

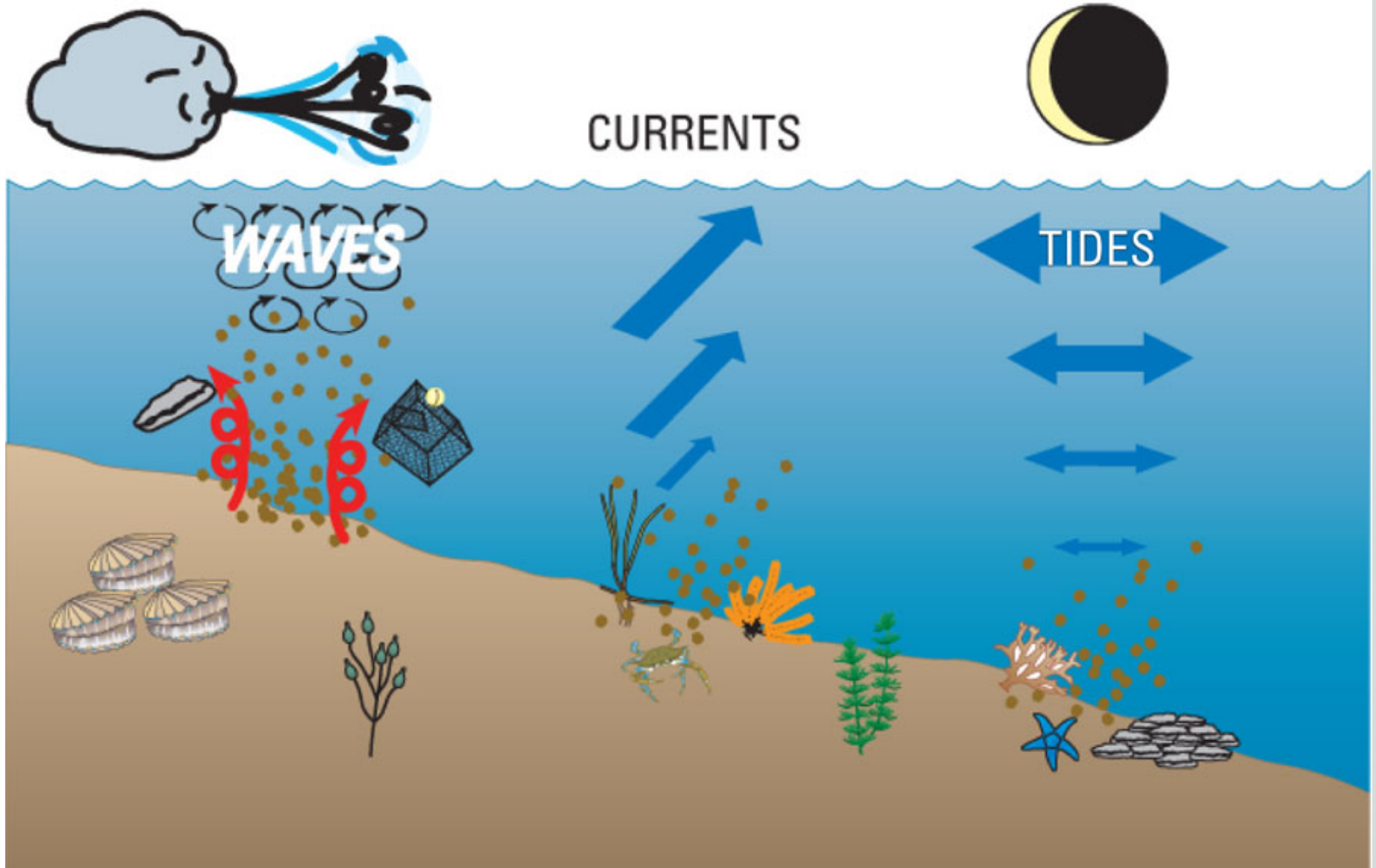
Sediment Transport Dynamics, Part I

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Sediment Characteristics

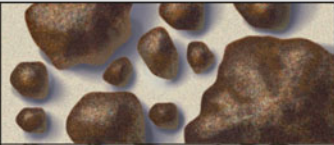
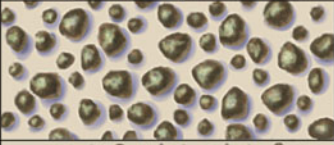
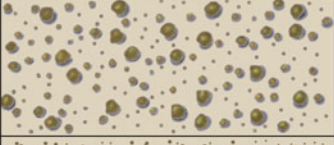
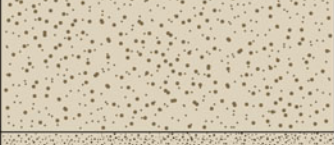
Grain Size, Distribution, Bottom Roughness
Density, Fall Velocity

Factors influencing non-cohesive sediment transport
Initiation of Motion, Turbulence, Bottom Stress
Conservation of Momentum $\rightarrow$ Sediment Velocity
Conservation of Mass $\rightarrow$ Sediment Concentration



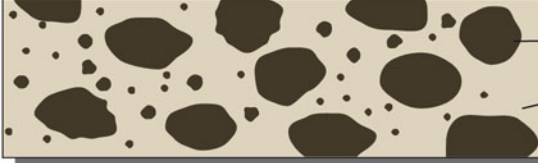
USGS –Forcing Mechanisms for
Sediment Transport on Continental Shelves

Sediment Grain Size

A. Grain size		
"Gravel" > 2mm	Pebbles 4–64 mm	
	Granules 2–4 mm	
	Coarse sand 0.5–2 mm	
	Medium sand 0.25–0.5 mm	
	Fine sand 0.06–0.25 mm	
	Silt 0.004–0.06 mm	
Clay < 0.004 mm		
		

