CIEG 680 Homework 1 **Solutions**

1) DD 2.1

**Discuss the relative merits of the fall velocity versus the grain size as a descriptor of sediment behavior in the nearshore zone.**

Many processes in the nearshore are governed, or more accurately, can be described by a relationship to the sediment grain size. However, typical analysis of nearshore sediment involves sample splitting, sieving and either settling tube or a particle analyzer to find the fraction of fines. The result is a distribution of sediment sizes where it is generally assumed that the particles are spherical in nature, which is not necessarily true. For instance beach porosity is largely affected by grain size and can be used to estimate the packing efficiency of the sediment, also beach steepness has been shown to be affected by the particle size with larger particles tending to have steeper beaches (foreshore). One explanation is that larger particles allow more beach permeability such that sediment carried on the uprush is deposited on the upper beach as the uprush and backwash are absorbed into the beachface. Also many sediment transport formulations, for instance the Bagnold/Bailard approach, rely on some estimate of the fluid power affecting the bed. A quadratic drag law is generally employed whereby an empirical friction coefficient is needed. This coefficient can be obtained from a Law of the Wall formulation where it is related to some measure of the grain size, specifically $d_{n,}$ where the value is the diameter for which n% of the sediment is finer (easily obtained from our cumulative percent plots). It becomes clear then that the grain size can be used a descriptor of nearshore sediment behavior in terms of beach steepness, porosity and also within the context of common transport formulations.

As good as the grain size seems for nearshore purposes, it is also lacking much information. For instance, standard analysis using sieves captures particles whose middle axis is larger than the sieve size and then the particles are generally assumed spherical. There is no information regarding the shape such as angularity, roughness or roundness which can affect the fall velocity as well as drag forces at the bed. For instance, consider two particles of the same 'diameter' (from sieve analysis) one is perfectly spherical and the other is a disc laying flat. More surface area of the spherical particle will be facing the flow and will be more easily mobilized which will affect net sediment transport. Also, angular and/or rough particles tend to drag more against themselves than do spherical particles making them more difficult to mobilize.

The fall velocity can be a good descriptor of sediment behavior as (assuming it is measured) it takes into account the shape, roughness and density of the grain. This is important as the grain may tumble or waft in the water rather than falling straight down which could increase its time to return to the bed. The importance here is, "what is the time scale of grain settling to the time scale of the fluid motions?". For instance, non-dimensional parameters such as the Dean number, $H_b/wT$ and a type of Froude number, $w/\mathrm{sqrt}(gH_b)$ can be used to gage the relative effects between fluid processes and the grain settling. That is, does a suspended grain settle before say an oscillating flow reverses direction. Beach placers are a good example of this. Some beaches are composed of quartz as well as heavy minerals (illite, horneblende for example) which tend to grade across the swash zone. Nature sorts these particles out based on their fall velocities (densities), NOT sizes. During uprush, the fluid power is strong enough to transport both the quartz and the heavy minerals. As the flow slows, the heavy minerals rapidly drop out of the water column and upon backwash are less easily suspended or mobilized so that the quartz minerals are transported offshore while the heavy minerals remain behind as placers.

2) DD 2.5

**An analysis of a sand sample shows that $d_{84}$ = 1.6ϕ, $d_{50}$=1.5ϕ, and $d_{16}$=1.2ϕ. Is the sediment well sorted? What is the mean diameter?**

The sediment is well-sorted if $\sigma_\varphi$ is ≤0.5. For this sample,

$$\sigma_\phi = \frac{(d_{84} - d_{16})}{2} = \frac{(1.6 - 1.2)}{2} = 0.2$$. The sand is well-sorted.

The mean diameter is obtained from either

$$M_{d\phi} = \frac{(d_{84} + d_{16})}{2} = \frac{(1.6 + 1.2)}{2} = 1.4\phi = 0.379mm \quad \text{or}$$

$$M_{d\phi} = \frac{(d_{84} + d_{50} + d_{16})}{3} = \frac{(1.6 + 1.5 + 1.2)}{3} = 1.43\phi = 0.371mm$$

3) DD 2.7 parts a and b only. "Sample" the cumulative distribution at ½ phi intervals.

