POST-DREDGING RESIDUAL SEDIMENT STABILIZATION

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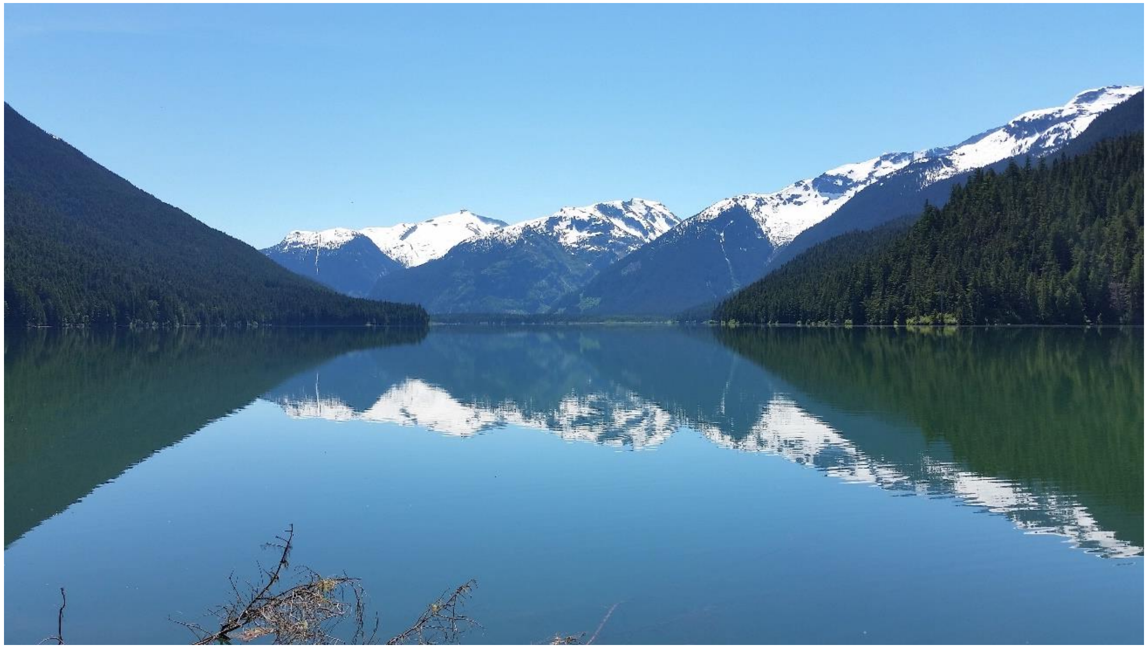
Looking for Bears in BC



Cheatamus Lake

Beautiful BC Backcountry

Garibaldi Lake

Rainbow Falls

Generated Residuals

- Remain after dredging (Bridges, et al 2008)
  - Palermo and Patmont (2007) show from 1.7 to 8.7% for some projects
- Physical characteristics (Palermo and Patmont, 2007)
  - Modified sediment structure
  - High moisture content (50% to 250%)
  - Very unstable state
  - <u>Probably</u> weighted toward fines and organics
- Contaminant characteristics depend upon source, which we do not fully understand.
- This "diluted" state increases their susceptibility to transport.