B. Rounding		
		
Angular	Sub-rounded	Well-rounded

C. Sorting	
	Poorly sorted
	Well-sorted

D. Grains and matrix	
	Grain Matrix

Φ	PHI - mm CONVERSION $\phi = \log_2 (d \text{ in mm})$ $1 \mu\text{m} = 0.001\text{mm}$	Fractional mm and Decimal inches	SIZE TERMS (modified from Wentworth, 1929)	SIEVE SIZES		Intermediate diameters of natural grains equivalent to sieve size	Number of grains per mg		Settling Velocity (Quartz, 20°C)		Threshold Velocity for traction cm/sec	
				ASTM No. (U.S. Standard)	Tyler Mesh No.		Quartz spheres	Natural sand	Spheres (Gibbs, 1971) cm/sec	Crushed (Ruby)	(Nevin, 1946)	in flow of 1m depth (modified from Hjulstrom, 1939)
-8	256	10.1"	BOULDERS									
-7	128	5.04"	COBBLES									
-6	64.0	2.52"		2 1/2"	2"						200	
-5	53.9		very coarse	2.12"								
-4	45.3			1 1/2"	1 1/2"						150	
-3	33.1	1.26"		1 1/4"	1.05"							
-2	32.0		coarse	1.06"								
-1	26.9			3/4"	.742"							
0	22.6	0.63"	medium	5/8"	.525"						100	
1	17.0			1/2"	.371"							
2	16.0	0.32"	fine	7/16"								
3	13.4			3/8"								
4	11.3	0.16"	very fine	5/16"								
5	9.52		(granules)	.265"	3							
6	8.00	0.08"		4	4							
7	6.73		very coarse	5	5							
8	5.66	0.04"		6	6							
9	4.76		coarse	7	7							
10	4.00			8	8							
11	3.36	0.03"	medium	10	9							
12	2.83			12	10							
13	2.38		fine	14	12							
14	2.00			16	14							
15	1.63	0.02"	very fine	18	16	1.2	.72	.6				
16	1.41		coarse	20	20							
17	1.19			25	24	.86	2.0	1.5				
18	1.00	1/2	medium	30	28	.59	5.6	4.5				
19	.840			35	32							
20	.707	1/4	fine	40	35	.42	15	13				
21	.545			45	42							
22	.500		very fine	50	48	.30	43	35				
23	.420	1/8	coarse	60	60							
24	.354			70	65	.215	120	91				
25	.297		medium	80	80							
26	.250	1/16	fine	100	100	.155	350	240				
27	.210			120	115							
28	.177		very fine	140	150	.115	1000	580				
29	.149		coarse	170	170							
30	.125	1/32		200	200	.080	2900	1700				
31	.105		medium	230	250							
32	.088			270	270							
33	.074	1/64	fine	325	325							
34	.062			400								
35	.053		very fine									
36	.044		coarse									
37	.037											
38	.031	1/128	medium									
39	.02											
40	.016	1/64	fine									
41	.01											
42	.008	1/128	very fine									
43	.005											
44	.004	1/256	coarse									
45	.003											
46	.002	1/512	very fine									
47	.001		CLAY									
48	.001	1/1024	Clay/Silt boundary for mineral analysis									

$$\phi = -\log_2 D/D_0,$$

where

ϕ is the Krumbein phi scale,

D is the diameter of the particle, and

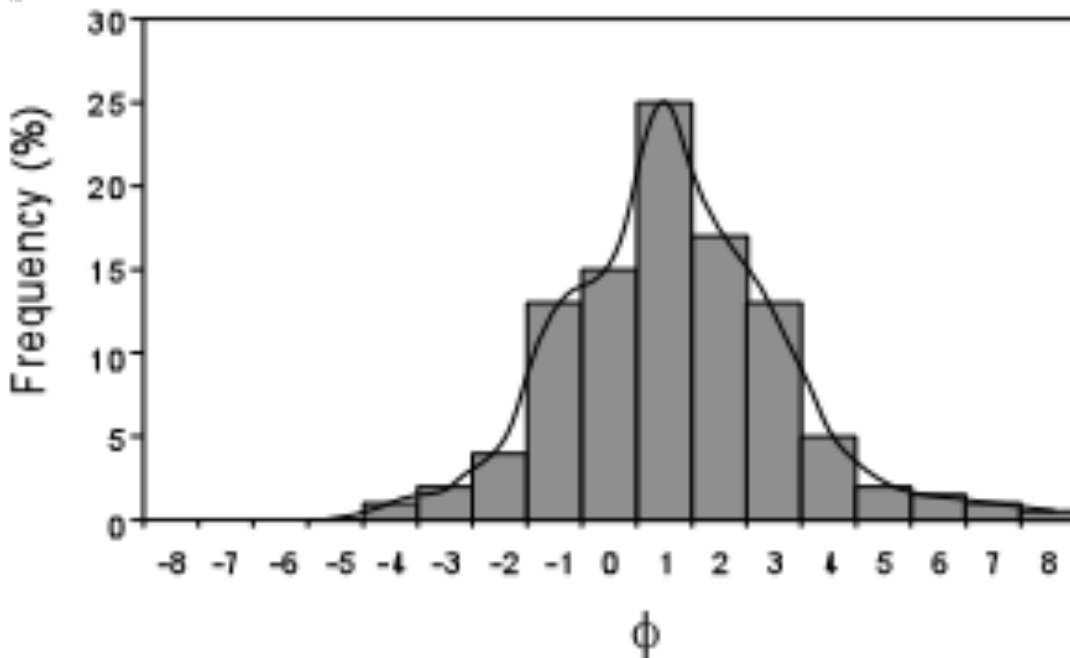
D_0 is a reference diameter, equal to 1 mm (to make the eq