**From the cumulative sand size distribution shown in figure 2.8,**
**(a) compute the median, mean, skewness and kurtosis.**

Obtain diameter values visually from Figure 2.8 being careful to recognize that the scale is percent finer rather than percent coarser.

| **Phi name** | $\phi_5$ | $\phi_{16}$ | $\phi_{50}$ | $\phi_{84}$ | $\phi_{95}$ |
|---|---|---|---|---|---|
| **Phi value** | -1 | 0.62 | 1.60 | 2.00 | 2.32 |
| **d, mm** | 2.0 | 0.65 | 0.33 | 0.25 | 0.2 |

Mean $=\mu_\phi = M_{d\phi} = \frac{\phi_{84} + \phi_{16}}{2} = \frac{2.00 + 0.62}{2} = 1.31\phi = 0.4mm$

Folk and Ward formula

Mean = $\frac{\phi_{84}+\phi_{50}+\phi_{16}}{3}=1.41\phi=0.38mm$

Standard Deviation

$\sigma_\phi$ = $\frac{\phi_{84}-\phi_{16}}{2}=\frac{2.00-0.62}{2}=0.69\phi=0.62mm$

Skewness = $\alpha_\phi$= $\frac{M_\phi-\phi_{50}}{\sigma_\phi}=\frac{1.31-1.60}{0.69}=-0.42$ (−0.32 using Folk and Ward mean)
slightly skewed toward smaller phi (larger grains).

Kurtosis = $\beta_\phi$ = $\frac{(\phi_{16}-\phi_5)+(\phi_{95}-\phi_{84})}{2\sigma_\phi}=\frac{(0.62--1)+(2.32-2.00)}{2*0.69}=1.41$.
This is greater than 0.65 so the distribution is leptokurtic, i.e. 'peaky'.

(b) **Show the actual sand size distribution and compare it with a normal distribution having the same mean and standard deviation.**

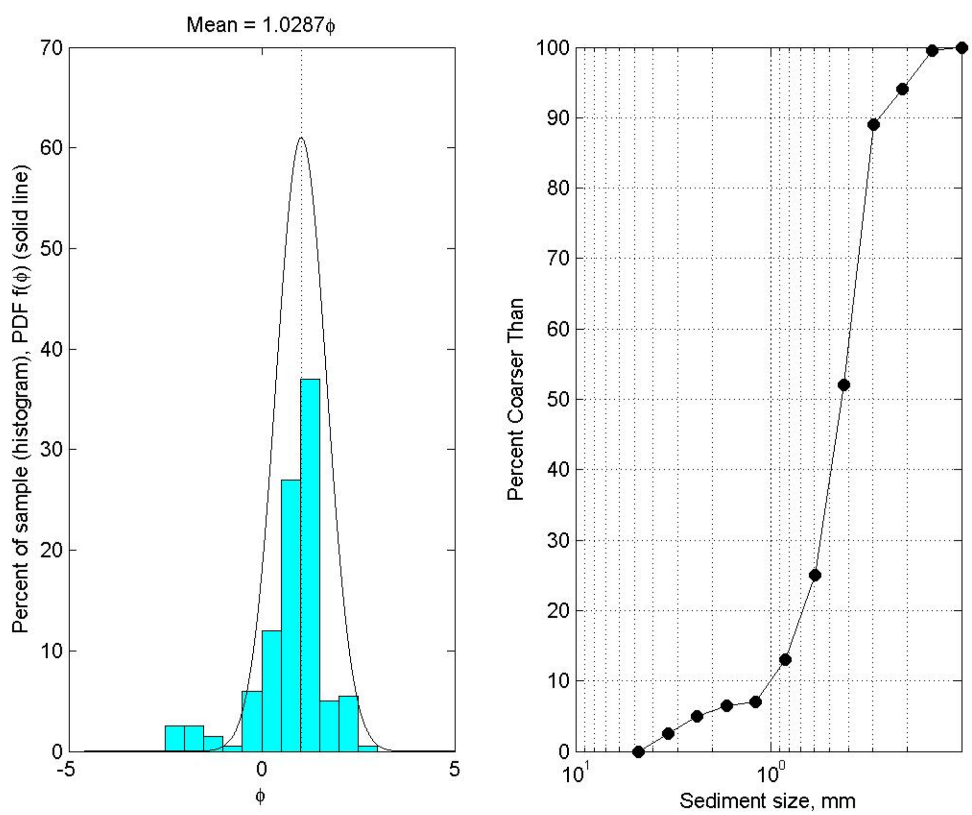
There are only 8 data points in the cumulative distribution with the bin size not equally spaced. Typically, sediment is sieved at ¼ or ½ $\phi$ intervals, so make the assumption that the distribution is log-normal between the data points and 'sample' the cumulative distribution at ½ $\phi$ intervals from –2.5 to 3.5.

