

CEE 3500 – Fall 2005 – Final Exam

Name: KEY Code: \_\_\_\_\_

Enter your answer in this answer sheet by CIRCLING the correct answer. DO NOT FILL the circle. Turn in the answer sheet only. You can keep the rest of the exam.

ANSWER SHEET

- |      |     |     |     |     |      |     |     |     |     |
|------|-----|-----|-----|-----|------|-----|-----|-----|-----|
| [1]  | (a) | (b) | (c) | (d) | [15] | (a) | (b) | (c) | (d) |
| [2]  | (a) | (b) | (c) | (d) | [16] | (a) | (b) | (c) | (d) |
| [3]  | (a) | (b) | (c) | (d) | [17] | (a) | (b) | (c) | (d) |
| [4]  | (a) | (b) | (c) | (d) | [18] | (a) | (b) | (c) | (d) |
| [5]  | (a) | (b) | (c) | (d) | [19] | (a) | (b) | (c) | (d) |
| [6]  | (a) | (b) | (c) | (d) | [20] | (a) | (b) | (c) | (d) |
| [7]  | (a) | (b) | (c) | (d) | [21] | (a) | (b) | (c) | (d) |
| [8]  | (a) | (b) | (c) | (d) | [22] | (a) | (b) | (c) | (d) |
| [9]  | (a) | (b) | (c) | (d) | [23] | (a) | (b) | (c) | (d) |
| [10] | (a) | (b) | (c) | (d) | [24] | (a) | (b) | (c) | (d) |
| [11] | (a) | (b) | (c) | (d) | [25] | (a) | (b) | (c) | (d) |
| [12] | (a) | (b) | (c) | (d) | [26] | (a) | (b) | (c) | (d) |
| [13] | (a) | (b) | (c) | (d) | [27] | (a) | (b) | (c) | (d) |
| [14] | (a) | (b) | (c) | (d) | [28] | (a) | (b) | (c) | (d) |
|      |     |     |     |     | [29] | (a) | (b) | (c) | (d) |
|      |     |     |     |     | [30] | (a) | (b) | (c) | (d) |

Time : 1 hr 5min to finish  
 used by instructor  
 to finish exam

Select the correct answer for the following 14 questions. Circle your answer in the answer sheet.

[1]. In Newton's law of viscosity,  $\tau = \mu \frac{du}{dy}$ ,  $\tau$  is the shear stress,  $du/dy$  is the velocity gradient, and  $\mu$  is the \_\_\_\_\_.

- (a) bulk modulus of elasticity      (b) surface tension  
(c) absolute viscosity              (d) kinematic viscosity

[2]. A barometer is an instrument used to measure \_\_\_\_\_.

- (a) flow velocity      (b) atmospheric pressure      (c) absolute viscosity      (d) fluid density

[3]. Kinematic viscosity has dimensions of \_\_\_\_\_.

- (a) length<sup>2</sup>/time (L<sup>2</sup>/T)      (b) mass-length<sup>2</sup>/time (ML<sup>2</sup>/T)      (c) length/time (L/T)      (d) length/time<sup>2</sup> (L/T<sup>2</sup>)

[4]. Which of the following instruments would you use to measure pressure?

- (a) propeller meter      (b) v-notch weir      (c) rotameter      (d) Bourdon gage

[5]. The velocity  $V$  in a pipe of diameter  $D$  carrying a discharge  $Q$  is given by

- (a)  $\frac{4 \cdot Q}{\pi \cdot D^4}$       (b)  $\frac{\pi \cdot Q}{4 \cdot D^4}$       (c)  $\frac{4 \cdot Q}{\pi \cdot D^2}$       (d)  $\frac{4 \cdot Q}{\pi \cdot D^5}$

[6]. Which of the following devices is not used to measure discharge (or flow rate) in a pipeline:

- (a) rotameter      (b) broad-crested weir      (c) orifice plate      (d) elbow meter
- ↑ right answer

[7]. The velocity distribution  $v(r)$  in a pipeline of radius  $r_o$  is given by the equation:

- (a)  $v_{max} \cdot (1 - r/r_o)$       (b)  $v_{max} \cdot (1 - (r/r_o)^3)$       (c)  $v_{max} \cdot (1 - (r/r_o)^2)$       (d)  $v_{max} \cdot (1 - \ln(r/r_o))$

[8]. What flow number would you use to design a model of a stilling basin in which a hydraulic jump will be created?

