TECHNICAL MEMORANDUM

From: Bruce Tiffany, P.E.
To: Industrial Users of the King County Sanitary Sewer System
Cc: Industrial Waste Program Staff
Date: October 7, 2011 (Ver. 1)
Re: King County Industrial Waste Program – Minimum Standards for Sedimentation Tanks Used at Construction Dewatering Sites

Introduction

Construction sites have numerous processes that generate wastewater that cannot meet acceptance standards for discharge to surface water – even after treatment. For these circumstances, it is acceptable for construction process wastewaters to be discharged to the King County sanitary sewer system, if certain acceptance criteria are met and after appropriate treatment.

The main concern with receipt of construction dewatering wastewater to the sanitary sewer is the risk of high levels of settleable solids being discharged to local sewer lines and creating a sewer obstruction problem. The primary wastewater treatment process for removal of settled solids is referred to as sedimentation, although the term gravitational settling is used as well. Other forms of solid removal such as filtration or centrifugation are higher level forms of treatment and, if needed for a particular site, would be positioned after the sedimentation process.

Since sedimentation is the first, and often the only, wastewater treatment process for construction dewatering treatment, this technical memorandum will be limited to the minimum standards for sedimentation tanks used at construction dewatering sites.

Background on Gravitational Settling of Particles

Sedimentation, or gravitational settling, is the separation of suspended particles that are heavier than water. The main forces at play in the process of gravitational settling are gravity and viscosity. Gravity is the force which pulls downward on particles as a function of their mass. This gravitational force is opposed by the viscosity of water. As particles get smaller and smaller the viscosity of water has more influence. To conceptualize the impact of viscosity, try to imagine the settling velocity of a pebble dropped in a column of water compared to this same pebble being dropped in a column of corn syrup. As you can imagine, the pebble dropped in corn syrup would take much longer to reach the bottom of the column. A similar process takes place between large and small particles in water. Clay particles are very small and are strongly influenced by viscosity, silt particles are larger in size and are less influenced by viscosity, with larger sand particles being affected even less. This can be observed by a review of **Table 1** below, which presents the calculated terminal settling velocities for ideal spherical particles according to Stokes Law.

Table 1: Particle Settling Per Stokes Law

Stokes Law: Assumes spherical particles and Reynolds No. <0.3

g = gravitational constant =	9.8067	m/s^2	
Pp = Particle Density =	2,649.28	kg/m^3	Assumed Particle s.g. of 2.65
Pw = Water Density =	999.73	kg/m^3	Assume Temperature = 10°C (50°F)
Re = Reynolds No. = (Vt*Dp)/v =		---	Assume Temperature = 10°C (50°F)
v = kinematic viscosity = µ/Pw =	1.31E-06	m^2/s	Assume Temperature = 10°C (50°F)
µ = absolute viscosity of water =	1.31E-03	kg/m-s	Assume Temperature = 10°C (50°F)

Vt = Terminal Settling Velocity

$$Vt = \frac{(g)(Pp-Pw)(Dp)^2}{(18)(\mu)}$$

Diameter of Particle (Dp), µm	Diameter of Particle (Dp), m	Re	Vt, m/s	Vt, ft/min.	Comments
4	4.00E-06	3.36E-05	1.10E-05	2.16E-03	Wentworth Scale: 4 µm = silt/clay cutoff
5	5.00E-06	6.57E-05	1.72E-05	3.38E-03	
10	1.00E-05	5.25E-04	6.87E-05	1.35E-02	
15	1.50E-05	1.77E-03	1.55E-04	3.04E-02	Equivalent Overflow Rate (gpd/ft^2)
20	2.00E-05	4.20E-03	2.75E-04	5.41E-02	583
25	2.50E-05	8.21E-03	4.30E-04	8.45E-02	910
30	3.00E-05	1.42E-02	6.19E-04	1.22E-01	1,311
35	3.50E-05	2.25E-02	8.42E-04	1.66E-01	1,785
40	4.00E-05	3.36E-02	1.10E-03	2.16E-01	2,331
45	4.50E-05	4.79E-02	1.39E-03	2.74E-01	2,950
50	5.00E-05	6.57E-02	1.72E-03	3.38E-01	3,642
60	6.00E-05	1.13E-01	2.47E-03	4.87E-01	5,244
70	7.00E-05	1.80E-01	3.37E-03	6.63E-01	Wentworth Scale: 62.5 µm = sand/silt cutoff
80	8.00E-05	2.69E-01	4.40E-03	8.66E-01	

