

MAIN BRANCH ENERGY DISSIPATOR

$$Q_{100} = 1870 \text{ cfs}$$

In the channel

$$\text{Slope} = 1.23\%$$

$$n = 0.13$$

$$SS_1 = SS_2 = 2:1$$

$$\text{Bottom Width} = 10'$$

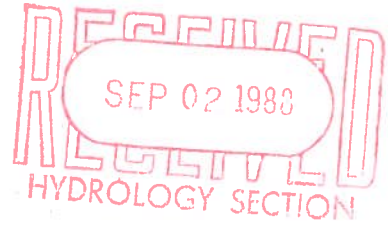
$$y_n = 4.16'$$

$$y_c = 6.76'$$

$$V_n = 24.56 \text{ fps}$$

$$V_c = 11.76 \text{ fps}$$

$$F = 2.56$$

For 30' Grade Check

$$b = 30'$$

$$SS_1 = SS_2 = 3:1$$

$$y_c = 4.25'$$

$$V_c = 10.29 \text{ fps}$$

For 50' Grade Check

$$b = 50'$$

$$SS_1 = SS_2 = 3:1$$

$$y_c = 3.29'$$

$$V_c = 9.50 \text{ fps}$$

Find Conj. Depth in Channel

$$z_1 = 1.77'$$

$$A_1 = 76.21 \text{ ft}^2$$

$$\frac{Q_1^2}{A_1 g} = 1425.00$$

$$Z_1 A_1 + \frac{Q_1^2}{A_1 g} = 1559.89 = Z_2 A_2 + \frac{Q_2^2}{A_2 g}$$

$$1559.89 = Z_2 A_2 + \frac{108,599.38}{A_2}$$

$$Z_2 A_2 = \frac{1}{3} y_2 \left(2 \left(\frac{1}{2} \right) y_2 (2 y_2) + \frac{1}{2} y_2 (y_2) (10) \right)$$

$$A_2 = y_2 (2 y_2) + 10 y_2 = 2 y_2^2 + 10 y_2$$

$$= \frac{2}{3} y_2^3 + 5 y_2^2$$

$$\therefore 1559.89 = \frac{2}{3} y_2^3 + 5 y_2^2 + \frac{108,599.38}{2 y_2^2 + 10 y_2}$$

$$3119.78 y_2^2 + 15598.9 y_2 = 1.33 y_2^5 + 76.67 y_2^4 + 50 y_2^3 + 108,599.38$$

$$1.33 y_2^5 + 16.67 y_2^4 + 50 y_2^3 - 3119.78 y_2^2 - 15598.9 y_2 + 108,599.38 = 0$$

solve for y_2 ; $y_2 = 10.13$

$$L_{\text{jump}} = 5.8(10.13) = 58.75 \text{ or } 6.9(10.13 - 4.16) = 41.1$$

$$1870 = 30(3)(H)^{3/2}$$

$$H = 7.57$$

$$1870 = 50(3)(H)^{3/2}$$

$$H = 5.38$$

ANALYZE DROPS

30' GRADE CHECK

$$\frac{y_1}{Dz_0} = .54 \left(\frac{4.25}{3} \right)^{1.275} \Rightarrow 2.53' = y_1$$

$$\frac{y_2}{Dz_0} = 1.66 \left(\frac{4.25}{3} \right)^{.81} \Rightarrow y_2 = 6.60'$$

$$\frac{L_d}{Dz} = 4.3 \left(\frac{4.25}{Dz} \right)^{.81} \Rightarrow 17.10' = L_d$$

$$L_j = 6.9 (6.60 - 2.53) = 28.11$$

N/A

50' GRADE CHECK

$$\frac{y_1}{Dz} = .54 \left(\frac{3.29}{2.5} \right)^{1.275} \Rightarrow 1.92' = y_1$$

$$\frac{y_2}{Dz} = 1.66 \left(\frac{3.29}{2.5} \right)^{.81} \Rightarrow 5.18' = y_2$$

$$\frac{L_d}{Dz} = 4.3 \left(\frac{3.29}{2.5} \right)^{.81} \Rightarrow 13.43' = L_d$$

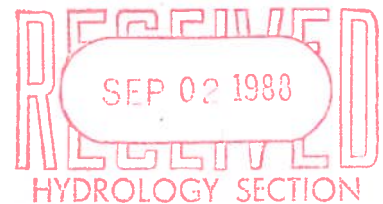
$$L_j = 6.9 (5.37 - 1.82) \Rightarrow 22.49' = L_j$$

SUMMARY OF FLOW CALCULATIONS FOR MAIN BRANCH CHANNEL

NOTE: 105 cfs is added to ~~at~~ Main Br. flows shown on Master Drainage Plan because this is 100 yr. run-off at time of peak from the diversion around Shenandoah Units II + III. This applies to flows east of Galt Course Road.