- (a) Weber                      (b) Reynolds                      (c) Mach                      (d) Froude

[9]. The Darcy-Weisbach equation is used to calculate friction head loss in a pipe. The expression for the Darcy-Weisbach equation in terms of the discharge  $Q$  in a pipe of diameter  $D$  and length  $L$  is:

(a)  $h_f = \frac{8fLQ^2}{\pi^2 g D^5}$       (b)  $h_f = \frac{32fLQ^2}{\pi^2 g D^5}$       (c)  $h_f = \frac{8fLQ^5}{\pi^2 g D^2}$       (d)  $h_f = \frac{8fLQ^2}{\pi g D^5}$

$V = \frac{4Q}{\pi D^2}$ ,  $\frac{V^2}{2g} = \frac{16Q^2}{\pi^2 D^4} \cdot \frac{1}{2g} = \frac{8Q^2}{\pi^2 g D^4}$ ,  $h_f = f \frac{L V^2}{D 2g} = f \frac{L}{D} \frac{8Q^2}{\pi^2 g D^4} = \frac{8fLQ^2}{\pi^2 g D^5}$

[10]. For a channel with an adverse slope ( $S_o < 0$ ), the critical depth of flow is:

- (a) finite                      (b) infinite                      (c) zero                      (d) none of the above

[11]. The ratio of the actual discharge to the ideal discharge in a sluice gate is referred to as the \_\_\_\_\_ coefficient.

- (a) Bernoulli                      (b) velocity                      (c) contraction                      (d) discharge

[12]. While analyzing gradually varied open channel flow you find that the channel has a steep slope. If the depth of flow at a point is measured to be  $y_o < y < y_c$  the gradually varied flow (GVF) curve is most likely to be a(n) \_\_\_\_\_ curve.

- (a) M1                      (b) S1                      (c) S2                      (d) S3



[13]. The discharge over an ogee spillway is calculated using the formula:

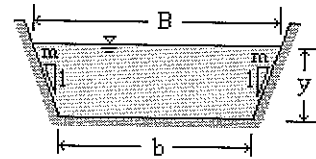
- (a)  $Q = C_w LH$       (b)  $Q = C_w LH^2$       (c)  $Q = C_w LH^{5/2}$       (d)  $Q = C_w LH^{3/2}$

[14]. If a pipe flow has a Reynolds number  $R = 1200$  then the flow is:

- (a) laminar                      (b) transitional                      (c) turbulent                      (d) none of the above

Solve the following four problems. The problems are numbered I, II, III, and IV. Each problem has four questions numbered as 15, 16, 17, and 18, for Problem I; 19, 20, 21, 22, for Problem II; 23, 24, 25, 26, for Problem III; and 27, 28, 29, and 30, for Problem IV. Select the closest numerical answer or the correct answer to each question. **Circle your answer in the answer sheet.**

**Problem [I].** A symmetric trapezoidal channel with a bottom width  $b = 10.5 \text{ ft}$  and a side slope  $m = 2$  carries water under uniform flow at a depth  $y_o = 2.5 \text{ ft}$ . The channel is laid on a slope of  $S_o = 0.00035 \text{ ft/ft}$ , and it's lined with concrete ( $n = 0.012$ ).



[15]. Calculate the discharge  $Q$  for this channel.

- (a) 172 cfs      (b) 132 cfs      (c) 152 cfs      (d) 102 cfs

[16]. Calculate the Froude number for the uniform flow.

- (a) 0.44      (b) 0.84      (c) 1.24      (d) 0.24

[17]. If the critical depth for this channel is  $y_c = 1.53 \text{ ft}$ , calculate the critical slope  $S_c$ .

- (a) 0.21000      (b) 0.02100      (c) 0.00210      (d) 0.00021

[18]. What type of slope does this channel have?