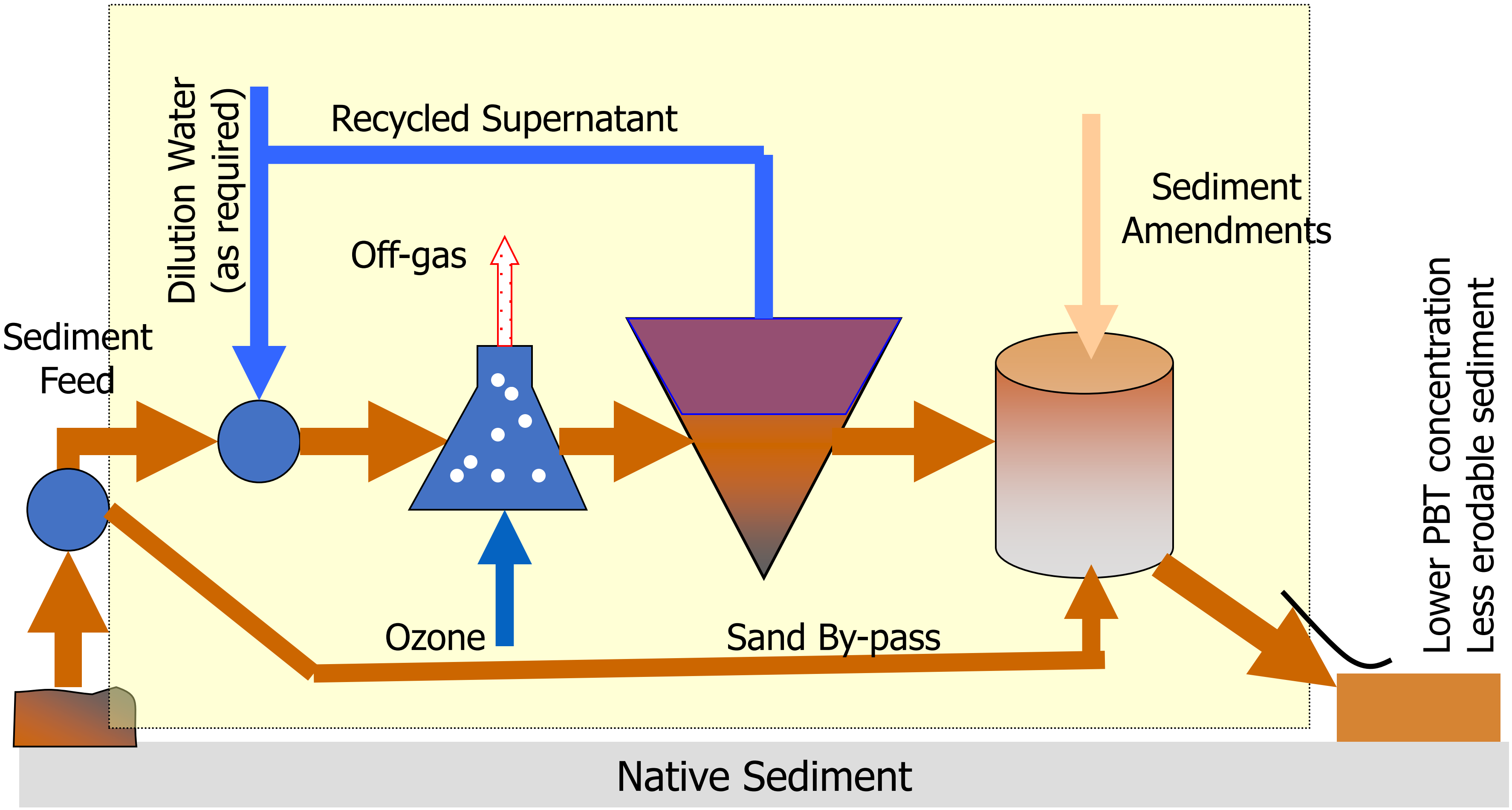
Overview

- Hypothesis
  - Resuspension and transport of post-dredging “generated” residuals contribute significantly to suspended sediment and contaminant transport from dredging operations
- Potential Solution
  - Rapid stabilization of generated residuals could potentially reduce sediment and contaminant loss
- Information Needed
  - Data demonstrating the increased susceptibility of generated residuals to transport
  - Data showing the ability of various stabilization materials to increase stability
  - Testing to evaluate alternative placement approaches