STATION 27+50 to 39+87

$$\begin{aligned} Q_{100} &= 1169 \text{ cfs} \\ \text{Slope} &= 2.68\% \\ \text{Side Slopes} &= 2:1 \\ \text{Bottom Width} &= 10' \\ \text{Use } n &= .013 \end{aligned}$$



$$\begin{aligned} D_n &= 2.68' \\ V_n &= 28.47 \text{ fps} \\ F &= 3.56 \end{aligned}$$

$$\text{Min Radius} = 720.0'$$

$$\begin{aligned} \text{Super Elevation (s)} &= \frac{1.3 (28.47)^2 (10 + 2(2)(2.68))}{g(720)} \\ &= 0.94' \end{aligned}$$

$$\begin{aligned} \text{Req'd free board} &= .7(2 + .025(28.47)(2.68)^{1/3}) \\ &= 2.09' \end{aligned}$$

$$\text{Total Req'd depth} = 2.68 + .94 + 2.09 = \underline{5.71'}$$

say 6'

STATION 26+00 to 27+50

$$\begin{aligned} Q_{100} &= 1169 \text{ cfs} \\ \text{Slope} &= 3.62\% \\ \text{Side slopes} &= 2:1 \\ \text{Bottom Width} &= 10' \\ \text{Use } n &= .013 \end{aligned}$$

$$\begin{aligned} D_n &= 2.47' \\ V_n &= 31.67 \text{ fps} \\ F &= 4.10 \end{aligned}$$



$$\text{Req'd Freeboard} = .7(2 + .025(31.67)(7.10)^{1/3})$$

$$= 2.29'$$

$$\text{Total Req'd Depth} = 2.47 + 2.29 = \underline{4.76'} \leftarrow$$

6', OK

STATION 12+50 to 22+81

$$Q_{100} = 1607 + 105 = 1712 \text{ cfs}$$

$$\text{Slope} = 2.23\%$$

$$\text{Sideslopes} = 2:1$$

$$\text{Bottom Width} = 10'$$

$$n = .013$$

$$D_n = 3.43'$$

$$V_n = 29.63 \text{ fps}$$

$$F = 3.35$$

$$\text{Min Radius} = 1126.65$$

$$\text{Super Elevation (s)} = \frac{1.3(29.63)^2(10 + 2(2)3.43)}{g(1126.65)}$$

$$= 0.75'$$

$$\text{Req'd Freeboard} = .7(2 + .025(29.63)(3.43)^{1/3})$$

$$= 2.18'$$

$$\text{Total Req'd Depth} = 3.43 + 0.75 + 2.18 = \underline{6.36'} \leftarrow$$

way 6.5'

STATION 10+92 to 12+50

$$Q_{100} = 1712 \text{ cfs}$$

$$\text{Slope} = 1.23\%$$

$$\text{Sideslopes} = 2:1$$

$$\text{Bottom Width} = 10'$$

$$n = .013$$

$$D_n = 3.99'$$

$$V_n = 23.89 \text{ fps}$$

$$F = 2.53$$

$$\text{Req'd Freeboard} = .7(2 + .025(23.89)(3.99)^{1/3}) = 2.06$$

$$\text{Total Req'd Depth} = 3.99 + 2.06 = \underline{6.05'} \leftarrow$$

6.5', OK

STA 6+00 to 10+92

$$Q_{100} = 1870 + 105 = 1975 \text{ cfs}$$

$$\text{Slope} = 1975 \text{ cfs}$$

$$\text{Sideslopes} = 2:1$$

$$\text{Bottom Width} = 10'$$

$$n = .013$$

$$D_n = 4.28'$$

$$V_n = 24.83 \text{ fps}$$

$$F = 2.56$$

$$\text{Min. Radius} = 1488.05'$$

$$\begin{aligned} \text{Super Elevation} &= \frac{1.3 (24.83)^2 (10 + 2(2)(4.28))}{g (1488.05)} \\ &= 0.46 \end{aligned}$$