- (a) mild      (b) critical      (c) steep      (d) adverse

$$b = 10.5 \text{ ft}, m = 2, y_o = 2.5 \text{ ft}, S_o = 0.00035, n = 0.012$$

$$A = (b + my_o)y_o = (10.5 + 2 \times 2.5) \times 2.5 = 38.75 \text{ ft}^2$$

$$P = b + 2y_o\sqrt{1+m^2} = 10.5 + 2 \times 2.5 \times \sqrt{1+2^2} = 21.68 \text{ ft}$$

$$R_h = \frac{A}{P} = \frac{38.75 \text{ ft}^2}{21.68 \text{ ft}} = 1.79 \text{ ft}$$

$$B = b + 2my_o = 10.5 + 2 \times 2 \times 2.5 = 20.5 \text{ ft}$$

$$D_h = \frac{A}{B} = \frac{38.75 \text{ ft}^2}{20.5 \text{ ft}} = 1.89 \text{ ft}$$

$$[15] V = \frac{Q}{A} = \frac{132.35 \text{ cfs}}{38.75 \text{ ft}^2}$$

$$V = 3.42 \text{ fps}$$

$$[15] Q = \frac{1.486}{n} A R_h^{2/3} \sqrt{S_o} = \frac{1.486}{0.012} \times 38.75 \times 1.79^{2/3} \times \sqrt{0.00035} = 132.35 \text{ cfs.}$$

$$[17] \text{ For } y_c = 1.53 \text{ ft}, A_c = (b + my_c)y_c = (10.5 + 2 \times 1.53) \times 1.53 = 20.75 \text{ ft}^2$$

$$P_c = b + 2y_c\sqrt{1+m^2} = 10.5 + 2 \times 1.53 \times \sqrt{1+2^2} = 17.34 \text{ ft}$$

$$R_{hc} = \frac{A_c}{P_c} = \frac{20.75 \text{ ft}^2}{17.34 \text{ ft}} = 1.20 \text{ ft}, \text{ From Manning's eqn:}$$

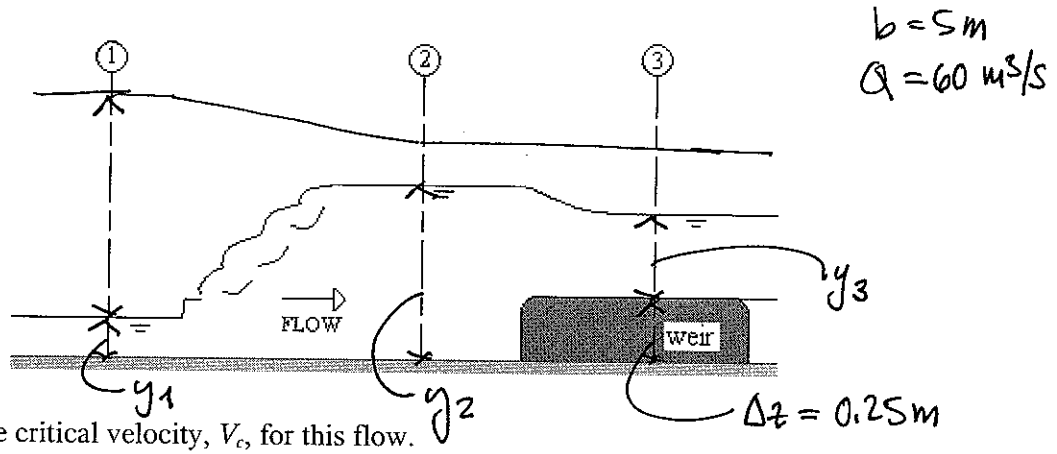
$$F_r = \frac{V}{\sqrt{gD_h}} = \frac{3.42}{\sqrt{32.2 \times 1.89}}$$

$$F_r = 0.44$$

$$S_c = \left( \frac{Qn}{1.486 A_c R_{hc}^{2/3}} \right)^2 = \left( \frac{132.35 \times 0.012}{1.486 \times 20.75 \times 1.20^{2/3}} \right)^2 = 0.00208 \approx 0.0021$$

[18] Since  $y_o = 2.5 \text{ ft}$   
 $> y_c = 1.53 \text{ ft}$

**Problem [II].** The figure below shows a rectangular channel of width  $b = 5 \text{ m}$  carrying a flow  $Q = 60 \text{ m}^3/\text{s}$ . A hydraulic jump with conjugate depths  $y_1$  and  $y_2$  occurs upstream of a  $0.25\text{-m}$ -high broad-crested weir (section 3).



[19]. Determine the critical velocity,  $V_c$ , for this flow.

