Equations for computing submerged flow in Parshall flumes

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Preface: The information provided below is intended for use with *existing* Parshall flumes operating in the submerged-flow correction zone. *If you are contemplating construction of a new Parshall flume, you are strongly urged to consider a long-throated flume. Information about long-throated flumes is available on the WinFlume home page.*

Figures 8-16 and 8-17 in the new Water Measurement Manual provide a means for correcting free-flow discharges through Parshall flumes to account for the effect of submergence.

Figure 8-17 is for flumes of 10-ft width, with multiplying factors for larger flumes up to 50-ft width, and can be easily converted to equation form:

$$Q_{correction} = \frac{W}{10} X h_a^2$$

$$X = \left(3.364 + 20.19 S^2 \ln S\right)^2$$

or

$$X = -308.12 + 1212.85(S) - 1597.529(S^2) + 704.083(S^3)$$

where $Q_{correction}$ is the discharge reduction in ft^3/s, h_a is the upstream head in feet, W is the flume width in feet, and S is the submergence ratio, h_b/h_a. Either expression for X works well; different dataloggers may accept one more readily than the other.

The free flow discharge, Q_{free}, is computed using established formulas, and the net submerged flow is then $Q_{net} = Q_{free} - Q_{correction}$

Figure 8-16 is for flumes of 1-ft width, and includes multiplying factors for use with flumes of 2- to 8-ft width. Figure 8-16 is more difficult to convert to an equation form, due to its non-linear nature (in log-log space) at low upstream heads and low submergences. Hilaire Peck (1988, PAP-523) tested 1-ft Parshall flumes and developed an equation to compute discharge reductions due to submergence:

$$Q_{correction} = 0.000132 h_a^{2.123} e^{9.284S}$$

where e is the base of natural logarithms, 2.7183. This equation yields smaller discharge reductions and does not have the non-linear character of Parshall's chart (Fig. 8-16).

Converting Figure 8-16 to a tractable equation would be a tedious exercise. Also, Peck's more detailed experiments on 1-ft flumes indicate less discharge reduction due to submergence than do Parshall's limited data, making the value of such an effort questionable. More detailed physical testing is needed to extend Peck's data for use on 2- to 8-ft wide flumes. However, in the interim, it is reasonable to use Peck's equation for 1-ft wide flumes and the multiplying factors shown on Figure 8-16 to obtain discharge corrections for 2- to 8-ft wide flumes, with one caveat. Peck's equation is only valid for flow conditions on the right side of the discontinuity that he observed in submerged flow rating curves (i.e., submergences less than about 85 to 90 percent). (Note: Peck has an equation applicable to the left side of the discontinuity, but procedures for defining the exact point of discontinuity are not well defined.)

Thus, for flumes of 1- to 8-ft width the discharge reduction in ft^3/s can be computed using:

$$Q_{correction} = M\left(0.000132 h_a^{\,2.123} e^{9.284S}\right)$$

where M is a multiplying factor that varies as follows:

Size of Flume, W (feet)	Multiplying Factor, M
1	1.0
1.5	1.4
2	1.8
3	2.4
4	3.1
5	3.7
6	4.3
7	4.9
8	5.4