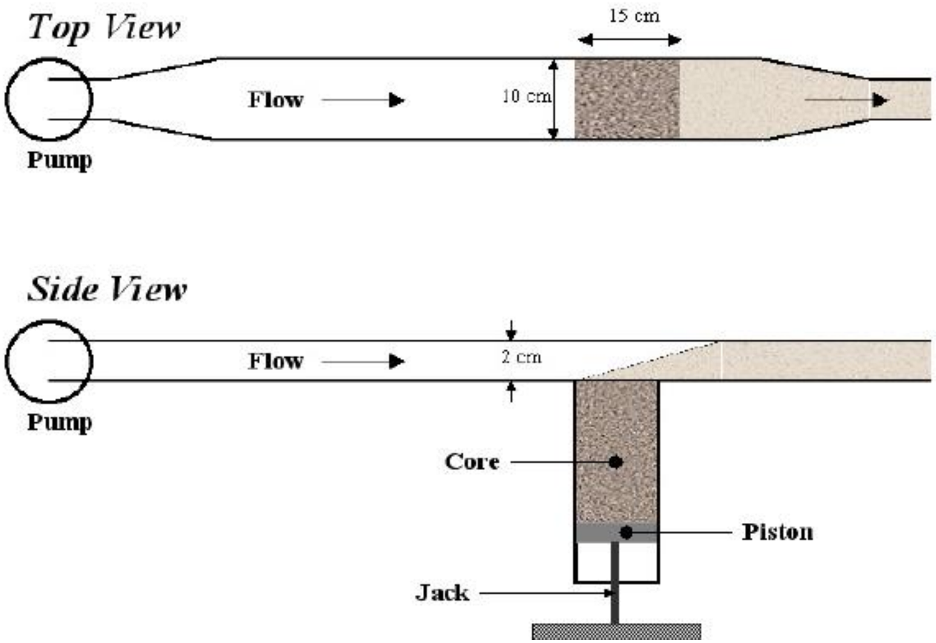
Repurposed Data

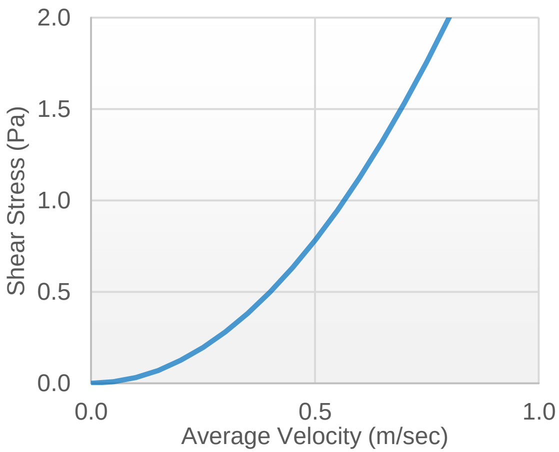
- Prior studies on In Situ Sediment Treatment System
  - US Patent Number 7115203
- Concept
  - “Slice” top sediment layer from bottom, treat and amend (as necessary), stabilize, replace as stabilized layer
  - Effective treatment required dilution of sediment to a liquid
  - Time required to return sediment to a “thickened phase” too long for practical application
  - Potential application as stabilization system (sans treatment)
  - Ben Starr (2007) conducted studies on:
    - Possible amendments and their effectiveness at increasing stability
    - Utilized SedFlume to measure erodibility and critical shear stress