- (a)  $2.9 \text{ m/s}$       (b)  $3.9 \text{ m/s}$       (c)  $4.9 \text{ m/s}$       (d)  $5.9 \text{ m/s}$

[20]. If the depth over the weir is the critical depth  $y_c$ , determine the depth of flow at section 2,  $y_2$ , assuming no energy losses between sections 2 and 3.

- (a)  $1.91 \text{ m}$       (b)  $3.21 \text{ m}$       (c)  $4.51 \text{ m}$       (d)  $5.71 \text{ m}$

[21]. Determine the conjugate depth  $y_1$  of the hydraulic jump using the value of  $y_2$  found in [20].

- (a)  $1.82 \text{ m}$       (b)  $0.82 \text{ m}$       (c)  $2.82 \text{ m}$       (d)  $3.82 \text{ m}$

[22]. Calculate the head loss across the hydraulic jump.

- (a)  $0.12 \text{ m}$       (b)  $0.02 \text{ m}$       (c)  $0.22 \text{ m}$       (d)  $0.32 \text{ m}$

[19],  $q = \frac{Q}{b} = \frac{60}{5} = 12 \text{ m}^2/\text{s}$ ,  $y_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{12^2}{9.806}} = 2.44 \text{ m}$ ,  $V_c = \frac{q}{y_c} = \frac{12}{2.44} = 4.92 \text{ m/s}$

[20].  $y_2 + \frac{q^2}{2g y_2^2} = y_3 + \frac{V_3^2}{2g} + \Delta z \Rightarrow y_3 = y_c = 2.44 \text{ m}, V_3 = V_c = 4.92 \text{ m/s}$   
 $y_3 + \frac{V_3^2}{2g} + \Delta z = 2.44 + \frac{4.92^2}{2 \times 9.806} + 0.25 = 3.92$   
 $\frac{q^2}{2g} = \frac{12^2}{2 \times 9.806} = 7.34$

$y_2 + \frac{7.34}{y_2^2} = 3.92$

Check possible solutions

$y_c \neq y_2 = 1.91, \text{ LHS} = 3.92,$   
 $y_c < y_2 = 3.21, \text{ LHS} = 3.92, \leftarrow \text{correct solution } y_2 = 3.21 \text{ m}$   
 $y_2 = 4.51, \text{ LHS} = 4.87$   
 $y_3 = 5.71,$

Problem [II] ... continued

$$[21] \quad y_1 = \frac{y_2}{2} \left( -1 + \sqrt{1 + \frac{8q^2}{\gamma y_2^3}} \right) = \frac{3.21}{2} \left( -1 + \sqrt{1 + \frac{8 \times 12^2}{1.806 \times 3.21^3}} \right) = 1.82 \text{ m}$$

$$[22] \quad \star \quad h_L = \frac{(y_2 - y_1)^3}{4y_1 y_2} = \frac{(3.21 - 1.82)^3}{4 \times 3.21 \times 1.82} = 0.115 \text{ m} \approx 0.12 \text{ m}$$

**Problem [III].** A rectangular open channel of width  $b = 10 \text{ ft}$ , laid on a slope  $S_o$ , carries a discharge  $Q = 40 \text{ cfs}$  in a gradually varied flow. The Manning's resistance coefficient is  $n = 0.020$ .

[23]. If a uniform flow were to occur in this channel the normal depth would be  $y_o = 2.56 \text{ ft}$ . Determine the bed slope  $S_o$ :

- (a) 0.22                      (b) 0.022                      (c) 0.0022                      **(d) 0.00022**

[24]. Determine the critical flow depth,  $y_c$ , for this channel:

- (a) 1.20 ft                      (b) 1.00 ft                      **(c) 0.80 ft**                      (d) 0.60 ft

[25]. At a section of the channel the depth of flow is  $y_1 = 3.0 \text{ ft}$ . Using a single step, determine the distance  $\Delta x$  from this section to another section where the depth of flow is  $y_2 = 3.3 \text{ ft}$ . Select the closest value for  $\Delta x$ :

- (a) 3000 ft**                      (b) 2000 ft                      (c) 1000 ft                      (d) 4000 ft

[26]. What type of gradually varied flow curve would exist between the two sections described above?

