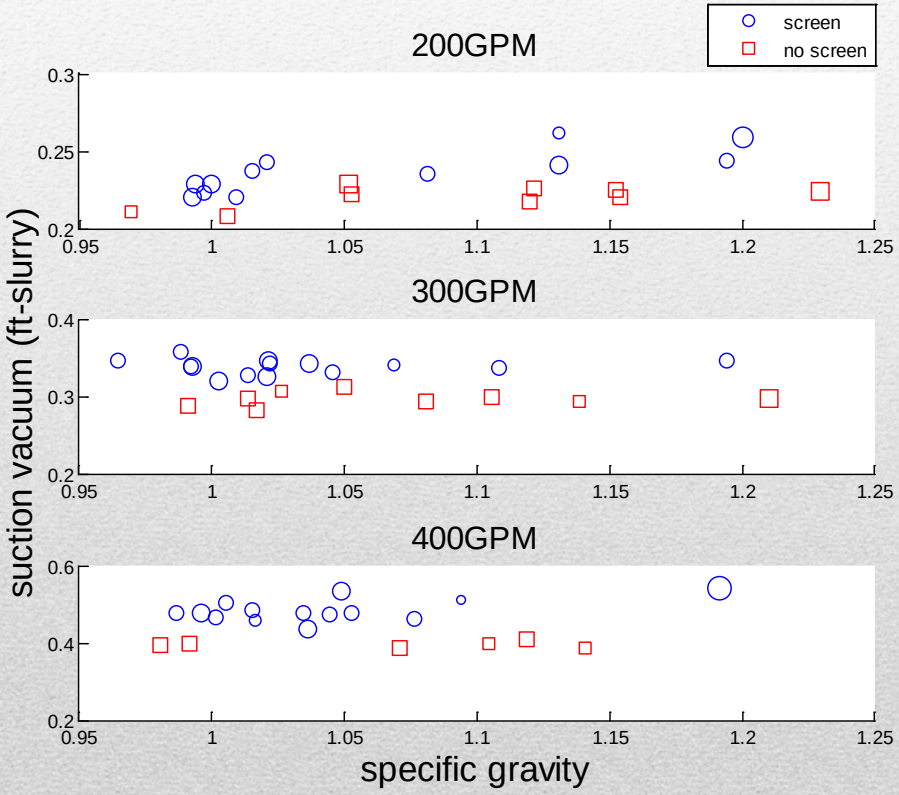


- If pressure began to rise due to clogging of the screen, data were disregarded
- It was found that sand & debris collected on the front of the screen and held in place by the intake flow
- To clear the sand & debris:
  - Flow rate reduced to a minimum value
  - Discharge ball valve was shut
  - Back pressure was created in suction line

Suction Pressure

$$P(ft-slurry) = \frac{P(psi) \cdot 144}{\gamma_{water} \cdot SG_{mixture}}$$





Data Analysis

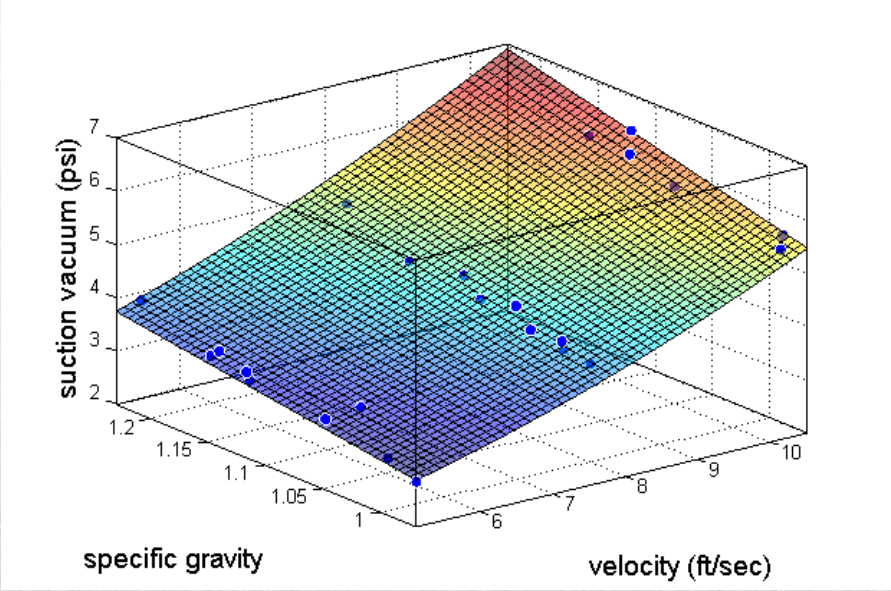
- Suction pressure data sets were fit using the MATLAB plane fit function
- Difference between the two data sets was attributed to the screen
- Head loss was calculated using:

$$h_{l_{screen}} = \frac{P_{suction_{screen}} - P_{suction_{no\ screen}}}{\gamma_{water} \cdot SG_{mixture}}$$