This equation can be rearranged to find diameter using ϕ :

$$D = D_0 \times 2^{-\phi}$$



Sediment Grain Size



$$\phi = -\log_2 D/D_0,$$

where

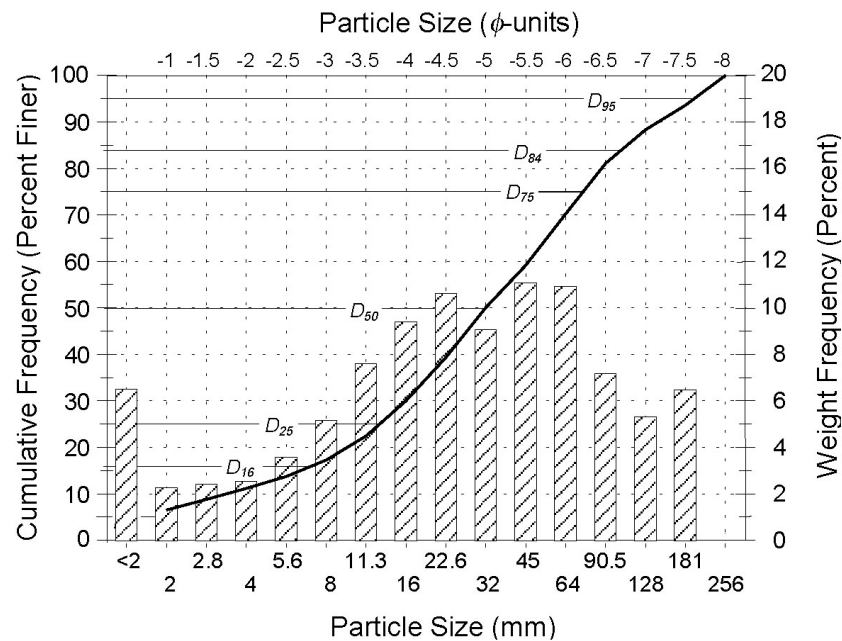
ϕ is the Krumbein phi scale,

D is the diameter of the particle, and

D_0 is a reference diameter, equal to 1 mm (to make the equation dimensionless).

This equation can be rearranged to find diameter using ϕ :

$$D = D_0 \times 2^{-\phi}$$



Sediment Grain Size

Fig. 2.12: Frequency distribution (histogram with hatched bars) and cumulative frequency distribution curve (thick line) with indicated percentile values for data listed in Table 2.3.

Sediment Density

TABLE 6.5 Formula and Specific Gravity of Common Soil Minerals

Type of mineral	Formula	Specific gravity	Comments
Quartz	SiO ₂	2.65	Silicate, most common type of soil mineral
K Feldspar	KAlSi ₃ O ₈	2.54–2.57	Feldspars are also silicates and are the second most common type of soil mineral.
Na or Ca Feldspar	NaAlSi ₃ O ₈	2.62–2.76	
Calcite	CaCO ₃	2.71	Basic constituent of carbonate rocks
Dolomite	CaMg(CO ₃) ₂	2.85	Basic constituent of carbonate rocks
Muscovite	varies	2.76–3.0	Silicate sheet type mineral (mica group)
Biotite	complex	2.8–3.2	Silicate sheet type mineral (mica group)
Hematite	Fe ₂ O ₃	5.2–5.3	Frequent cause of reddish-brown color in soil
Gypsum	CaSO ₄ ·2H ₂ O	2.35	Can lead to sulfate attack of concrete
Serpentine	Mg ₃ Si ₂ O ₅ (OH) ₄	2.5–2.6	Silicate sheet or fibrous type mineral
Kaolinite	Al ₂ Si ₂ O ₅ (OH) ₄	2.61–2.66	Silicate clay mineral, low activity
Illite	complex	2.60–2.86	Silicate clay mineral, intermediate activity
Montmorillonite	complex	2.74–2.78	Silicate clay mineral, highest activity

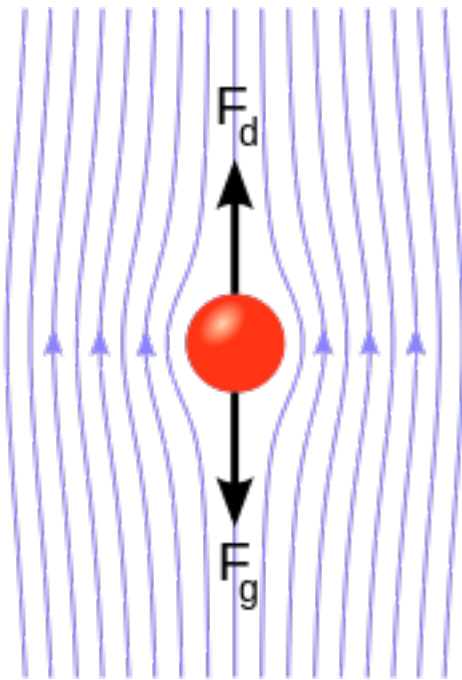
NOTE: Silicates are very common and account for about 80% of the minerals at the Earth's surface.

$$S.G. = \frac{\text{Density of object}}{\text{Density of Water}} = \frac{174.8 \frac{\text{lbs}}{\text{ft}^3}}{62.4 \frac{\text{lbs}}{\text{ft}^3}} = 2.8$$

Water Viscosity

Temperature - t - (°C)	<u>Dynamic Viscosity</u> - μ - (Pa s, N s/m ²) x 10 ⁻³	<u>Kinematic Viscosity</u> - ν - (m ² /s) x 10 ⁻⁶
0	1.787	1.787
5	1.519	1.519
10	1.307	1.307
20	1.002	1.004
30	0.798	0.801
40	0.653	0.658
50	0.547	0.553
60	0.467	0.475
70	0.404	0.413
80	0.355	0.365
90	0.315	0.326
100	0.282	0.29