The distribution is developed by realizing that, for instance, the percent finer than 3.0$\phi$ minus percent finer than 3.5$\phi$ must be the % sediment captured in the 3.5$\phi$ hypothetical sieve. Extend this reasoning to all phi bins and develop a distribution by visually extracting the % finer values from Figure 2.8.

The % sediment in each bin is calculated as described above such that the % sediment in a given row is the % caught in that sieve. For example the value of 0.5 for 3.5$\phi$ row is the sediment that would fall through the 3.0$\phi$ sieve but be caught in the 3.5$\phi$ sieve. The $\phi$ at bin center is the average $\phi$ value between the sieve that the sediment fell through and the sieve it was caught in since we do not seek to subdivide the sediment further than ½$\phi$ intervals here.

| ϕ | d, mm | % finer than | % sediment in each bin | ϕ at bin center |
|---|---|---|---|---|
| 3.5 | 0.09 | 0 | 0.5 | 3.25 |
| 3.0 | 0.13 | 0.5 | 5.5 | 2.75 |
| 2.5 | 0.18 | 6.0 | 5 | 2.25 |
| 2.0 | 0.25 | 11.0 | 37 | 1.75 |
| 1.5 | 0.35 | 48.0 | 27 | 1.25 |
| 1.0 | 0.50 | 75.0 | 12 | 0.75 |
| 0.5 | 0.71 | 87.0 | 6 | 0.25 |
| 0.0 | 1.00 | 93.0 | 0.5 | -0.25 |
| -0.5 | 1.40 | 93.5 | 1.5 | -0.75 |
| -1.0 | 2.00 | 95.0 | 2.5 | -1.25 |
| -1.5 | 2.82 | 97.5 | 2.5 | -1.75 |
| -2.0 | 4.00 | 100 | 0 | -2.25 |
| -2.5 | 5.7 | 100 | 0 | |

The resulting distribution and reconstructed cumulative distribution at ½ϕ intervals:



4) DD 2.8

**A sand grain settling in a fluid with a high concentration of like sand grains falls slower than if it were the only settling grain (Richardson and Zaki, 1954). Explain why.**

There are several reasons with 2 given here:

Assuming still water, the force balance relates to the weight of the grain, the buoyancy force and the drag force. The weight of the sand grain in question will not change if the fluid is sediment rich, but the buoyancy force will because it is related to the density of the surrounding fluid that now is sediment rich.

As an example, Assume we have a fluid with initial density of $\rho$ in a finite tank of volume, 1 $m^3$. Then if we remove say $\varepsilon$, for $\varepsilon < 1$ portion of the pure fluid leaving $(1-\varepsilon)$ in the tank and replace the $\varepsilon$ portion with sediment we still have 1 $m^3$ of material. Vigorously shake the tank such that sediments are uniformly distributed within the fluid. The density becomes (assuming 1035 kg $m^{-3}$ for seawater and 2650 kg $m^{-3}$ for sediment) $(1-\varepsilon)*1035$ kg $m^{-3}$ + $\varepsilon *2650$ kg $m^{-3}$ which is more dense than the original fluid. As fluid density increases, the fall velocity decreases so that in a homogenous mixture of fluid and sediment, the sand grain will fall slower.

In addition, falling grains displace water thus inducing an upward fluid velocity. This upward velocity tends to slow falling grains.

5) Write a Matlab function that will take an input of phi sizes and corresponding weights or phi sizes and corresponding percent of sample and return the mean, median, skewness, kurtosis, make a histogram of the input sample and make a cumulative sand size distribution on a semilog plot.