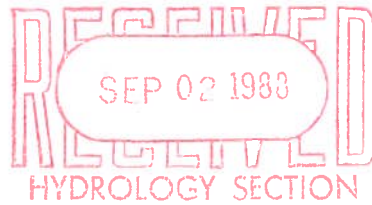
$$\begin{aligned} \text{Req'd Freeboard} &= \frac{.7(2 + .025(24.47)(4.17)^{1/3})}{1} \\ &= 2.11 \end{aligned}$$

$$\begin{aligned} \text{TOTAL Req'd Depth} &= 4.28 + .46 + 2.11 = \underline{\underline{6.85'}} \leftarrow \\ &\text{say } 7' \end{aligned}$$

SUMMER '87

73-38-054

1-14-88



REVISED DUE TO
CHANNEL/BRIDE CHANGING
FROM A 1.5:1 TO A 2:1
SIDE SLOPES

COMPLITATIONS

$$\Delta = 1.40 - 1.14 = .16'$$

FOR MAIN BRANCH

PIEDRAS MARCADAS

JUNCTION

@

GOLF COURSE

ROAD

$$Q = 350 \text{ cfs} \quad d = 66" \quad n = 0.013 \quad S = \frac{9}{388} = 0.023$$

$$\rightarrow D_n = 3.36$$

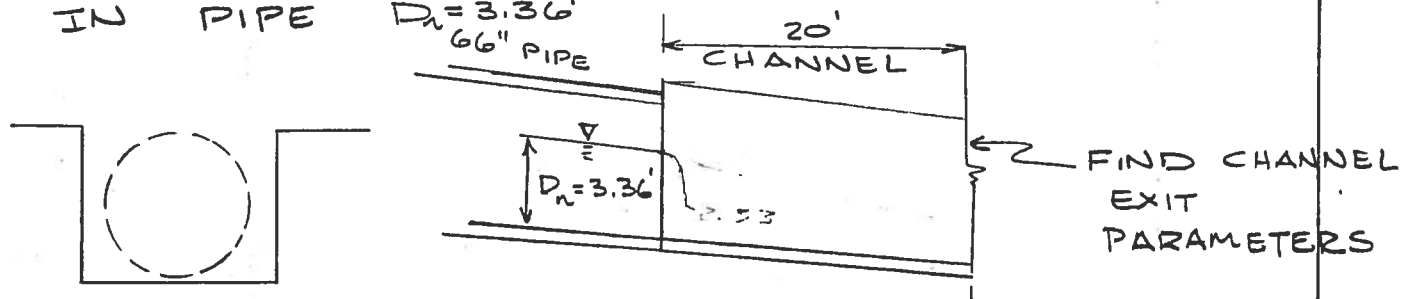
$$V_n = 23.2 \text{ fps}$$

$$F = 2.43$$

$$V_c = 5.02'$$

ASSUME NO LOSSES IN MOMENTUM
BECAUSE OF RADIUS PIPE AND 390' LENGTH
TO FLOW INTO NORMAL DEPTH

ASSUME EXIT VELOCITY = 23.2 fps
IN PIPE



$$Q = 350 \text{ cfs} \quad n = 0.015 \quad S = 0.023 \quad SS_1 = 0$$

$$SS_2 = 0$$

$$W = 6.5'$$

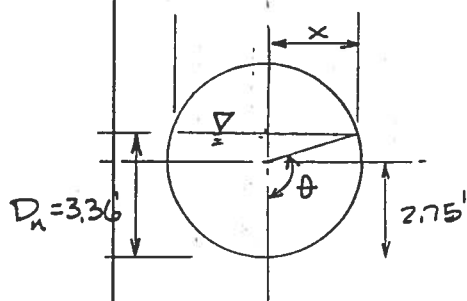
$$D_1 = ?$$

$$D_2 = 0$$

$$D_n = 2.73$$

$$V = 19.70 \text{ fps}$$

$$F = 2.10$$

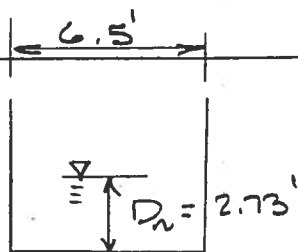


$$\theta_{\text{PIPE}} = 180 - \cos^{-1} \left(\frac{3.36 - 2.75}{2.75} \right) = 102.82^\circ$$