- Head loss value was multiplied by associated $\frac{2g}{V^2}$ to evaluate the minor loss coefficient (K)

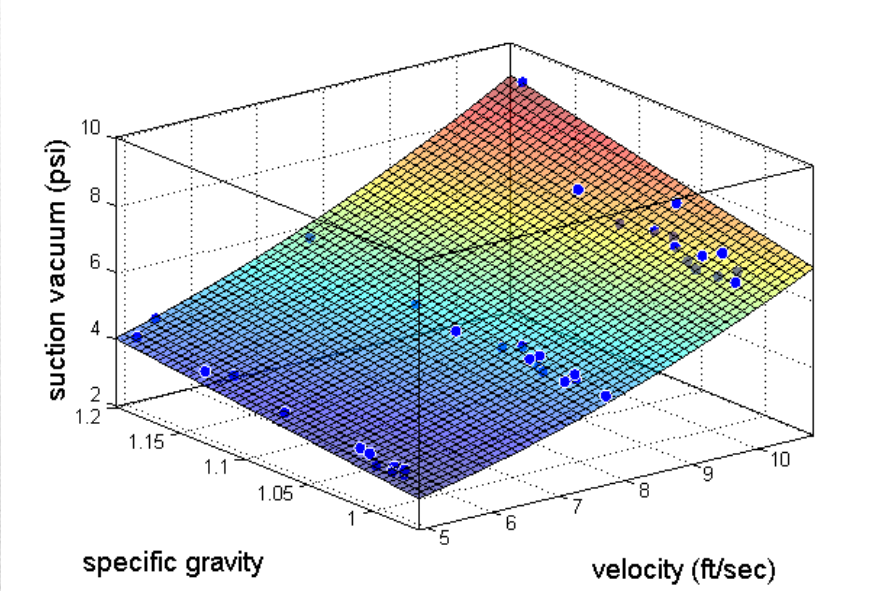
Plane Fit

No Screen



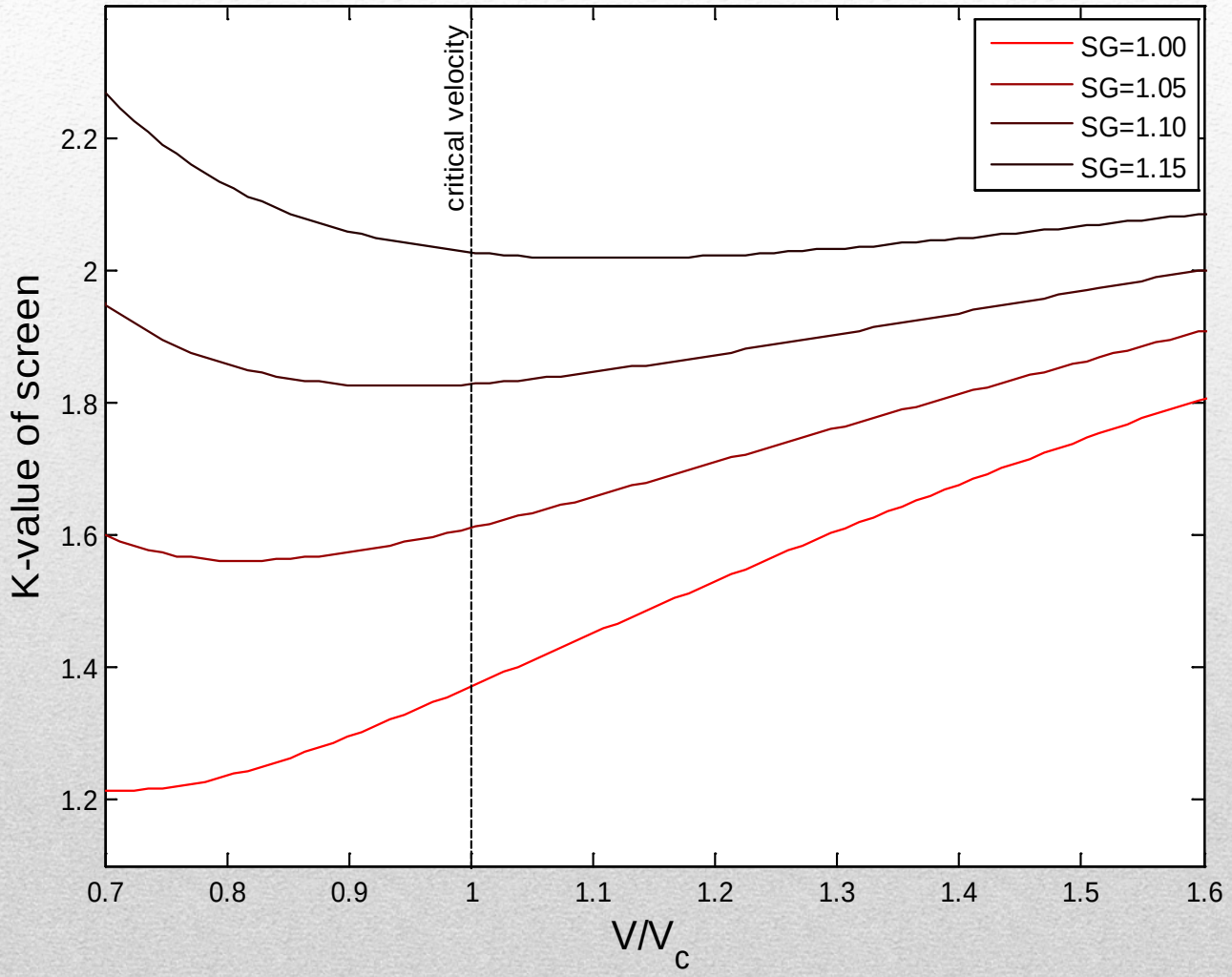
R^2=0.987

Screen



R^2=0.974

Screen Entrance Loss



Scaling

- Froude Scaling
- $Fr = \frac{u}{\sqrt{Dg}}$
- $\left(V_{swing}\right)_m = \left(V_{swing}\right)_p \left[\frac{(D_{cutter})_m}{(D_{cutter})_p}\right]^{\frac{1}{2}}$
- $(N_{cutter})_m = (N_{cutter})_p \left[\frac{(D_{cutter})_m}{(D_{cutter})_p}\right]^{\frac{1}{2}}$

- Critical Velocity
- $V_c = \frac{8.8\left[\frac{0.44\left(SG_S - SG_f\right)}{0.66}\right]^{0.55} D^{0.7} d_{50}^{1.75}}{d_{50}^2 + 0.11 D^{0.7}}$
- $\frac{Q_m}{Q_{cm}} = \frac{Q_p}{Q_{cp}}$

Scaling Results

Scaled Parameter	Model	Prototype
Screen Reduction in Area	65.1%	65.1%
Suction Line	10.16 cm (4 in)	101.6 cm (40 in)
Discharge Line	7.62 cm (3 in)	76.2 cm (30 in)
Sand Size (d_{50})	0.27 mm	0.27 mm
Cutter Speed	30 RPM	94.86 RPM
Swing Speed	4.06 cm/sec (1.6 in/sec)	14.2 cm/sec (5.06 in/sec)
Flow rate (suction velocity)	12.6 L/sec or 1.56 m/sec (200 GPM or 5.11 ft/sec)	3,271 L/sec or 4.04 m/sec (51,850 GPM or 13.25 ft/sec)
	18.9 L/sec or 2.33 m/sec (300 GPM or 7.65 ft/sec)	4,907 L/sec or 6.03 m/sec (77,780 GPM or 19.78 ft/sec)
	25.2 L/sec or 3.11 m/sec (400 GPM or 10.21 ft/sec)	6,543 L/sec or 8.05 m/sec (103,700 GPM or 26.40 ft/sec)

Conclusions

- A screen placed over the suction intake of a dredge has a minor loss coefficient varying with both velocity and specific gravity
- At higher specific gravities the loss increases greatly as the velocity falls further below that of the critical velocity ranging from 1.2 to 2.3
- At the critical velocity the minor loss coefficient varies between 1.4 and 2.1
- Above the critical velocity
  - With increasing specific gravity, the slope of the line decreases and showing the least variation at one and a half times the critical velocity, between 1.8 and 2.1
- The intake geometry, rotating cutter head, and motion of the carriage induced changes in the minor loss coefficient even at the specific gravity of water
- Sand and debris clogging the front of the screen can only be cleared when a back pressure is created in the laboratory

Recommended Future Research

- Test different screen configurations for performance and losses
- Investigate the relationship between sand size and screen opening size
- Experimentally determine losses of the intake without the cutter head as a function of specific gravity
- Measure changes in head loss relative to the cutter head rotation speed and swing velocity

Thank You!

Questions?