

## 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  $(Q_f)_{\text{measured}}$  vs.  $(Q_f)_{\text{calculated}}$ . The ordinate range should be the same as the abscissa range, with a diagonal line representing  $(Q_f)_{\text{measured}}/(Q_f)_{\text{calculated}} = 1.0$ .
- (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:

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

- (a) Determine  $C_s$  and  $n_s$ , using  $n_f$  from the free-flow rating.
- (b) Make a graph with plotted symbols for  $(Q_s)_{\text{measured}}$  vs.  $(Q_s)_{\text{calculated}}$ . The ordinate range should be the same as the abscissa range, with a diagonal line representing  $(Q_s)_{\text{measured}}/(Q_s)_{\text{calculated}} = 1.0$ .
- (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:

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

- (a) Determine  $C_s$ ,  $n_{s1}$  and  $n_{s2}$  based only on the submerged-flow data.
- (b) Make a graph with plotted symbols for  $(Q_s)_{\text{measured}}$  vs.  $(Q_s)_{\text{calculated}}$ . The ordinate range should be the same as the abscissa range, with a diagonal line representing  $(Q_s)_{\text{measured}}/(Q_s)_{\text{calculated}} = 1.0$ .
- (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:

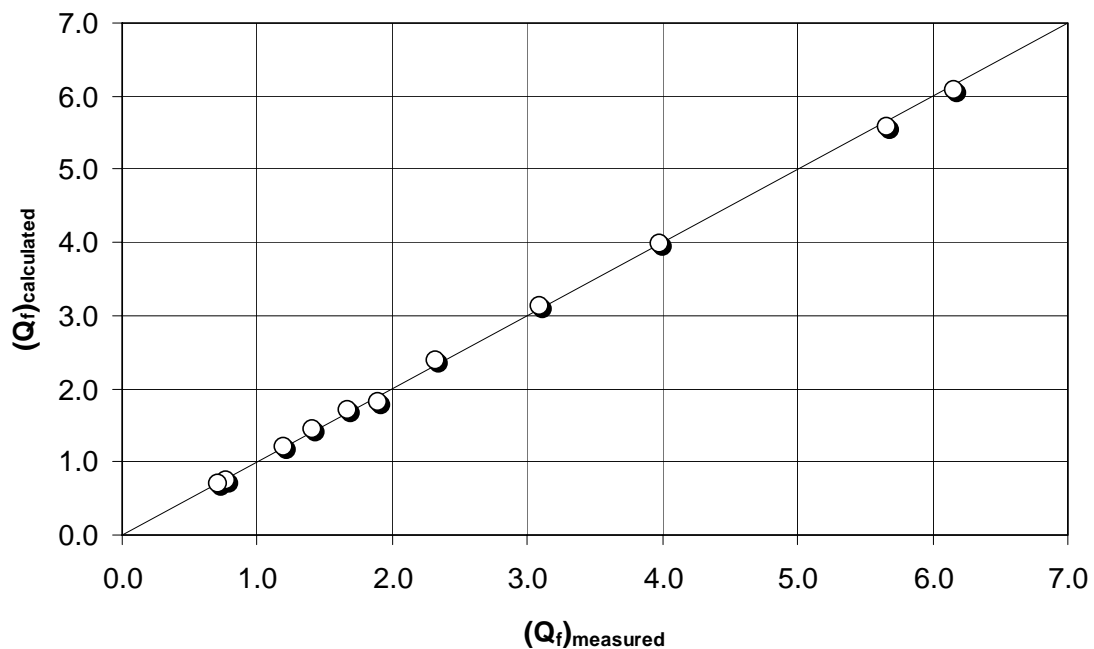
$$Q_f = C_f h_u^{n_f}$$

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:

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

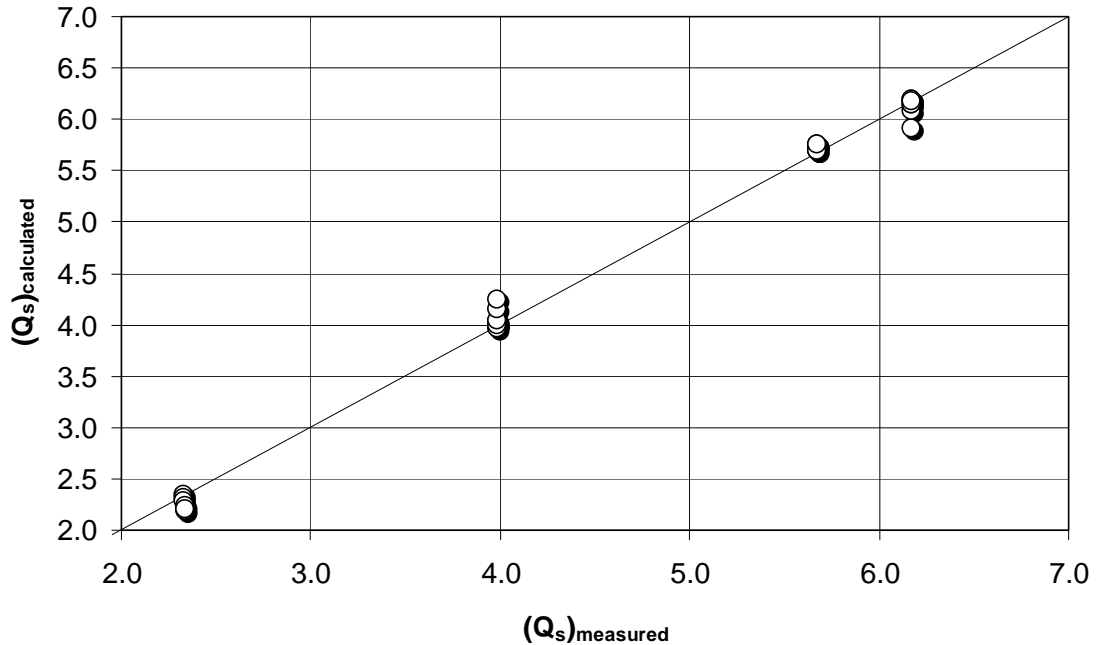
Make two new columns for  $\ln(Q_s/(h_u - h_d)^{n_f})$  and  $\ln(-\log_{10} S)$  in the spreadsheet. Do a linear regression using the LINEST spreadsheet function. The regression gives:

$$C_s = 2.62$$

$$n_s = 1.43$$

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

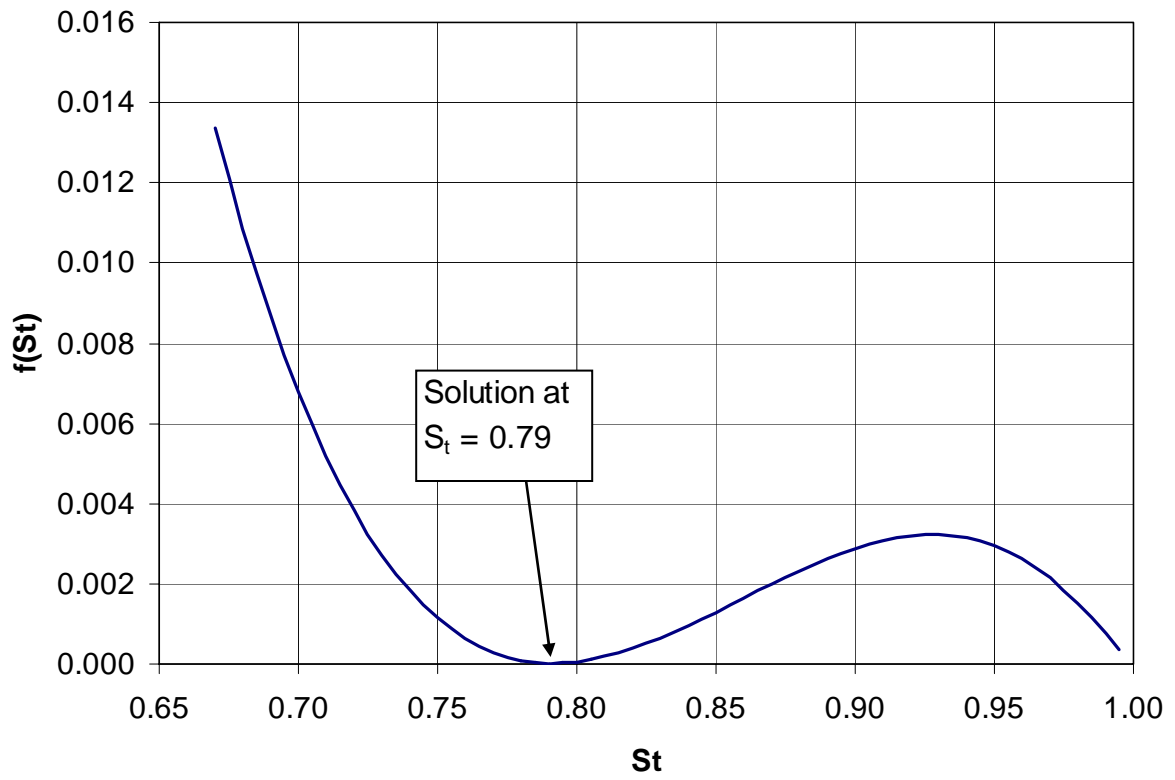
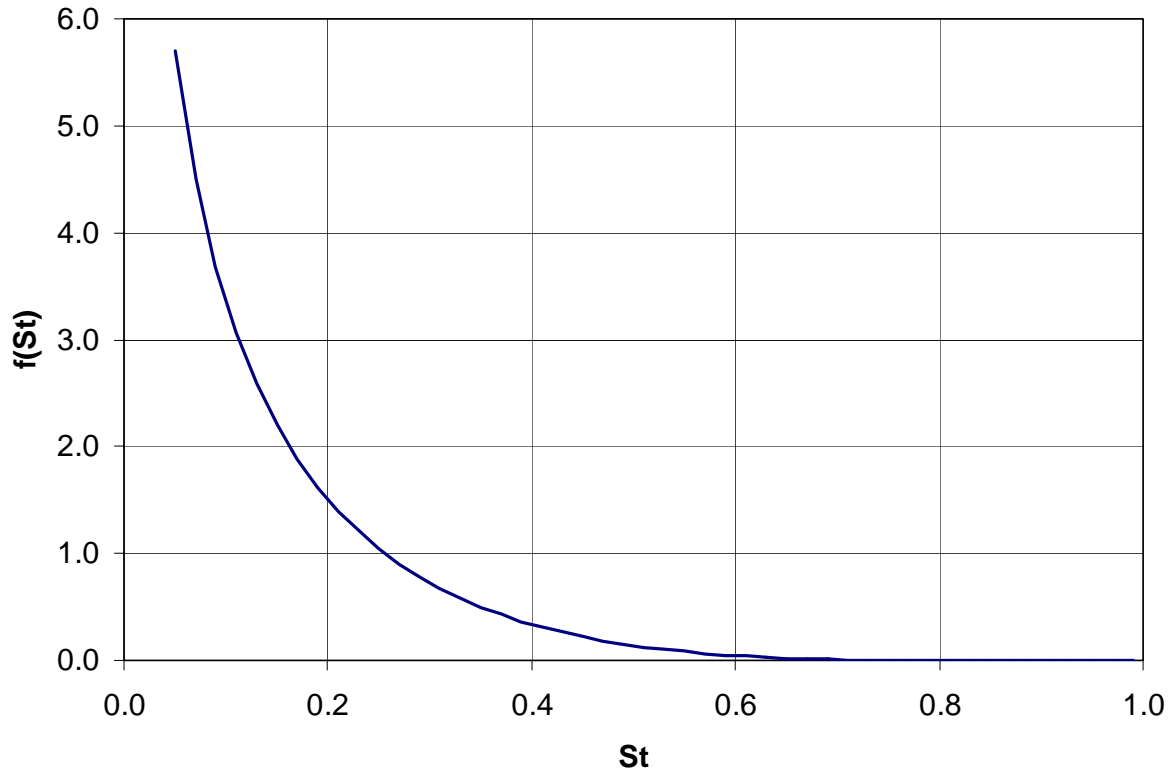
The  $R^2$  value is 0.999, indicating a very good fit, and this is also seen in the comparison graph:



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.



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

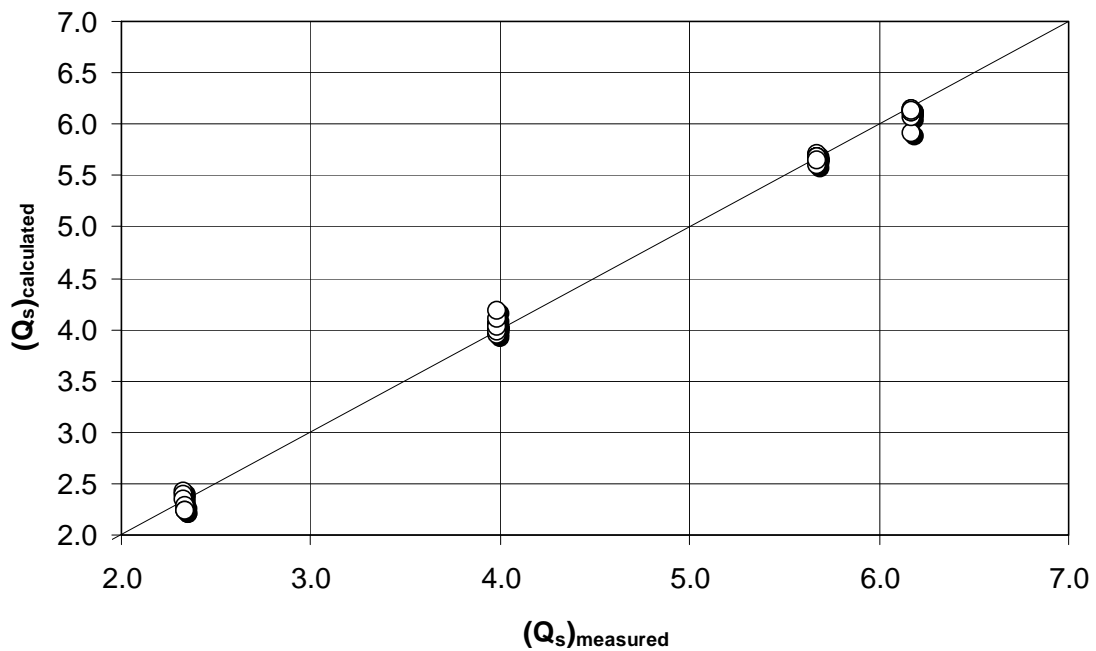
$$Q_s = \frac{C_s (h_u - h_d)^{n_{s1}}}{(-\log_{10} S)^{n_{s2}}}$$

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:

$$\begin{aligned} C_s &= 2.78 \\ n_{s1} &= 1.54 \\ n_{s2} &= 1.36 \end{aligned}$$

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.