As can be seen in **Table 1**, a 4 µm diameter particle (near the cutoff between clay and silt size fractions), has 1/100th the settling velocity of a 40 µm diameter particle (in the range between medium and coarse sized silt). One feature of sedimentation tank design is to set the particle settling velocity (V_t) equal to the overflow rate of the sedimentation tank (units: gpd/ft^2). Primary sedimentation tanks have overflow rates that range from a low of 800 gpd/ft^2 to a peak of 3,000 gpd/ft^2 (Metcalf & Eddy 1991). According to **Table 1**, this range of overflow rates would equate to terminal settling velocities for ideal particles with diameters in the range of approximately 25 µm to 45 µm. Some deviation from this theoretical estimation is to be expected because of the irregular shape of actual soil particles and because of inlet and outlet effects of sedimentation tanks. Even with this taken into consideration, sedimentation tanks should still be able to remove particles down to the mid- to upper-range of the silt size fraction.

For more information on size fractions of geological media, please see the table provided in **Appendix A** (USGS 2006).

Review of Rectangular Sedimentation Tanks by Local Suppliers

There are two known commonly used suppliers of portable sedimentation tanks used at construction sites in the Puget Sound area. These two suppliers are referred to as Supplier "A" and Supplier "B" and the technical information for common sedimentation tanks is provided below.

All of the sedimentation tanks reviewed from these suppliers were rectangular in shape and had general capacities ranging from 18,000 to 21,000 gallons. Most of the sedimentation tanks were of open design, but each supplier also provided a weir tank, designed with two weirs dividing the sedimentation tanks into thirds and oriented in an underflow-overflow configuration.

Important parameters for the sedimentation tanks are volume, length, and width. The working length and width of the sedimentation tank is important for calculating the tank surface area, which is a parameter needed to calculate the overflow rate of a sedimentation tank (units: gpd/ft^2). The working length and width of the sedimentation tank are also used to calculate an important design parameter called the aspect ratio, which is the ratio of the length divided by the width (aspect ratio = length/width – provided in decimal format).

- **Supplier "A":** The approximate dimensions of the sedimentation tanks reviewed are as follows:

  - **No. 1:** Volume: 19,400 gallons – Length: 40.5 ft – Width: 8.5 ft – Aspect Ratio: 4.76
  - **No. 2:** Volume: 21,000 gallons – Length: 43 ft – Width: 8.5 ft – Aspect Ratio: 5.06
  - **No. 3:** Volume: 17,600 gallons – Length: 43 ft – Width: 8 ft – Aspect Ratio: 5.38
  - **No. 4:** Volume: 21,000 gallons – Length: 35 ft – Width: 8 ft – Aspect Ratio: 4.38
  - **No. 5:** Volume: 20,000 gallons – Length: 35 ft – Width: 8 ft – Aspect Ratio: 4.38
  - **No. 6:** Volume: 20,000 gallons – Length: 45.5 ft – Width: 8.5 ft – Aspect Ratio: 5.35

- **Supplier "B"**: The approximate dimensions of the sedimentation tanks reviewed are as follows:

  - **No. 1:** Volume: 18,100 gallons – Length: 40 ft – Width: 8 ft – Aspect Ratio: 5.00
  - **No. 2:** Volume: 18,100 gallons – Length: 40 ft – Width: 8 ft – Aspect Ratio: 5.00
  - **No. 3:** Volume: 18,100 gallons – Length: 40 ft – Width: 8 ft – Aspect Ratio: 5.00
  - **No. 4:** Volume: 19,900 gallons – Length: 41.8 ft – Width: 8.5 ft – Aspect Ratio: 4.92
  - **No. 5:** Volume: 21,000 gallons – Length: 40 ft – Width: 8 ft – Aspect Ratio: 5.00
  - **No. 6:** Volume: 21,000 gallons – Length: 40 ft – Width: 8 ft – Aspect Ratio: 5.00

<u>Review of Standards for Rectangular Sedimentation Tanks</u>

Literature sources were reviewed for information on design standards for rectangular sedimentation tanks. Information was available for the key design parameters of hydraulic retention time, overflow rate, aspect ratio, and sediment accumulation.