Sediment Fall Velocity

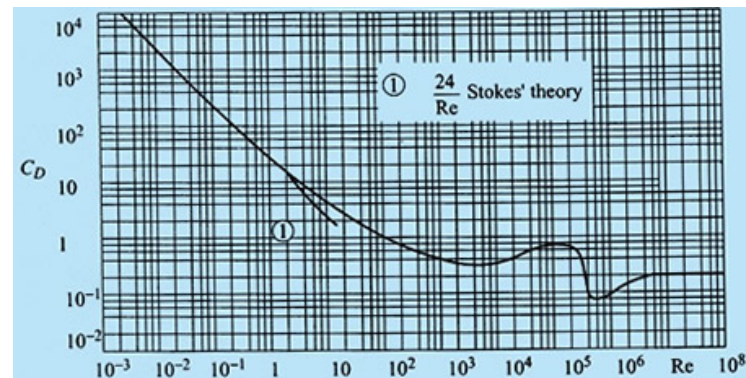
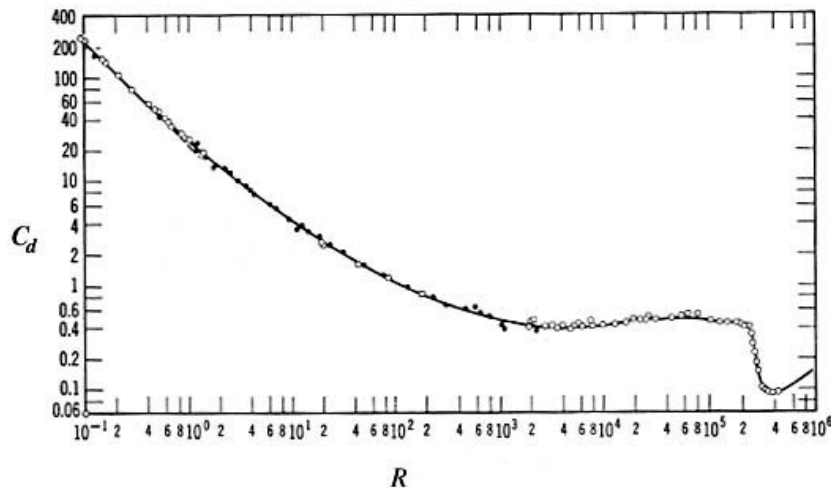


BUOYANT FORCE

$$F_G = (\underbrace{\rho_P}_{\text{density of particle}} - \underbrace{\rho}_{\text{density of fluid}}) \underbrace{g}_{\text{gravitational constant}} \underbrace{V_P}_{\text{volume of particle}}$$

DRAG FORCE

$$F_D = \frac{C_D}{2} \frac{A_P \rho v_s^2}{\text{area of particle}} \quad \text{drag coefficient} \quad \text{fluid} \quad \text{settling velocity}$$



Sediment Fall Velocity

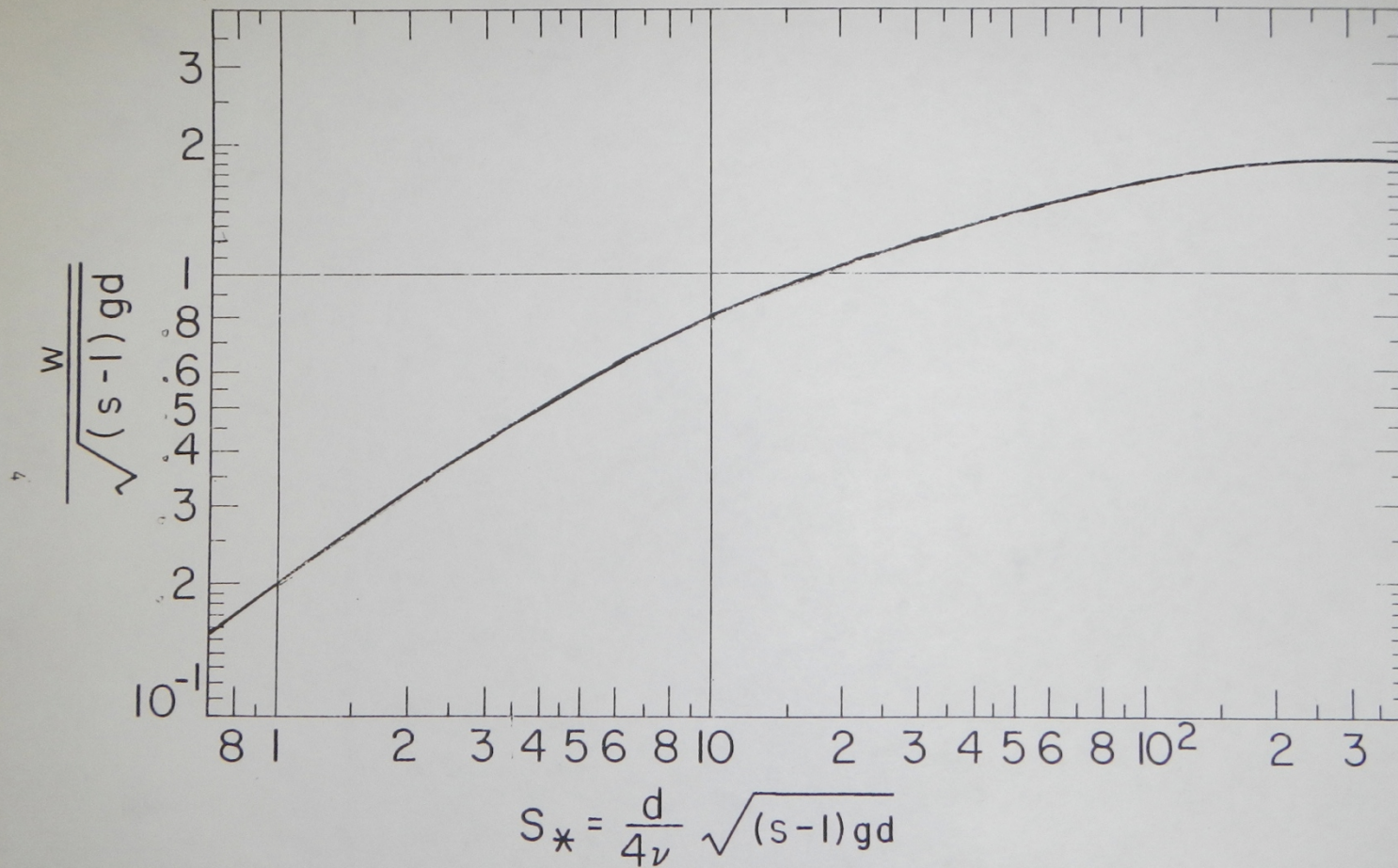


Figure 3 : Determination of the Fall Velocity of a Spherical Particle.

