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3.31. Flow in a rectangular open channel is choked when

$$\begin{aligned}
E_1 &= E_2 + \Delta z_c \\
y_1 + \frac{V_1^2}{2g} &= \frac{3}{2}y_c + \Delta z_c \\
y_1 + \frac{V_1^2}{2g} &= \frac{3}{2}\left(\frac{q^2}{g}\right)^{1/3} + \Delta z_c \\
y_1 + \frac{V_1^2}{2g} &= \frac{3}{2}\left(\frac{Q^2}{gb^2}\right)^{1/3} + \Delta z_c \\
y_1 + \frac{V_1^2}{2g} &= \frac{3}{2}\left[\frac{(V_1 b y_1)^2}{gb^2}\right]^{1/3} + \Delta z_c \\
y_1 + \frac{V_1^2}{2g} &= \frac{3}{2}\frac{(V_1^{2/3} y_1^{2/3})}{g^{1/3}} + \Delta z_c
\end{aligned}$$

Dividing by y_1 yields

$$1 + \frac{V_1^2}{2gy_1} = \frac{3}{2}\left(\frac{V_1^2}{gy_1}\right)^{1/3} + \frac{\Delta z_c}{y_1} \tag{1}$$

and defining

$$\text{Fr}_1 = \frac{V_1}{\sqrt{gy_1}}$$

then Equation 1 can be written as

$$\boxed{\frac{\Delta z_c}{y_1} = 1 + \frac{\text{Fr}_1^2}{2} - \frac{3}{2}\text{Fr}_1^{2/3}}$$

From Problem 3.30: $b = 3$ m, $Q = 4$ m^3/s, $y_1 = 1.5$ m, and $\Delta z_c = 0.15$ m. Therefore

$$\begin{aligned}
V_1 &= \frac{Q}{by_1} = \frac{4}{(3)(1.5)} = 0.889 \text{ m/s} \\
\text{Fr}_1 &= \frac{V_1}{\sqrt{gy_1}} = \frac{0.889}{\sqrt{(9.81)(1.5)}} = 0.232
\end{aligned}$$

which yields

$$\begin{aligned}
\frac{\Delta z_c}{y_1} &= 1 + \frac{\text{Fr}_1^2}{2} - \frac{3}{2}\text{Fr}_1^{2/3} \\
\frac{\Delta z_c}{1.5} &= 1 + \frac{(0.232)^2}{2} - \frac{3}{2}(0.232)^{2/3}
\end{aligned}$$

and solving for Δz_c gives

$$\boxed{\Delta z_c = 0.69 \text{ m}}$$