The information is provided with the value and the associated reference.

- **Hydraulic Retention Time (hours: hrs):**

  - **Minimum:** 3.5 hrs (Caltrans 2001), 1.5 hrs (Lindeburg 1997), 1.5 hrs (Metcalf & Eddy 1991)
  - **Maximum:** 5 hrs (Caltrans 2001), 2.5 hrs (Lindeburg 1997), 2.5 hrs (Metcalf & Eddy 1991)

- **Overflow Rate (gallons-per-day per square foot of surface area: gpd/ft^2):**

  - **Minimum:** 400 gpd/ft^2 (Lindeburg 1997), 800 gpd/ft^2 (Metcalf & Eddy 1991)
  - **Maximum:** 800 gpd/ft^2 (Dane County 2007), 2,000 gpd/ft^2 (Lindeburg 1997), 3,000 gpd/ft^2 (Metcalf & Eddy 1991)

- **Aspect Ratio (length:width → length/width (decimal)):**

  - **Minimum:** 3:1 → 3.0 (Ecology 2005), 3:1 → 3.0 (King County 2009), 3:1 → 3.0 (Lindeburg 1997), 4:1 → 4.0 (Metcalf & Eddy 1991)
  - **Preferred:** Greater than 4:1 → 4.0 (Lindeburg 1997)
  - **Maximum:** 5:1 → 5.0 (Lindeburg 1997), 5:1 → 5.0 (Metcalf & Eddy 1991)

- **Sediment Accumulation (level of sedimentation tank water column):**

  - **Maximum Sediment Accumulation at Maximum Wet Vault Water Column Height:** 1.5ft/8.0ft = 18.75% (Ecology 2005), 1.5ft/8.0ft = 18.75% (King County 2009).
  - **Maximum Sediment Accumulation at Mid-Point Wet Vault Water Column Height:** 1.5ft/6.0ft = 25% (Ecology 2005), 1.5ft/6.0ft = 25% (King County 2009).
  - **Maximum Sediment Accumulation at Minimum Wet Vault Water Column Height:** 1.5ft/4.0ft = 37.5% (Ecology 2005), 1.5ft/4.0ft = 37.5% (King County 2009).

Selection of Minimum Standards for Rectangular Sedimentation Tank Design

Based on literature information for rectangular sedimentation tank design and with the knowledge that several models of portable rectangular sedimentation tanks are readily available in the Puget Sound area, use of these devices is determined to be the minimum required treatment for construction dewatering wastewaters where settleable solids are encountered. For some sites, additional treatment could be required, or even recommended. For example, a pre-sedimentation tank could be used before the sedimentation tank(s) to equalize flows and remove larger quantities of coarse material (i.e., sand or gravel) or a pH neutralization tank could be added after the sedimentation tank(s) to facilitate a final pH adjustment to meet discharge limits. The standards for rectangular sedimentation tank design do not apply to other treatment units, such as a pre-sedimentation tank or a pH neutralization tank. These, or other treatment units, would need to be evaluated on a case-by-case basis.

The following are the minimum standards for rectangular sedimentation tank design. The sedimentation tank design must address each of the following:

- Minimum Hydraulic Retention Time (hours): **≥ 1.5 hours**

  The 1.5 hour hydraulic retention time is the minimum from the literature sources reviewed. This hydraulic retention time is based on the hydraulic capacity of the tank without accumulated sediment. Assuming a maximum sediment accumulation of 25% (see below), the minimum effective hydraulic retention time would be approximately 1.5 hours x 0.75 = 1.125 hours = 67.5 minutes. This minimum effective hydraulic retention time is fairly short; therefore, it will be important for dischargers to monitor sediment accumulation and total settleable solids in the discharged wastewater.