Bottom Stress

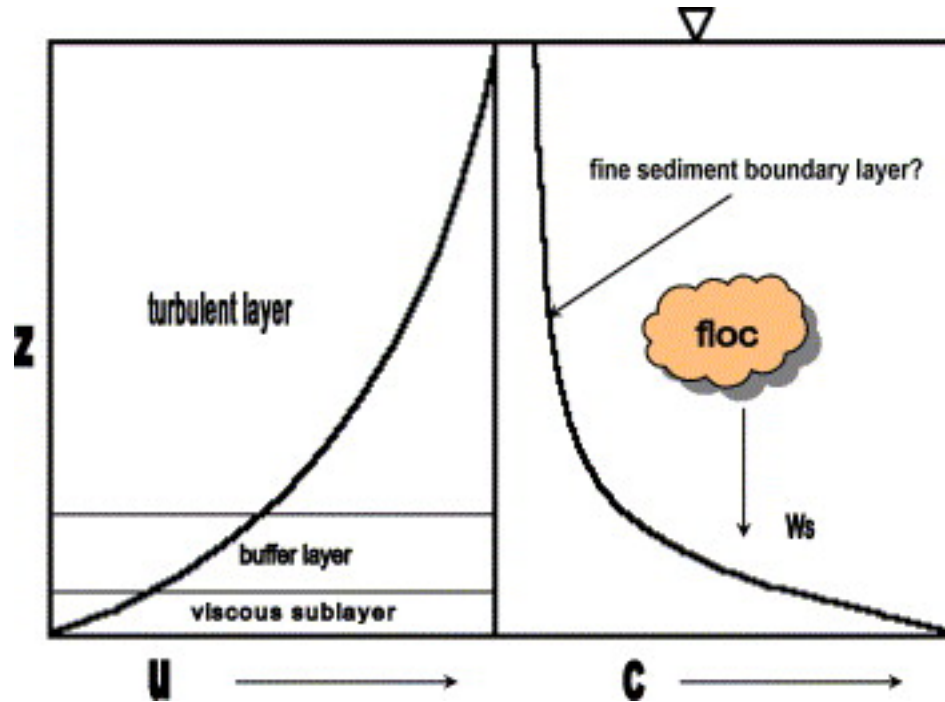


Figure 2 The structures of turbulent boundary layer and fine sediment boundary layer. Z the height above the bed; u the current velocity; C the concentration...

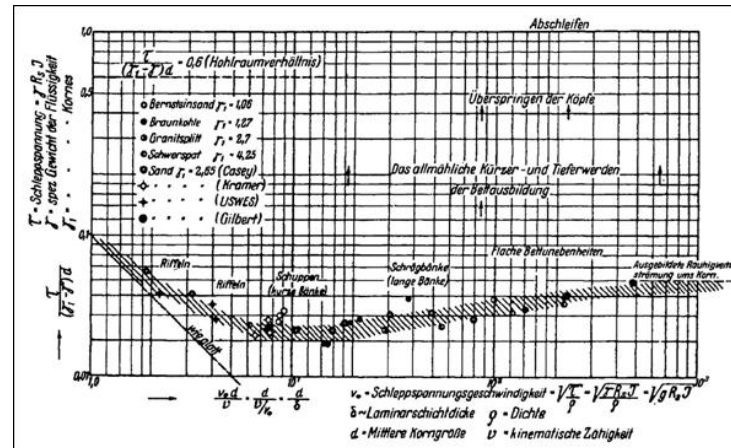
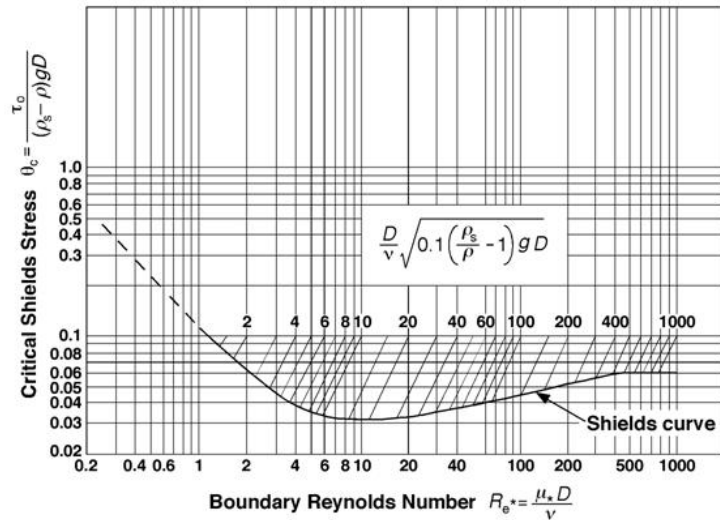
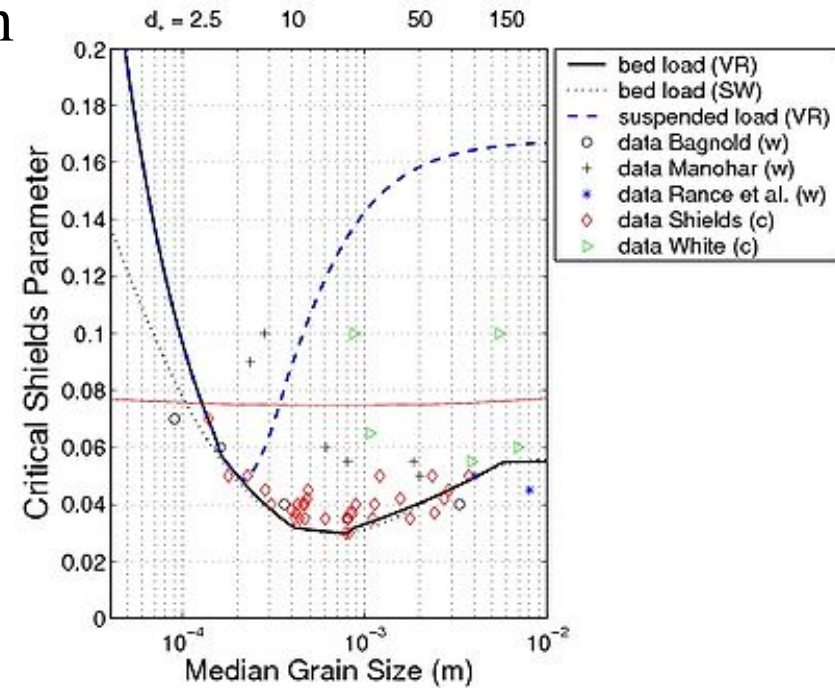
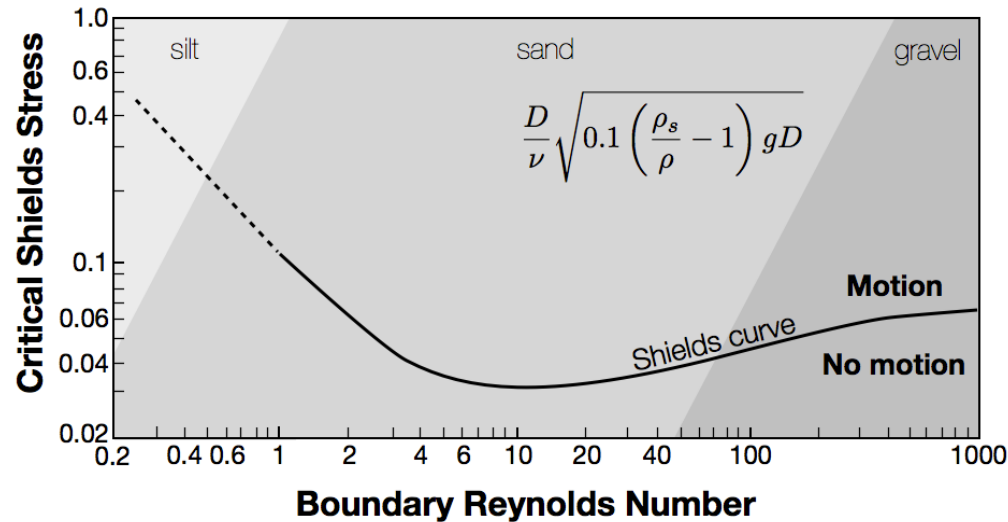
John Z. Shi, S.Y. Zhang, L.J. Hamilton