Treatment Scheme

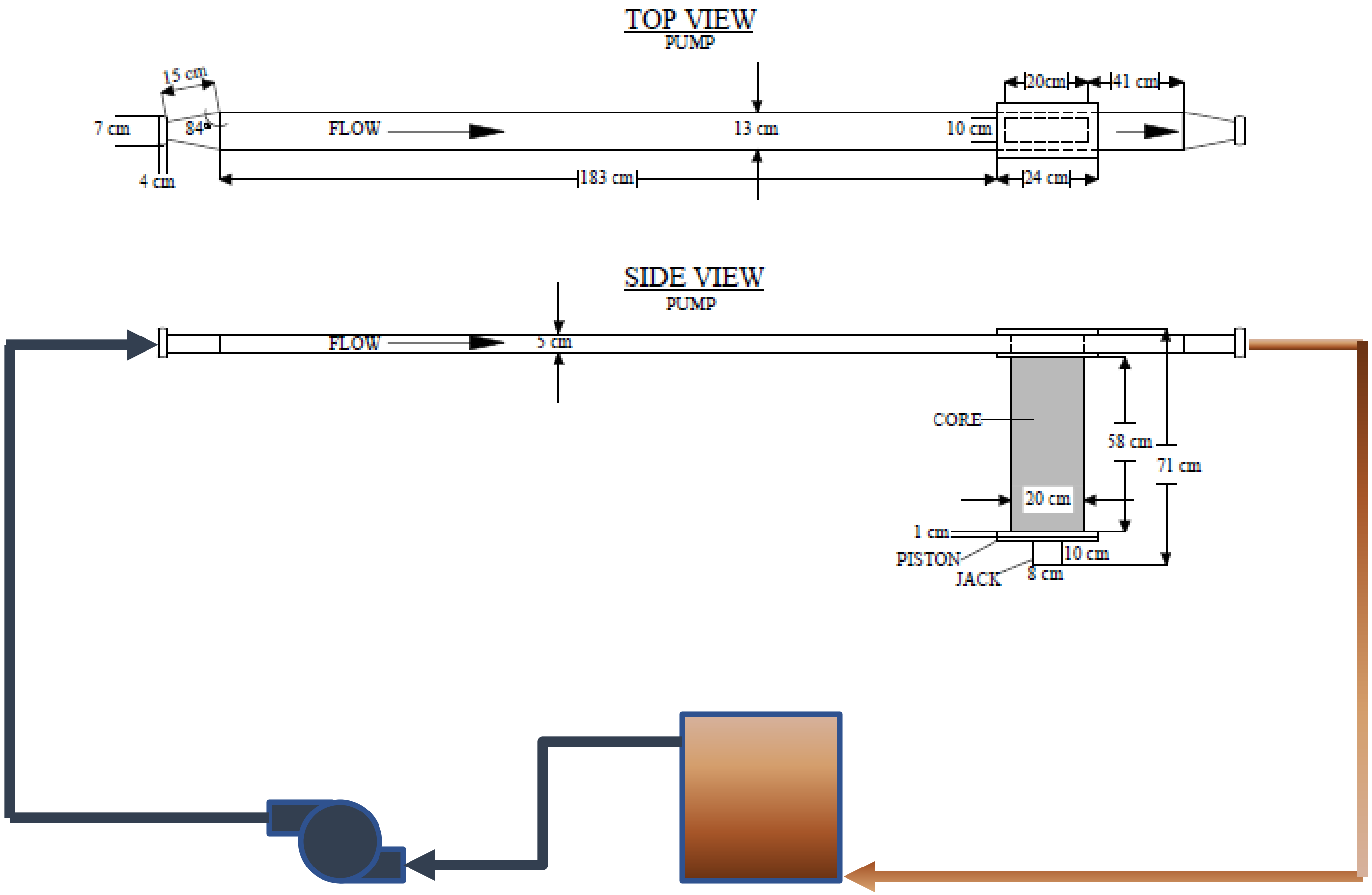


Erosion Measurement - SedFlume





Sediment Erodibility Testing



Erodibility of Tested Sediment at 0.6 Pa

Sediment Density		Erosion Rate (cm/min)
Dry Solids (%)	**Moisture Content (%)**	
20	400	Immeasurably High*
30	233	Immeasurably High*
40	150	Immeasurably High*
50	100	Immeasurably High*
60	67	0.2
***> 1 cm/sec**		

Sediment Amendments

- Started with sediment at ω = 400% (20% solids w/w)
  - Approximately the transition concentration between settling and thickening
- **Completely mixed** sediment with commonly available additives
  - Bentonite, Kaolinite, Lime, Sand
  - Combinations of above
- Additives ranged from 25% to 300% of initial dry solids mass
- Atterberg limits determined for SOME samples

Erosion rates (cm/min) at 0.60 Pa Shear Stress (from Starr, 2007)

