BIE 5300/6300 Assignment #5
Open-Channel Constriction Calibrations

06 Oct 04 (due 12 Oct 04)

Show your calculations in an organized and neat format. Indicate any assumptions or relevant comments.

You have measured data in a spreadsheet file (attached) for an open-channel constriction (non-orifice flow). One data set is for free-flow conditions, the other for submerged-flow.

I. Develop a free-flow rating for this constriction using the following equation:

$$Q_f = C_f h_u^{n_f}$$

- (a) Determine C_f and n_f.
- (b) Make a graph with plotted symbols for $(Q_f)_{measured}$ vs. $(Q_f)_{calculated}$. The ordinate range should be the same as the abscissa range, with a diagonal line representing $(Q_f)_{measured}/(Q_f)_{calculated} = 1.0$.
- (c) Comment on the data fit, using correlation or other such indices, as appropriate.

II. Develop a submerged-flow rating for this constriction using the following equation:

$$Q_s = \frac{C_s\left(h_u - h_d\right)^{n_f}}{\left(-\log_{10} S\right)^{n_s}}$$

- (a) Determine C_s and n_s, using n_f from the free-flow rating.
- (b) Make a graph with plotted symbols for $(Q_s)_{measured}$ vs. $(Q_s)_{calculated}$. The ordinate range should be the same as the abscissa range, with a diagonal line representing $(Q_s)_{measured}/(Q_s)_{calculated} = 1.0$.
- (c) Comment on the data fit, using correlation or other such indices, as appropriate.

III. Solve for transition submergence, S_t, for the above calibration.

- (a) Determine S_t.
- (b) Make a graph of S_t (from 0.1 to 0.99 on the abscissa) vs. the function value ($Q_f - Q_s = 0$) and indicate where the solution(s) exist, if any.
- (c) If you don't get any solution for S_t, try adjusting C_s slightly so that you get a solution. If you do this, show the adjusted C_s value.

IV. Re-do the submerged-flow rating using the following equation:

$$Q_s = \frac{C_s\left(h_u - h_d\right)^{n_{s1}}}{\left(-\log_{10} S\right)^{n_{s2}}}$$

(a) Determine C_s, n_{s1} and n_{s2} based only on the submerged-flow data.
(b) Make a graph with plotted symbols for $(Q_s)_{measured}$ vs. $(Q_s)_{calculated}$. The ordinate range should be the same as the abscissa range, with a diagonal line representing $(Q_s)_{measured}/(Q_s)_{calculated} = 1.0$.
(c) Comment on the data fit, using correlation or other such indices, as appropriate.
(d) Comment on the data fit using this equation, as opposed to using the Q_s equation from (II) above.

Solutions:

I. Develop a free-flow rating for this constriction using the following equation:

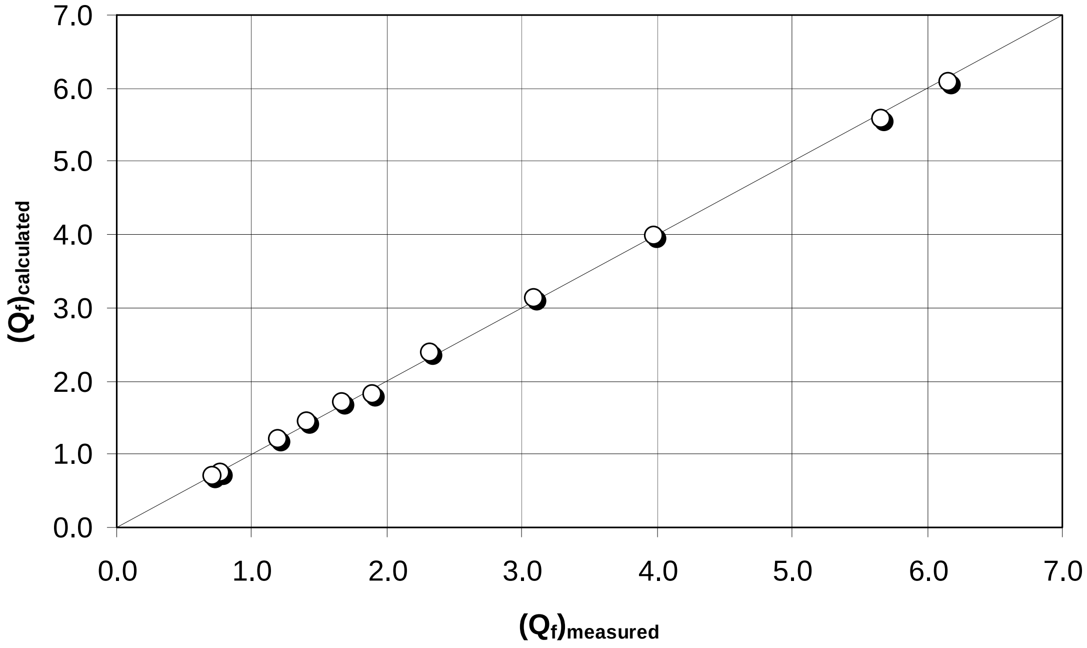
$$Q_f = C_f h_u^{n_f}$$

Make two new columns for ln(Q_f) and ln(h_u) in the spreadsheet. Do a linear regression using the LINEST spreadsheet function. The regression gives:

C_f= 5.57
n_f = 1.61

for Q_f in cfs; and h_u in ft.

The R^2 value is 0.999, indicating a very good fit, and this is also seen in the comparison graph:



II. Develop a submerged-flow rating for this constriction using the following equation:

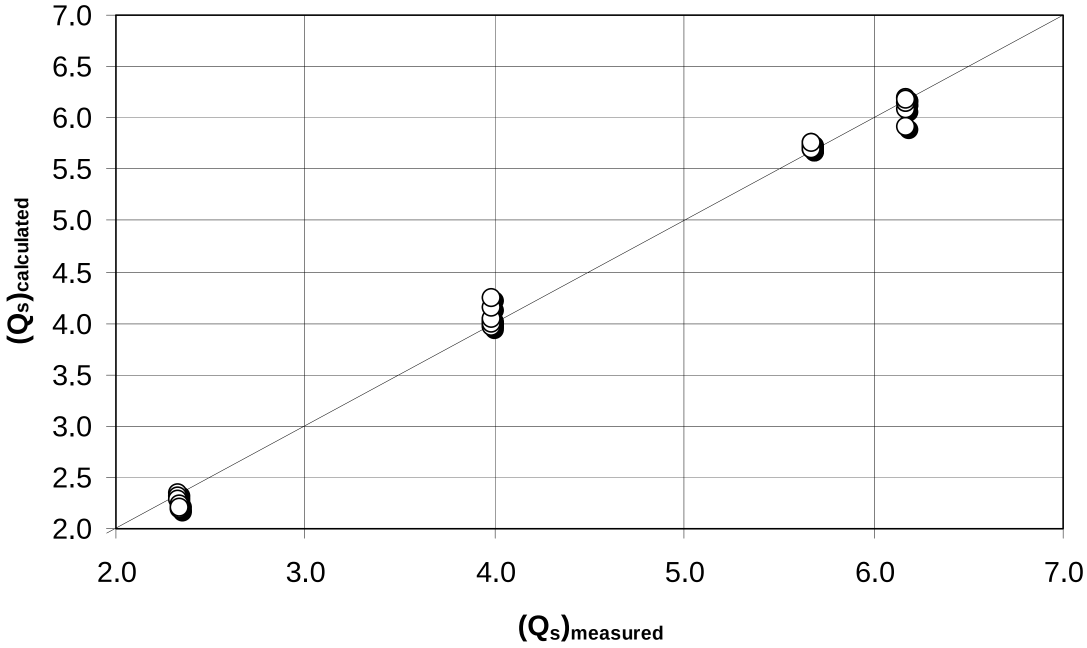
$$Q_s = \frac{C_s (h_u - h_d)^{n_f}}{(-\log_{10} S)^{n_s}}$$

Make two new columns for ln($Q_s/(h_u-h_d)^{nf}$) and ln(-$\log_{10}S$) in the spreadsheet. Do a linear regression using the LINEST spreadsheet function. The regression gives:

$C_s = 2.62$
$n_s = 1.43$

for Q_s in cfs; and h_u & h_d in ft.