Bottom fine sediment boundary layer and transport processes at the mouth of the Changjiang Estuary, China

Journal of Hydrology Volume 327, Issues 1–2 2006 276 - 288

<http://dx.doi.org/10.1016/j.jhydrol.2005.11.039>

Shields Criteria – Initiation of Motion



Shields Criteria – Initiation of Motion

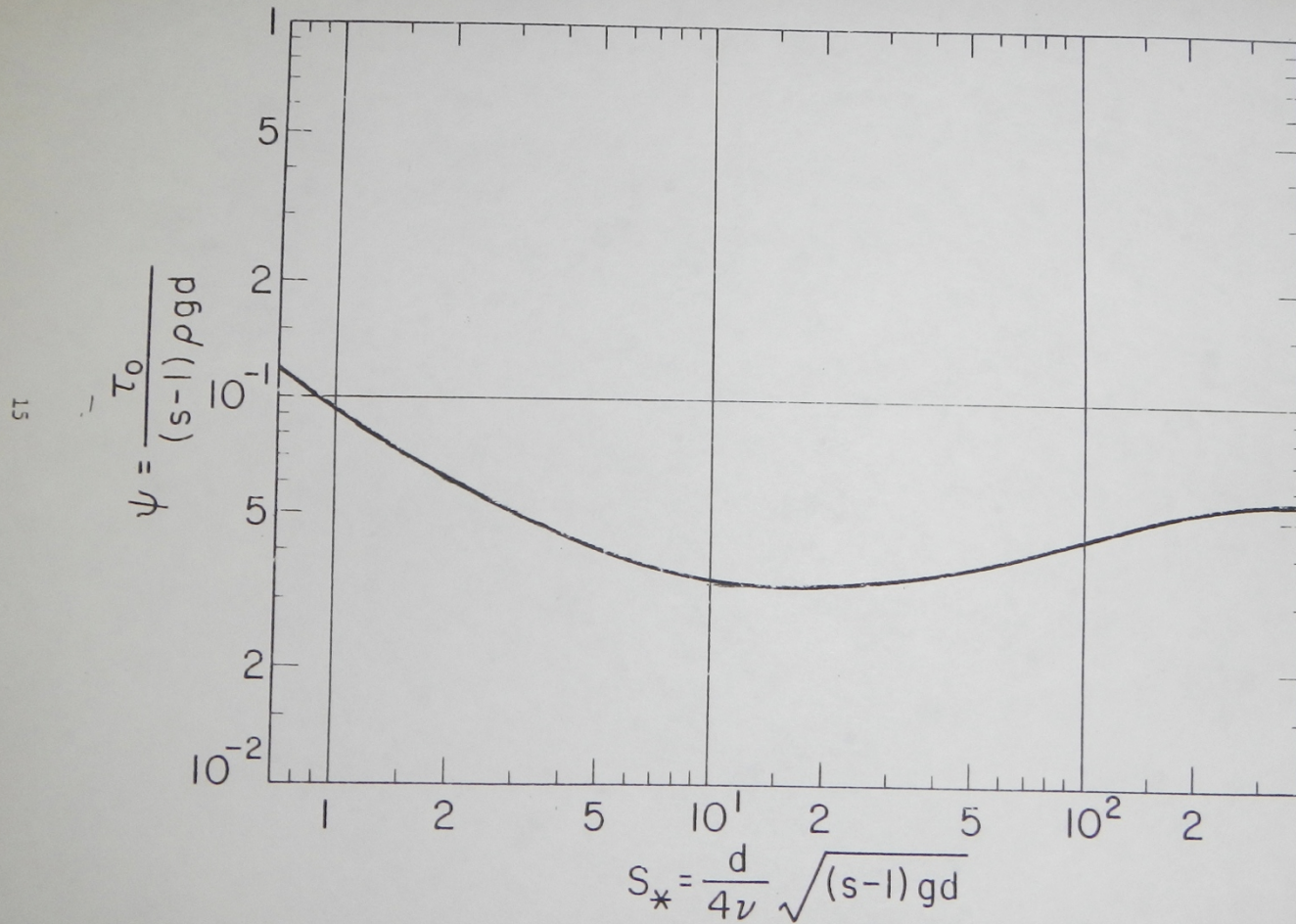
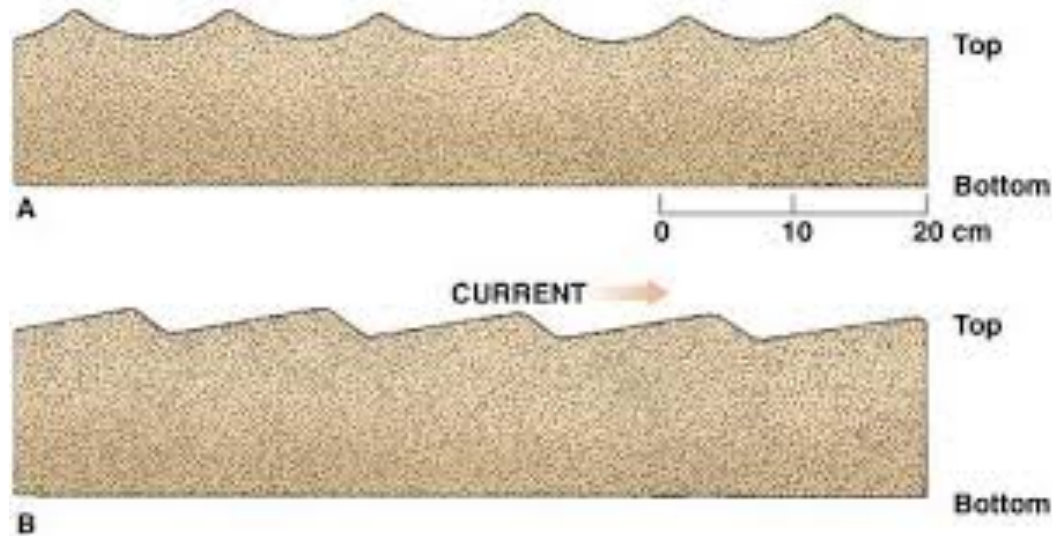