Initial Density (g/cm³)	Final Density (g/cm³)	Add. (%)	Dry Mixture Additive Composition						
			Sand	Bentonite	Kaolinite	1S:1B*	1S:1K**	Lime	1S:1L***
0.23	0.30	25		2.0		H			
0.23	0.37	50	H	0.24	H	0.16	H	H	H
0.23	0.45	75		0.16		L			
0.23	0.53	100	H	L	H	L	H	0.15	0.10
0.23	0.73	300	H	L	0.18	L	0.16	H	L
0.23	0.96	200	H	-	L		L	L	L
0.23	1.24	250	H	L	L	L	L		
0.37	0.73	67	H	L	0.22	L	0.22		
0.37	0.96	100						0.40	
0.37	1.24	130	H	L	L	L	L		
0.53	0.73	50	H	L	0.58	L	0.65		
0.53	1.24	75	H	L	L	L	L	0.025	
0.73	1.24	40	H	L	L	L	L		
0.96	1.24	17	H	L	L	L	L		

Notes:

H = high erosion rate too high to measures (> 1 cm/sec)
L = immeasurably low erosion rate
***1S:1B = dry additive was equal parts sand and bentonite**
****1S:1K = dry additive was equal parts sand and kaolinite**
*****1S:1L = dry additive was equal parts sand and Lime**

Incipient shear stresses, τ (Pa), and associated velocities, U (m/sec),(from Starr, 2007).

Initial Density (g/cm³)	Final Density (g/cm³)	Add. (%)	Dry Mixture Additive Composition							
				Sand	Bentonite	Kaolinite	1S:1B*	1S:1K**	Lime	1S:1L***
0.23	0.30	25	τ (Pa)	-	H	-	H	-	H	H
			U (m/s)							
0.23	0.37	50	τ (Pa)	-	0.36	H	0.36	-	0.11	0.05
			U (m/s)		0.34		0.34		0.17	0.11
0.23	0.45	75	τ (Pa)	-	0.47	-	0.47	-	-	-
			U (m/s)		0.40		0.40			
0.23	0.53	100	τ (Pa)	-	-	0.11	-	-	0.36	L
			U (m/s)			0.17			0.34	
0.23	0.73	150	τ (Pa)	-	-	0.47	-	-	-	-
			U (m/s)			0.40				
0.23	0.96	250	τ (Pa)	-	-	L	-	-	-	-
			U (m/s)							

Notes:

H = erosion observed at flows too low to measure

L = No erosion observed at highest flowrate

***1S:1B = dry additive was equal parts sand and bentonite**

****1S:1K = dry additive was equal parts sand and kaolinite**

*****1S:1L = dry additive was equal parts sand and Lime**

Erodibility and Sediment Characteristics

- Liquidity Index aggregates in situ density with many complex sediment characteristics