- (a) M1**                      (b) M2                      (c) M3                      (d) other

[23]  $b = 10 \text{ ft}$ ,  $Q = 40 \text{ cfs}$ ,  $n = 0.020$ ,  $y_o = 2.56 \text{ ft}$ ,  $S_o = ?$

$A = by_o = 10 \times 2.56 = 25.6 \text{ ft}^2$ ,  $P = b + 2y_o = 10 + 2 \times 2.56 = 15.12 \text{ ft}$

$R_h = \frac{A}{P} = \frac{25.6 \text{ ft}^2}{15.12 \text{ ft}} = 1.69 \text{ ft}$                        $Q = \frac{1.486}{n} A R_h^{2/3} S_o^{1/2} \Rightarrow S_o = \left( \frac{Qn}{1.486 A R_h^{2/3}} \right)^2$

$S_o = \left( \frac{40 \times 0.020}{1.486 \times 25.6 \times 1.69^{2/3}} \right)^2 = 0.00022$

[24]  $q = \frac{Q}{b} = \frac{40}{10} = 4 \text{ ft}^2/\text{s}$ ,  $y_c = \left( \frac{q^2}{g} \right)^{1/3} = \left( \frac{4^2}{32.2} \right)^{1/3} = 0.79 \text{ ft} \approx 0.80 \text{ ft}$

[26]  $y_o = 2.56 \text{ ft}$ ,  $y_c = 0.80 \text{ ft}$ ,  $y_s = 3.0 \text{ ft}$ ,  $y_e = 3.3 \text{ ft}$ , both  $y_s$  and  $y_e$  are larger than  $y_o \Rightarrow M1$

[25] ... see next page

$$b = 10 \text{ ft}, n = 0.020$$

Problem [III] ... continued

$$q = 4 \text{ ft}^2/\text{s}$$

$$y_1 = 3.0 \text{ ft}$$

$$v_1 = \frac{q}{y_1} = \frac{4}{3} = 1.33 \text{ fps}$$

$$E_1 = y_1 + \frac{v_1^2}{2g} = 3 + \frac{1.33^2}{2 \times 32.2} = 3.027 \text{ ft}$$

$$A_1 = by_1 = 10 \times 3 = 30 \text{ ft}^2$$

$$P_1 = b + 2y_1 = 10 + 2 \times 3 = 16 \text{ ft}$$

$$R_{h1} = \frac{A_1}{P_1} = \frac{30}{16} = 1.875 \text{ ft}$$

$$\bar{V} = \frac{1}{2}(v_1 + v_2) = \frac{1}{2}(1.33 + 1.21) = 1.27 \text{ fps}$$

$$\bar{V} = \frac{1.486}{n} R_h^{2/3} S_f^{1/2}$$

$$\Rightarrow S_f = \left( \frac{n \bar{V}}{1.486 R_h^{2/3}} \right)^2 = \left( \frac{0.020 \times 1.27}{1.486 \times 1.9325^{2/3}} \right)^2 = 0.000121$$

$$S_0 = 0.00022$$

$$\Delta x = \frac{E_1 - E_2}{S_0 - S_f} = \frac{3.027 - 3.32}{-(0.00022 - 0.000121)} = \frac{-0.293}{-0.000099} = 2959.60 \text{ ft}$$

$$y_2 = 3.3 \text{ ft}$$

$$v_2 = \frac{q}{y_2} = \frac{4}{3.3} = 1.21 \text{ fps}$$

$$E_2 = 3.3 + \frac{1.21^2}{2 \times 32.2} = 3.32 \text{ ft}$$

$$A_2 = by_2 = 10 \times 3.3 = 33 \text{ ft}^2$$

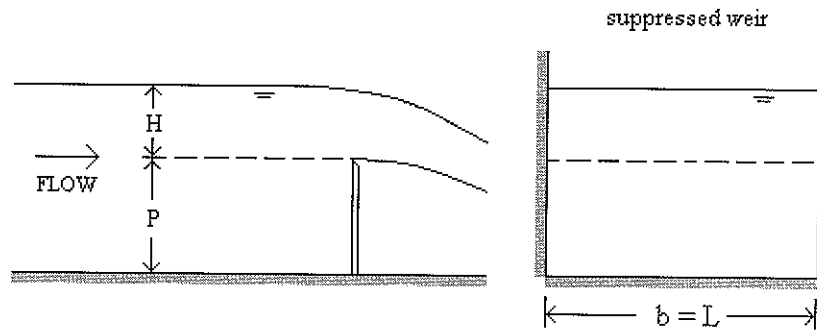
$$P_2 = b + 2y_2 = 10 + 2 \times 3.3 = 16.6 \text{ ft}$$

$$R_{h2} = \frac{A_2}{P_2} = \frac{33}{16.6} = 1.99 \text{ ft}$$

$$\bar{R}_h = \frac{1}{2}(R_{h1} + R_{h2}) = \frac{1}{2}(1.875 + 1.99)$$

$$\bar{R}_h = 1.9325$$

**Problem [IV].** A rectangular channel of width  $b = 10\text{ ft}$  is provided with a 1-ft-high suppressed rectangular weir.