Figure 5: Modified Shields Diagram

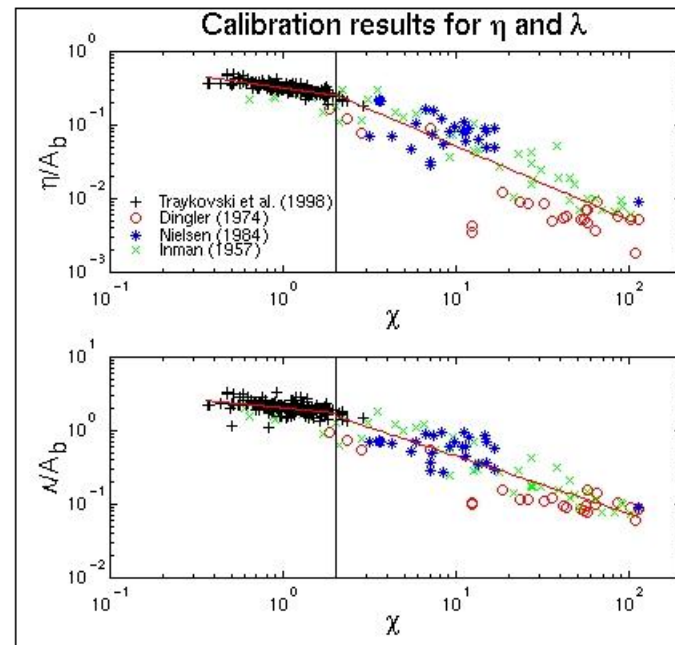
Bottom Roughness



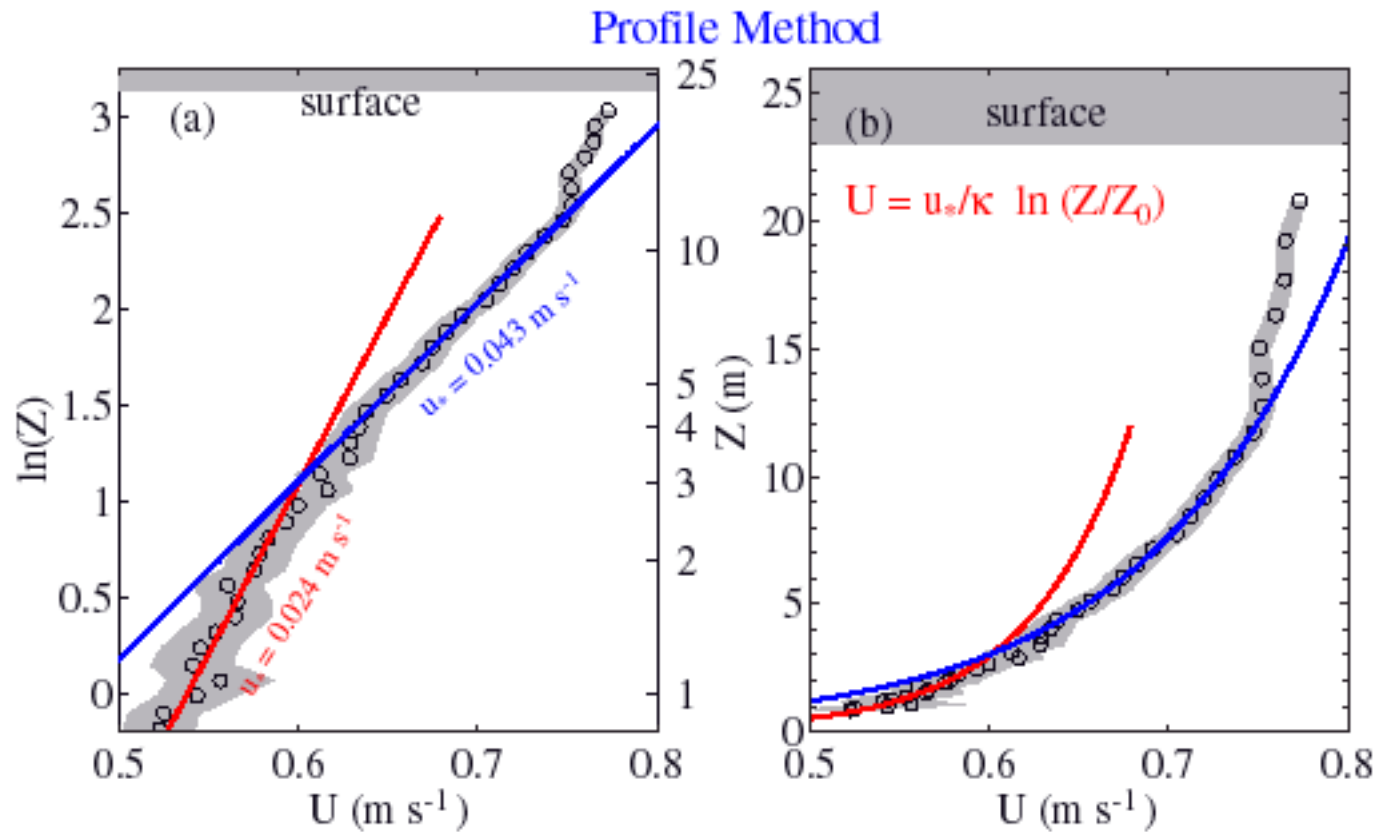
$$\frac{\eta}{A_b} = \begin{cases} 0.32X^{-0.34} & X < 2 \\ 0.52X^{-1.01} & X > 2 \end{cases}$$

