Flow Mechanics: Velocity Profiles Exercise

Complete the following exercises during lab or before the next class meeting. The exercise is intended to give you practice working with the relationships you have seen derived in class before you are asked to analyze field data from the Baker River. You may work together as you practice the mechanics involved, but turn in your own work as it will be graded.

Problem 1. Derive the relationship between $C_f$ (the generalized non-dimensional Darcy-Weisbach friction factor) and the ratio $\overline{u}/u_*$.

Problem 2. Using the relationships for $C_f$, $u(z)$, $\overline{u}$, $\tau_b$, and $u_*$ to derive the relationship between $C_f$ and the roughness parameter $z_o$, for the case of a very wide, rectangular channel. Comment briefly on the relationship (i.e. is there any obvious weakness in the bulk friction factor $C_f$?).

Problem 3. Derive the relationship between $C_f$ and Manning’s $n$. Comment briefly on Manning’s $n$. 
Problem 4. Using the above relationships, the Law of the Wall, and assuming steady, uniform flow, determine the following from the data given below: Slope (S), average velocity ($\bar{u}$), basal shear stress ($\tau_b$), shear velocity ($u_*$), roughness height ($z_o$), friction factor ($C_f$), and Manning’s n. Assume hydraulically rough flow over a plane-bed gravel channel (i.e. that $z_o = D_{84}/30$). How does the value of n compare to the tables given in your handout? How does the value of $C_f$ compare to Leopold’s relationship for $f$ as a function of grainsize and flow depth (see attached graph and equation)?

Grainsize $D_{84} = 128\text{ mm}$ (large cobbles)
Flow depth = 1.0 m

Measured Velocity Profile (cm/s):

$u(0.1) = 180$; $u(0.3) = 210$; $u(0.5) = 300$; $u(0.7) = 270$; $u(0.9) = 240$

$S =$

$\bar{u} =$

$\tau_b =$

$u_* =$

$z_o =$

$C_f =$

$n =$

Confirm that the assumption of hydraulically rough flow (HFR $\Rightarrow z_o = D_{84}/30$) is valid (see your roughness handout).