$$X_{\text{APE}} = \left((2.75')^2 - (3.36 - 2.75)^2 \right)^{1/2} = 2.68'$$

$$A_{\text{PIPE}} = \frac{2(102.82^\circ)}{360^\circ} \pi (2.75')^2 + (2.68')(0.6') = 15.21 \text{ ft}^2$$

$$R_{\text{PIPE}} = \frac{15.21}{\frac{2(102.82^\circ)}{360} \pi (5.5)} = 1.54$$



CHANNEL @ NORMAL

$$A_{ch} = 6.5' (2.73') = 17.75 \text{ ft}^2$$

$$R_{ch} = \frac{17.75}{2(2.73) + 6.50} = 1.48$$

$$V_m = \frac{V_{PIPE} + V_{ch}}{2} = \frac{23.2 + 19.70}{2} = 21.45$$

$$R_m = \frac{R_{PIPE} + R_{ch}}{2} = \frac{1.54 + 1.48}{2} = 1.51$$

$$E_1 = y_{PIPE} + \frac{(V_{PIPE})^2}{2g} = 3.36 + \frac{(23.2)^2}{2(32.2)} = 11.72$$

$$E_2 = y_{ch} + \frac{V_{ch}^2}{2g} = 2.73 + \frac{(19.70)^2}{2(32.2)} = 8.76$$

$$L = \frac{E_1 - E_2}{\left(\frac{n V_m}{1.49 R_m^{2/3}} \right)^{1/2} - S_0} = \frac{11.72 - 8.76}{\left(\frac{0.015 (21.45)}{1.49 (1.51)^{2/3}} \right)^{1/2} - 0.023} = 770'$$

PRORATE @ $L = 20'$ CHANNEL EXIT

$$V_{20} = 23.2 - \frac{20}{770} (23.2 - 19.70) = 23.10 \text{ fps}$$

MANNINGS EQ

$$Q = 350$$

$$V = 23.10 \text{ fps} \rightarrow D_{20} = 2.33'$$

@ CHANNEL EXIT

PROVIDE SMOOTH TRANSITION FROM
PIPE TO CHANNEL IN 20' TO REDUCE
LOSSES

$$Q = 174 \text{ cfs} \quad d = 54'' \quad n = 0.013 \quad S = \frac{5}{410} = 0.0122$$

$$\rightarrow D_n = 3.06 \quad V_n = 15.23 \quad F = 1.62$$

$$D_c = 3.83'$$

$$Q = 174 \text{ cfs} \quad d = 48'' \quad n = 0.013 \quad S = \frac{3}{90} = 0.0333$$

$$\rightarrow D_n = 2.39 \quad V_n = 22.40 \quad F = 2.79$$

$$D_c = 3.75'$$

$$\theta_c = 180 - \cos^{-1} \left(\frac{3.75 - 2.0}{2.0} \right) = 151.05^\circ$$

$$X_c = \left((2.0)^2 - (3.75 - 2.0)^2 \right)^{1/2} = 0.97'$$

$$A_c = \frac{2(151.05^\circ)}{360^\circ} \pi (2.0')^2 + 0.97'(1.75') = 12.24 \text{ ft}^2$$

$$V_c = \frac{Q}{A_c} = \frac{174}{12.24} = 14.2 \text{ fps} < 15.23 \text{ fps}$$

ASSUME FLOW THRU MANHOLE AT 74+00
LEAVES @ CRITICAL DEPTH

DETERMINE PARAMETERS @ EXIT OF PIPE

$$R_c = \frac{A_c}{W.P.} = \frac{12.24}{\frac{2(151.05^\circ)}{360} \pi \times 4'} = 1.16$$

$$\theta_n = 180 - \cos^{-1} \left(\frac{2.39 - 2.00}{2.00} \right) = 101.24^\circ$$

$$X_n = \left((2.0)^2 - (2.39 - 2.00)^2 \right)^{1/2} = 1.96'$$

$$A_n = \frac{2(101.24^\circ)}{360} \pi (2.0)^2 + 1.96'(0.39') = 7.83 \text{ ft}^2$$

$$R_n = \frac{A_n}{W.P.} = \frac{7.83}{\frac{2(101.24)}{360} \pi \cdot 4} = 1.11$$