$$LI = \frac{(\omega - LL)}{(LL - PL)}$$

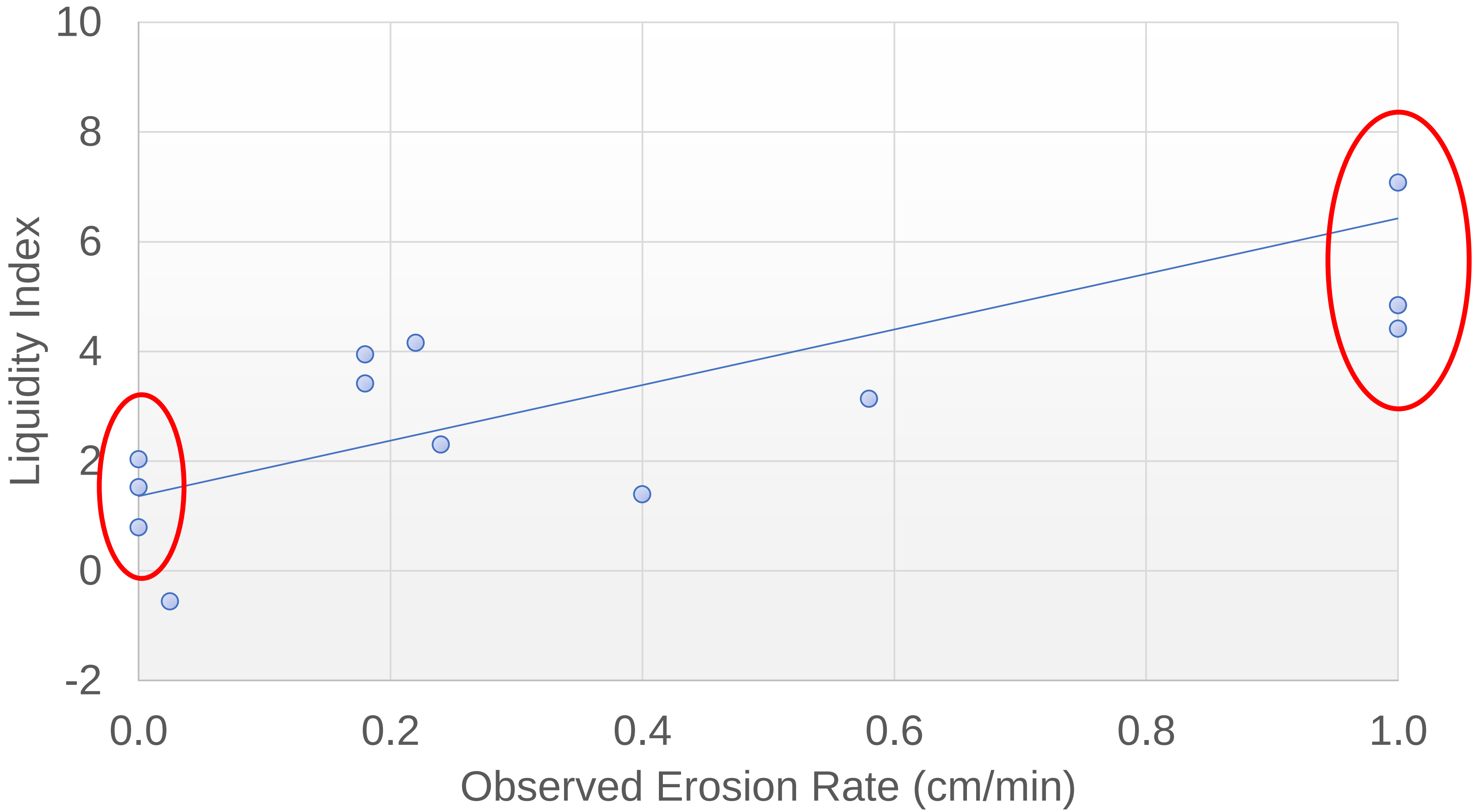
- Moisture Content (ω)
- Atterberg Limits
  - Liquid Limit (LL)
  - Plastic Limit (PL)
  - Plasticity Index (PI)