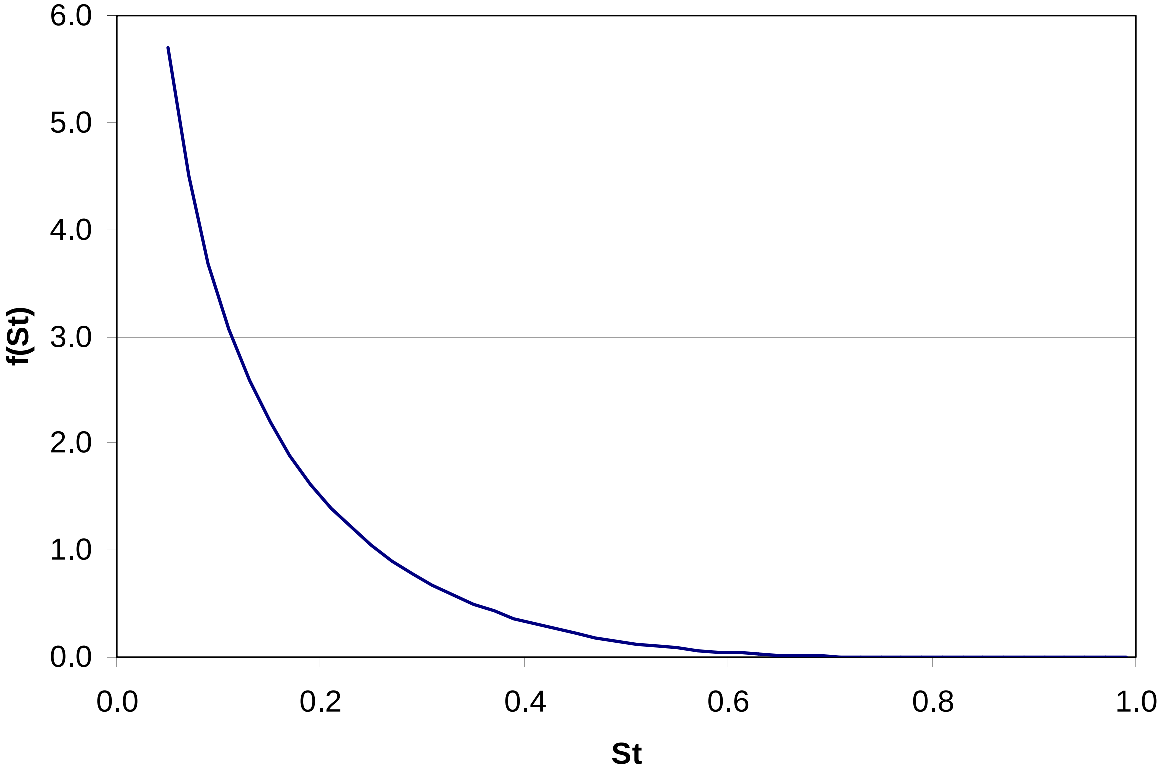
The R^2 value is 0.999, indicating a very good fit, and this is also seen in the comparison graph:

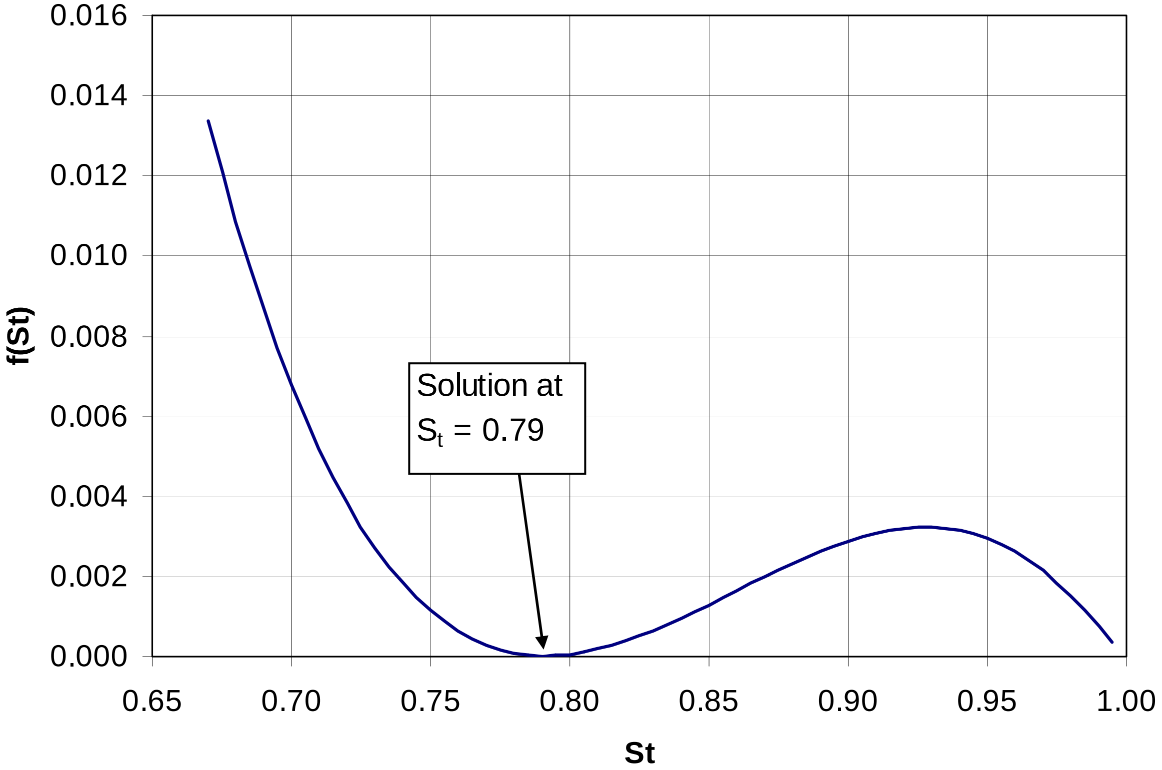


III. Solve for transition submergence, S_t, for the above calibration.

Use the equation for $f(S_t) = 0$, as shown in the lecture notes. This equation is derived by setting $Q_f = Q_s$. Make a table of S_t versus $f(S_t)$, then plot the results. The only solution is for $S_t = 1.00$, which is mathematically correct, but physically impossible.

Adjust C_s slightly, from 2.62 to 2.639, whereby a solution is found at about $S_t \approx 0.79$, as shown in the next graph.


6.0
5.0
4.0
3.0
2.0
1.0
0.0
f(St)
0.0
0.2
0.4
0.6
0.8
1.0
St


0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
f(St)
Solution at
S_t = 0.79
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
St

IV. Re-do the submerged-flow rating using the following equation:

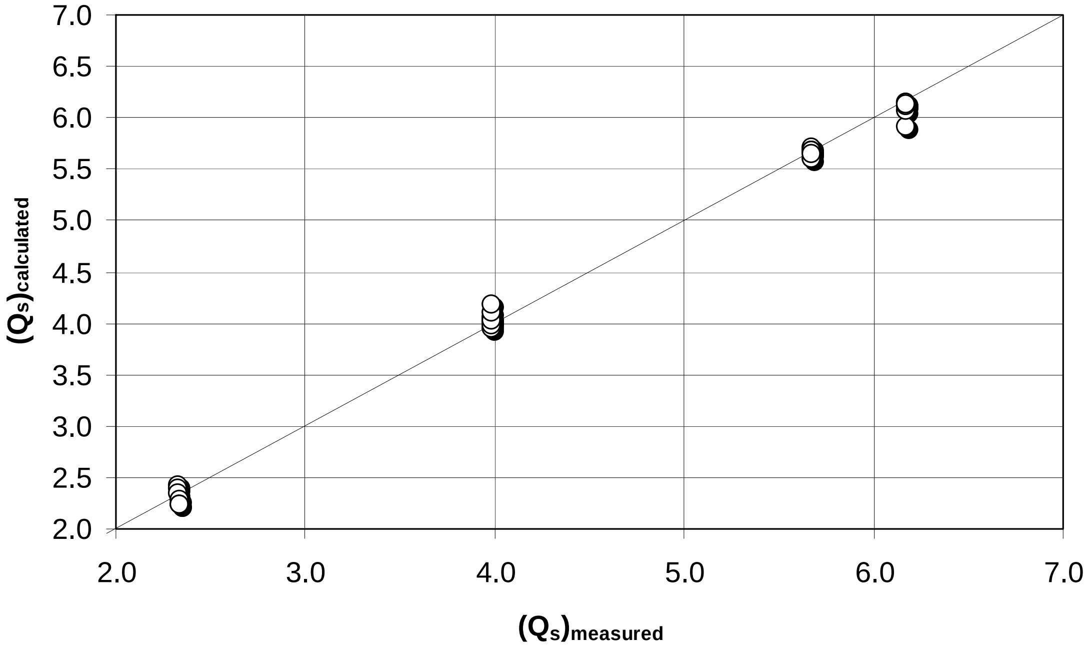
$$Q_s = \frac{C_s\left(h_u - h_d\right)^{n_{s1}}}{\left(-\log_{10} S\right)^{n_{s2}}}$$

Make three new columns for ln(Q_s), ln(h_u-h_d), and ln(-$\log_{10}$S) in the spreadsheet. Do a multiple linear regression using the LINEST spreadsheet function. The regression gives:

C_s= 2.78
n_{s1} = 1.54
n_{s2} = 1.36

for Q_s in cfs; and h_u & h_d in ft.

The R^2 value is 0.996, indicating a very good fit, and this is also seen in the comparison graph, which is very similar to the previous plot:



Even though the R^2 value is slightly lower than for the previous form of the submerged-flow equation, the sum of absolute deviations in measured and calculated discharges is less in this case.