$$R_m = \frac{R_u + R_c}{2} = \frac{1.16 + 1.11}{2} = 1.13$$

$$V_m = \frac{V_u + V_c}{2} = \frac{22.40 + 14.20}{2} = 18.3 \text{ fps}$$

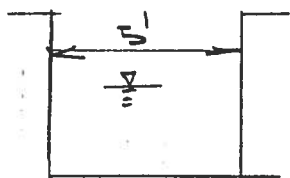
$$E_1 = y_c + \frac{V_c^2}{2g} = 3.75 + \frac{(14.2)^2}{2(32.2)} = 6.88$$

$$E_2 = y_u + \frac{V_u^2}{2g} = 2.39 + \frac{(22.40)^2}{2(32.2)} = 10.18$$

$$L = \frac{E_1 - E_2}{\left(\frac{n V_m}{1.49 R_m^{2/3}} \right)^2 - S_0} = \frac{6.88 - 10.18}{\left(\frac{0.013 (18.3)}{1.49 (1.13)^{2/3}} \right)^2 - 0.033} = \underline{\underline{290'}}$$

PRORATE PIPE EXIT @ $L = 70'$

$$V_{\text{EXIT}} = 14.2 + \frac{70}{290} (22.40 - 14.20) = \underline{\underline{16.2 \text{ fps}}}$$



SIDELCHANNEL @ NORMAL CONDITIONS

$$Q = 174 \quad n = 0.015 \quad S = 0.033 \quad SS_1 = 0$$

$$SS_2 = 0 \quad W = 5' \quad D_1 = ? \quad D_2 =$$

$$\rightarrow D_1 = 1.86' \quad V_n = 18.7 \text{ fps} \quad F = 2.42$$

SINCE NOT VELOCITY CHANGE FROM PIPE TO CHANNEL ASSUME

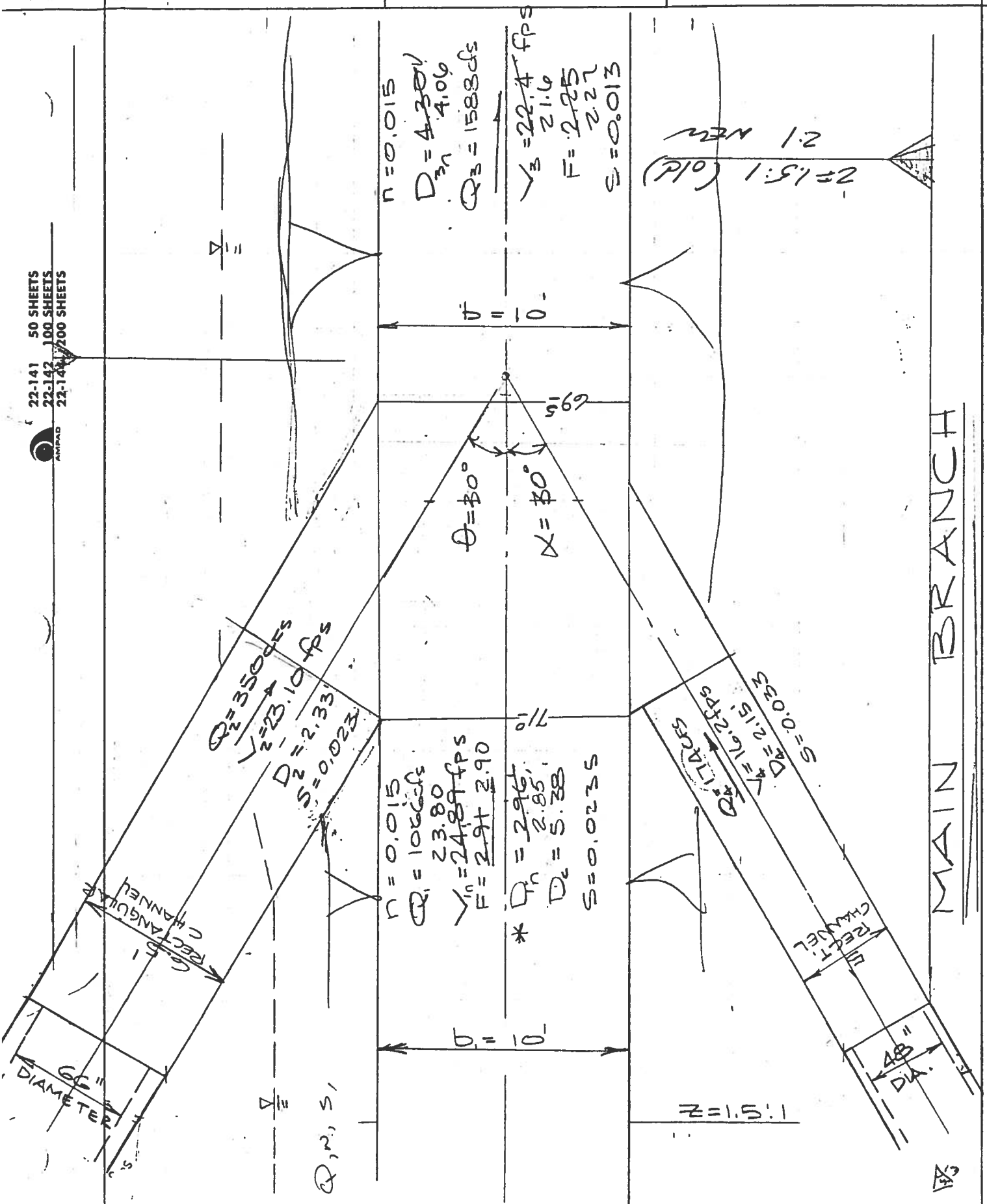
$$V = 16.2 \text{ fps @ CHANNEL EXIT @ } \underline{\underline{20'}}$$