Test your code for DD2.7. Turn in your code and results.

```
function [stats]=sedstats2(phisize,prc,flagtest);
%
%function [stats]=sedstats2(phisize,prc,flagtest);
%or
%function [stats]=sedstats2([],[],1);  % to run a test using data from Dean and
%Dalrymple homework
%
%input:
%    phisize - the phis size from the sediment bins
%    prc - the associated percent of sample for said bins (not fraction)
%        NOTE, phis size should start with finest.
%    flagtest - 0 will test the data from Dean and Dalrymple
%             - 1 will test data from a perfect log-normal dist
```

```
%       example: [stats]=sedstats2([],[],1)
%%       example: [stats]=sedstats2([],[],0)
%
%output:
%     stats - a vector of stats contaning in order median, mean, sorting
%     (phi units),  skewness, and kurtosis

%% test for the hw problem in Dean and Dalrymple
if nargin ==3
   if flagtest==0
      phisize=3.25:-.5:-2.25; %centers between sieve sizes
      prc=[0 .5 5.5 5 37 27 12 6 .5 1.5 2.5 2.5];
   elseif flagtest==1 % log normal
      phisize=10:-0.01:-10; %centers between sieve sizes
      mun=0.5; % a mean of 0.5
      sign=1;  % a sorting of 1
      prc=1/(sign*sqrt(2*pi))*exp( -(phisize-mun).^2/(2*sign^2)   );
      prc=prc/sum(prc) * 100;   % to get to percent
       % NOTE, the bar plot and histogram will not look correct
       % because I scaled here to make cumulative percent be 100
   else
      disp('wrong input for flagtest');
      stats=[];
      return
   end
end

%make sure phisize and prc are the same oreintation
[m,n]=size(phisize);
if m==1;   % means a column
   phisize=phisize';  % transpose
   prc=reshape(prc,size(phisize));
end

%% sed sizes in mm
sedsize=2.^(-phisize);   % sediment size

%% determine the required phi's and percent coarser for stats
%% we need phi (5,16,50,84,95);

%% step 1 - cumulative distribution
cumprc=100-cumsum(prc);  % gets us to percent coarser

% % %% flip phis size and sed size so they match percent coarser
% phisize=flipud(phisize);
% sedsize=flipud(sedsize);
```

```
% step 1 - interp to required phi sizes
prcstat=[5 16 50 84 95];  % the percents of interest

% unfortunatley we cannot take advatage of matlabs built in interpolation
% because we may have duplicate cumprc and the data must be unique.
% approach by brute force

% set up dummy indices
i=2:length(cumprc);
i_1=1:length(cumprc)-1;

for k=1:length(prcstat)  % once for each of interest
   clear l

   l=find(cumprc(i)<=prcstat(k) & cumprc(i_1)>prcstat(k));

   %% now direct interp between locs l and l+1
   phistat(k)=interp1(cumprc(l:l+1),(phisize(l:l+1)),prcstat(k));
   % could have taken interp as log10(2.^-phisize) and then undone later,
   % but would get same answer as doing interp using plain old phi
end  % k loop


%% now use formulas to determine stats
% median - stats(1)
stats(1)=phistat(3);

% mean - stats(2)
stats(2)=(phistat(4)+phistat(2) )/2;

% sorting - stats(3)
stats(3)=(phistat(4)-phistat(2) )/2;

% skewness - stats(4)
stats(4)=(stats(2)-stats(1) )/stats(3);

% kurtosis - stats(5)
stats(5)=((phistat(2)-phistat(1)) + (phistat(5)-phistat(4)) )/(2*stats(3));


%%%%%%%%%%%%plot below here
clf
subplot(121)
colo=[.7 .7 .7];
bar(phisize,prc,1,'c');
```

```
hold on

phin=-5:.001:5;
sign=stats(3);
mun=stats(2);
f_phi=1/(sign*sqrt(2*pi))*exp( -(phin-mun).^2/(2*sign^2)   );
plot(phin,f_phi*100,'k');
ax=axis;
plot([mun mun],[ax(3) ax(4)],':k');
xlabel('\phi')
ylabel('Percent of sample (histogram), PDF f(\phi) (solid line)');
title(['Mean = ', num2str(mun), '\phi']);

subplot(122)
semilogx(2.^(-phisize),cumprc,'k');
hold on
h=semilogx(2.^(-phisize),cumprc,'ko');
set(h,'MarkerFaceColor','k');
set(gca,'XDir','reverse');
grid on
xlabel('Sediment size, mm');
ylabel('Percent Coarser Than');
axis([0 10 0 100]);
```