  A different way to evaluate the minimum hydraulic retention time is to use the maximum instantaneous flow rate and the 1.5 hour (i.e., 90 minute) hydraulic retention time to calculate the minimum sedimentation tank volume required. For example, if a maximum instantaneous flow rate of 500 gpm is expected, then the minimum required sedimentation tank volume would be the following:

  Example: 500 gpm x 90 minutes = 45,000 gallons

  If an 18,000 gallon sedimentation tank were used, this would require the use of three (3) tanks operated in parallel. If a 21,000 gallon sedimentation tank were used, this would also require the use of three (3) tanks operated in parallel, as two (2) tanks would have an insufficient volume (42,000 gallons).

- Maximum Overflow Rate (gallons-per-minute per square foot of surface area: gpm/ft^2): **≤ 1.0 gpm/ft^2** or (gallons-per-day per square foot of surface area: gpd/ft^2): **≤ 1,440 gpd/ft^2**

The 1,440 gpd/ft^2 (1.0 gpm/ft^2) maximum overflow rate is based on the maximum overflow rate from the literature sources reviewed (3,000 gpd/ft^2), with a one-half (0.5x) adjustment to the surface area with the assumption that the effective surface area of the commercially-available rectangular sedimentation tanks is reduced by the inlet and outlet effects of open tanks or by the underflow-overflow configuration of typical weir tanks.

- Minimum Length-to-Width Ratio (length:width → length/width): **≥ 4:1 → ≥ 4.0**

  The 4:1 minimum length-to-width (i.e., aspect) ratio is the mid-point between the minimum and maximum values from the literature sources reviewed and it is the preferred minimum from one literature source reviewed (Lindeburg 1997). In addition, all of the sedimentation tanks reviewed from local suppliers had length-to-width ratios greater than 4:1.

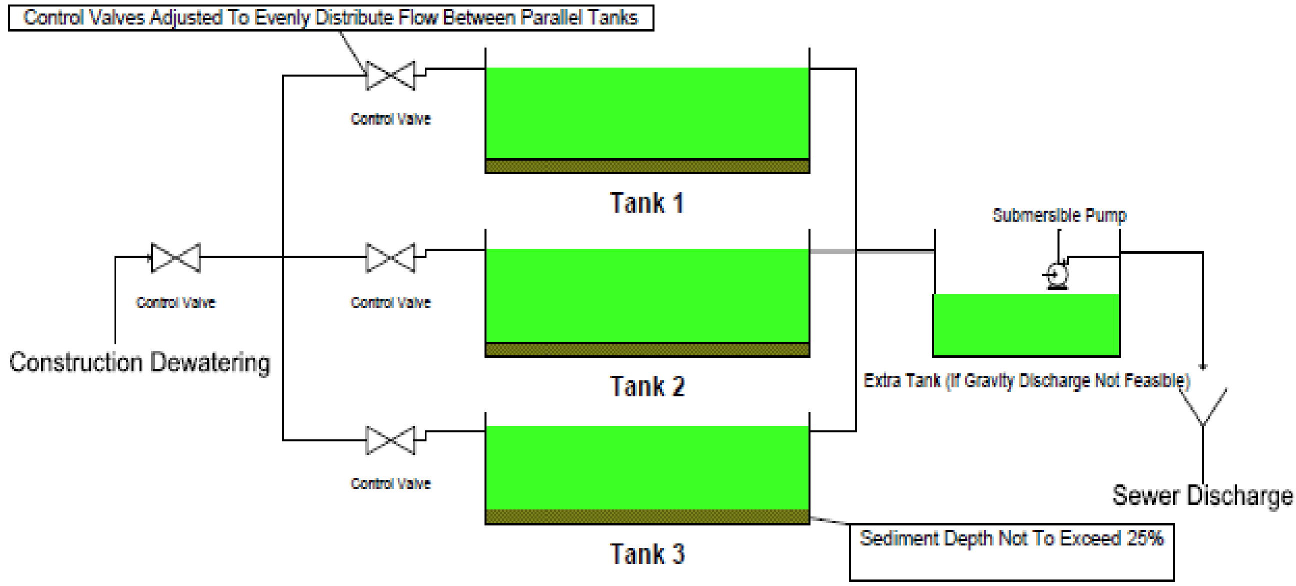
- Maximum Sediment Accumulation (level of sedimentation tank water column): **≤ 25%**