Erosion vs. Liquidity Index

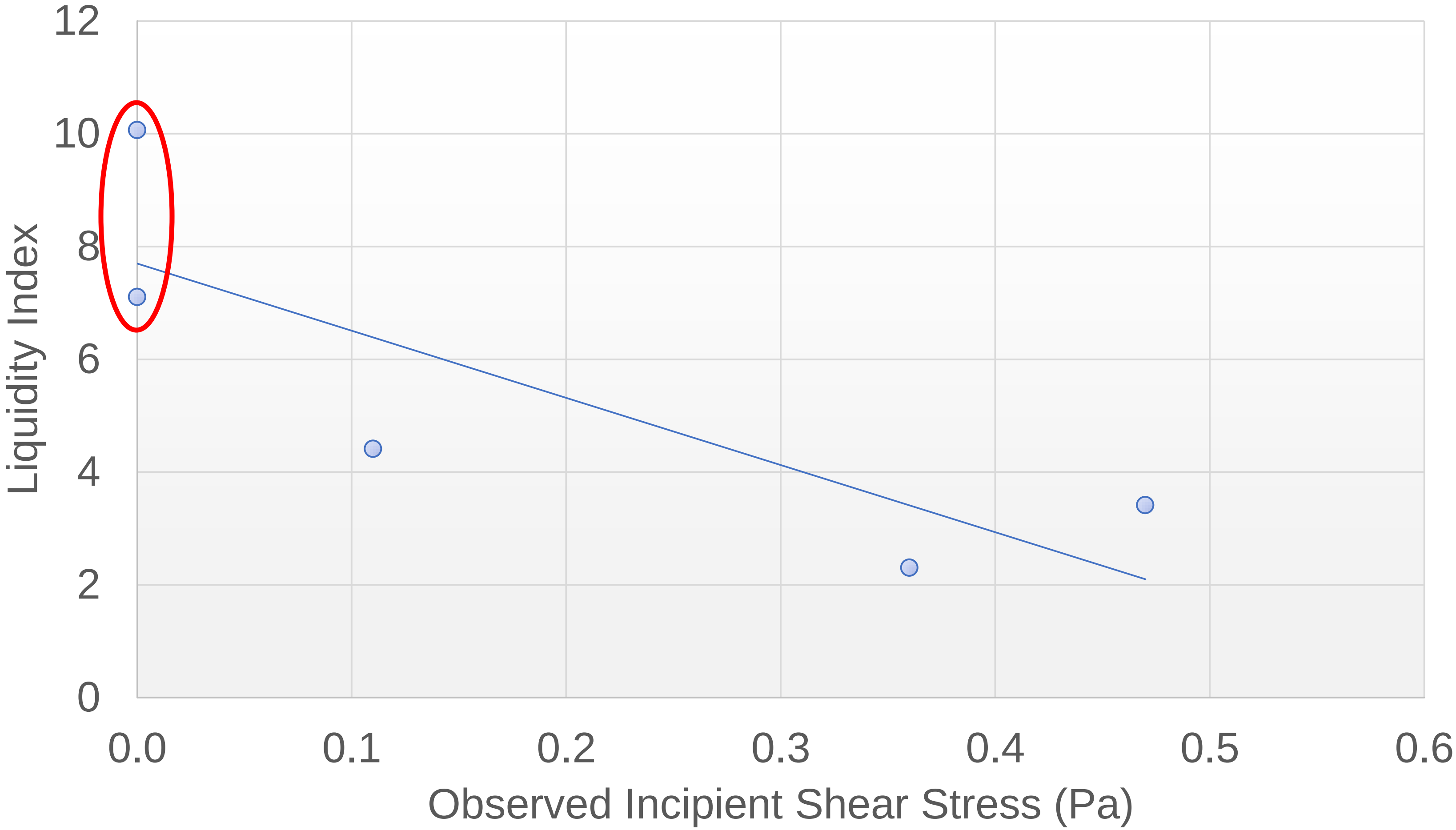
γ (g/cm^3)	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	$E_{0.6}$ (cm/min)	τ_c (Pa)
0.53	112.1	39.7	72.4	1.52	L	
0.96	47.2	28.0	19.2	2.03	L	
0.73	115.8	39.8	76.0	0.79	L	
1.24	62.6	50.0	12.6	-0.56	0.025	
0.73	48.6	27.3	21.3	3.41	0.18	0.47
0.73	45.1	26.6	18.6	3.95	0.18	
0.73	43.8	26.0	17.8	4.16	0.22	
0.37	118.6	30.7	87.9	2.30	0.24	0.36
0.96	61.4	47.3	14.1	1.40	0.40	
0.73	48.3	24.1	24.2	3.14	0.58	
0.53	54.1	26.0	28.1	4.41	H	0.11
0.73	60.9	50.6	10.2	4.84	H	
0.37	46.2	25.6	20.6	10.07	H	L
0.37	54.8	25.6	29.3	7.08	H	L

γ = Wet density (g/cm^3)
τ_c = Incipient shear stress (Pa)
$E_{0.6}$ = Erosion rate at 0.6 Pa (cm/min)

Erosion rate increases with Liquidity Index



Incipient Shear Stress increases with Liquidity Index



Conclusions

- When completely mixed, sand is not an effective stabilizing material
  - This does not mimic a sand cover!
- All other additives (bentonite, kaolinite, and lime) successfully stabilized sediment with modest amounts of additions
  - Lime was the least effective
  - Bentonite was the most effective
- Liquidity Index seems to be a potential indicator of sediment stability

Questions?