$$\frac{\lambda}{A_b} = \begin{cases} 2.04X^{-0.23} & X < 2 \\ 2.70X^{-0.78} & X > 2 \end{cases}$$

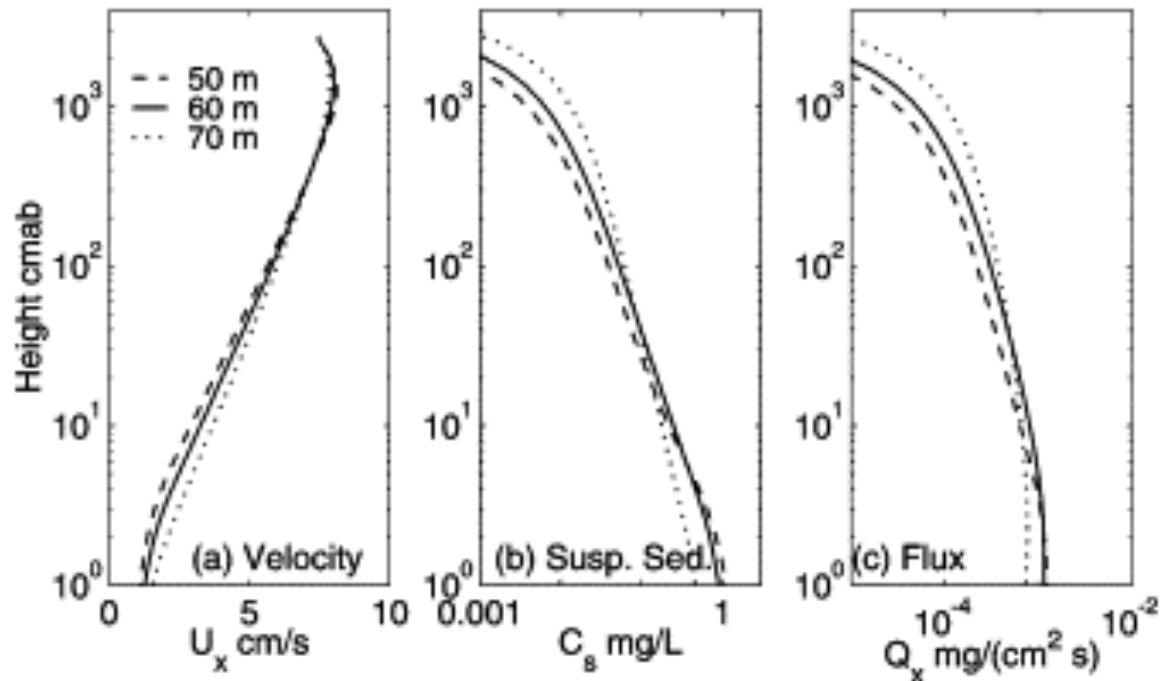
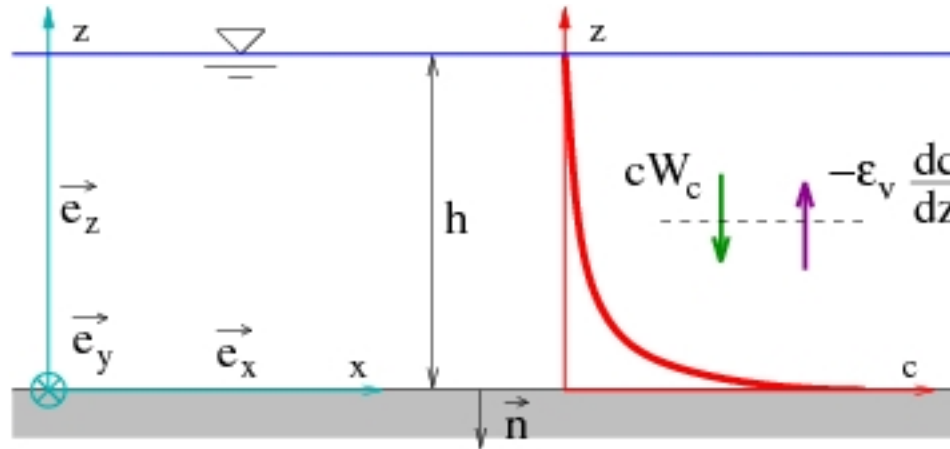
$$X = \frac{4\nu u_b^2}{d[(s-1)gd]^{3/2}}$$



Constant Stress Layer - Currents



Constant Stress Layer – Suspended Sediment



Sediment Transport Dynamics, Part II

Andrea Ogston
University of Washington

Factors influencing cohesive sediment transport

Flocculation/hindered settling
Fluid mud/Sediment gravity flows

Applications to the Amazon system
Fluid Muds on the Amazon Shelf
Downslope flux to clinoform foreset
Nearshore Processing - e.g., sediment
deposition /progradation processes on mud capes