  The 25% maximum sediment accumulation level is the mid-point between the minimum and maximum values from the literature sources reviewed. Because sediment removal is so critical for sedimentation tank performance, the highest sediment accumulation level from the literature sources (37.5%) was determined to be too high.

- Requirement to Add Additional Sedimentation Tanks In Parallel For Higher Flow Rates:

  When discharge rates exceed the capacity of a sedimentation tank, one or more additional sedimentation tanks will be needed to accommodate the higher flow rates. For these circumstances, additional tanks must be added **in parallel**, as illustrated in **Figure 1**. No additional treatment capacity is granted for sedimentation tanks configured **in series** (i.e., one after the other). For situations where sedimentation tanks are configured **in series**, the treatment capacity is determined by the largest sedimentation tank.

Figure 1: Example – Sedimentation Tanks Operated In Parallel



Exemption for Batch Sedimentation Tanks

At certain construction sites, the generation of process wastewater is intermittent and batch sedimentation for solids removal can be a viable option. For batch sedimentation discharges, the 25% maximum sediment accumulation standard still applies, but a minimum 60 minute quiescent settling time must be maintained. During this settling time, no discharges to the sedimentation tank can be received. This 60 minute quiescent settling time is equivalent to the settling time used for the settleable solids test (Standard Methods 2005).

Exemption for Developed Groundwater Extraction Wells

Groundwater extraction wells are sometimes used at construction dewatering sites to lower the water table elevation to facilitate excavation at a construction site. During the development of a groundwater extraction well, solids are generated which requires the use of a sedimentation tank for treatment. If the groundwater extraction well is installed correctly, after development the sand filter pack surrounding the screened section of the well typically does an adequate job of filtering out settleable solids. Therefore, as long as the discharge meets King County discharge limits, use of a sedimentation tank is not typically required for discharges from a developed groundwater extraction well. However, if the water meets the acceptance criteria for discharge to receiving waters, it is preferred that groundwater extraction well discharges are conveyed to the local storm drainage system. (**Note:** During wet weather months King County requires that dischargers demonstrate that discharges over 25,000 gallons per day cannot be conveyed to the local storm drainage system or surface waters.)