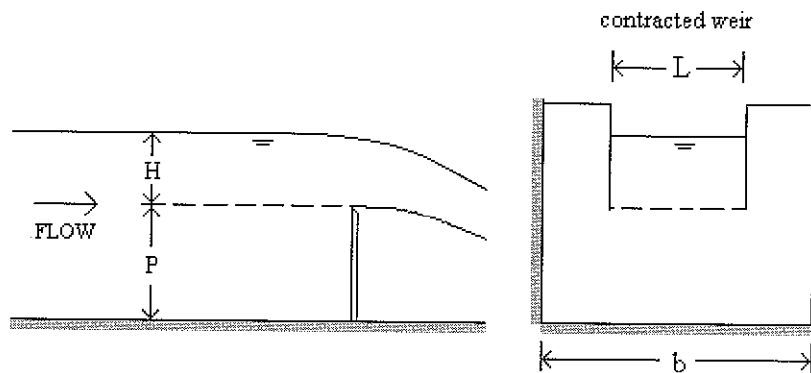


[27]. If a head  $H = 0.5\text{ ft}$  is measured upstream of the weir, what is the discharge over the weir? Use Rehbock's formulas to calculate the discharge coefficient  $C_d$ .

- (a) 12.3 cfs      (b) 11.3 cfs      (c) 13.3 cfs      (d) 10.3 cfs

[28]. What would be the flow velocity upstream of the suppressed weir described in [27]?

- (a) 0.02 fps      (b) 0.82 fps      (c) 1.82 fps      (d) 2.82 fps



[29]. Let the suppressed weir in the channel described in [27] be replaced by a contracted weir of length  $L = 6\text{ ft}$  and the same height  $P = 1\text{ ft}$ , with two contractions. If the weir coefficient is  $C_w = 3.32$ , what discharge would flow over the contracted weir if the head is  $H = 1.5\text{ ft}$ ?

- (a) 4.70 cfs      (b) 14.7 cfs      (c) 24.7 cfs      (d) 34.7 cfs

[30]. What would be the flow velocity upstream of the contracted weir described in [29]?

- (a) 0.39 fps      (b) 1.39 fps      (c) 2.39 fps      (d) 3.39 fps

Problem [IV] ... continued

$$H = 0.5 \text{ ft} \quad b = L = 10 \text{ ft}, \quad P = 1 \text{ ft}$$

[27] Suppressed weir

$$C_d = 0.605 + \frac{L}{305H} + 0.08 \frac{H}{P} = 0.605 + \frac{L}{305 \times 0.5} + 0.08 \frac{0.5}{1} = 0.652$$

$$Q = C_d \cdot \frac{2}{3} \sqrt{2g} L H^{3/2} = 0.652 \times \frac{2}{3} \times \sqrt{2 \times 32.2} \times 10 \times 0.5^{3/2} = \del{12.33} 12.33 \text{ cfs}$$

$$[28] \quad y = P + H = 1 + 0.5 = 1.5 \text{ ft}, \quad V = \frac{Q}{by} = \frac{12.33}{10 \times 1.5} = 0.82 \text{ fps}$$

$$[29] \quad L = 6 \text{ ft}, \quad P = 1 \text{ ft}, \quad n = 2, \quad C_w = 3.32, \quad H = 1.5 \text{ ft}$$

$$Q = C_w (L - 0.1nH) H^{5/2} = 3.32 \times (6 - 0.1 \times 2 \times 1.5) \times 1.5^{5/2}$$

$$Q = 34.76 \text{ cfs}$$

$$[30] \quad y = P + H = 1 + 1.5 = 2.5 \text{ ft}$$

$$V = \frac{Q}{by} = \frac{34.76}{10 \times 2.5} = 1.39 \text{ fps}$$