References

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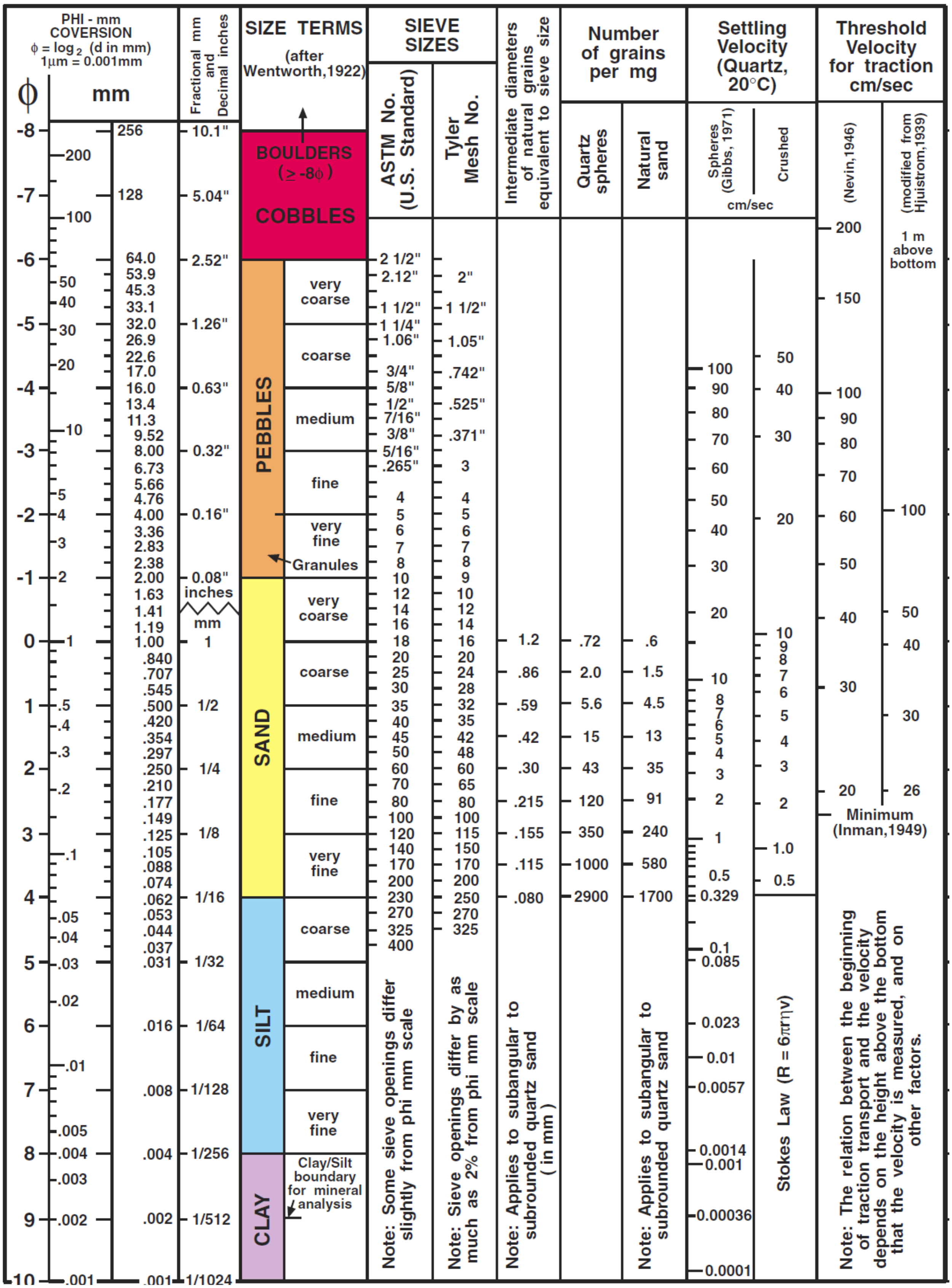
Appendix A

USGS – Geological Media Classification Table


PHI - mm COVERSION
ϕ = log2 (d in mm)
1µm = 0.001mm
ϕ
mm
Fractional mm and Decimal inches
SIZE TERMS
(after Wentworth,1922)
SIEVE SIZES
ASTM No. (U.S. Standard)
Tyler Mesh No.
Intermediate diameters of natural grains equivalent to sieve size
Number of grains per mg
Quartz spheres
Natural sand
Settling Velocity (Quartz, 20°C)
Spheres (Gibbs, 1971)
Crushed
cm/sec
Threshold Velocity for traction cm/sec
(Nevin,1946)
(modified from Hjulstrom,1939)
1 m above bottom
BOULDERS
(≥ -8ϕ)
COBBLES
PEBBLES
very coarse
coarse
medium
fine
very fine
Granules
SAND
very coarse
coarse
medium
fine
very fine
SILT
coarse
medium
fine
very fine
CLAY
Clay/Silt boundary for mineral analysis
inches
mm
Minimum (Inman,1949)
Stokes Law (R = 6πrηv)
Note: Some sieve openings differ slightly from phi mm scale
Note: Sieve openings differ by as much as 2% from phi mm scale
Note: Applies to subangular to subrounded quartz sand (in mm)
Note: Applies to subangular to subrounded quartz sand
Note: The relation between the beginning of traction transport and the velocity depends on the height above the bottom that the velocity is measured, and on other factors.