FROM MANNINGS

$$Q = 174 \text{ cfs} \quad V = 16.2 \text{ fps}$$

$$\rightarrow D_{2b} = 2.15'$$

PROVIDE SMOOTH TRANSITION FROM PIPE TO CHANNEL TO REDUCE LOSSES



* #'s to be used in Equilibrium Equation

EQUILIBRIUM EQUATION

$$P_3 + M_3 = P_1 + M_1 + M_2 \cos \theta + M_4 \cos \alpha + P_L + P_W - P_f$$

$$M_1 = \frac{Q_1^2}{(b_1 + z d_1) g d_1}$$

$$M_2 \cos \theta = \frac{Q_2^2}{b_2 d_2 g} \cos \theta$$

$$M_3 = \frac{Q_3^2}{(b_3 + z d_3) g d_3}$$

$$M_4 \cos \alpha = \frac{Q_4^2}{b_4 d_4 g} \cos \alpha$$

$$P_1 = \frac{d_1^2}{6} (3b_1 + 2z d_1)$$

$$P_3 = \frac{d_3^2}{6} (3b_3 + 2z d_3)$$

$$P_i = \left(\frac{b_1 + b_3}{2} \right) h \left[d_1 + \frac{(d_3 - d_1)(b_1 + 2b_3)}{3(b_1 + b_3)} \right]$$

$$P_w = \frac{d_1 + d_3}{4} \left[\frac{b_1 + b_3}{2} (d_1 - d_3) + h' (z d_1 + z d_3) + (b_3 + z d_3) d_3 - (b_1 + z d_1) d_1 \right]$$

$$P_f = \frac{L(s_1 + s_2)}{4} \left[(b_1 + z d_1) d_1 + (b_3 + z d_3) d_3 \right]$$

SOLVE FOR $h = z$

$$M_1 = \frac{Q_1^2}{(b + z d_1) d_1 g} = \frac{(1066)^2}{(10 + \frac{1.5(2.96)}{2.0 \cdot 2.85}) 2.96(32.2)} = \frac{1135.7}{788.7} \checkmark$$

$$M_2 \cos \theta = \frac{Q_2^2}{b_2 d_2 g} \cos \theta = \frac{(350)^2}{6.5(2.33)32.2} \cos 30^\circ = 217.5 \checkmark$$

$$M_3 = \frac{Q_3^2}{(b + z d_3) d_3 g} = \frac{(1588)^2}{(10 + \frac{1.5(4.30)}{2.04.06}) 4.30(32.2)} = \frac{1069.5}{1107.2} \checkmark$$

$$M_4 \cos \theta = \frac{Q_4^2}{b_4 d_4 g} \cos \theta = \frac{(174)^2}{5(2.15)32.2} \cos 30^\circ = 75.7 \checkmark$$

$$P_1 = \frac{2.85}{6} (3(10) + 2(\frac{2.0 \cdot 2.85}{1.5}) 2.96) = 56.0 \checkmark$$

$$P_3 = \frac{4.06}{6} (3(10) + 2(\frac{2.0 \cdot 4.06}{1.5}) 4.30) = 127.0 \checkmark$$

$$P_L = \left(\frac{10+10}{2} \right) z \left[\frac{2.85}{2.96} + \frac{4.06-2.85}{3(10+10)} (10+2(10)) \right] = \frac{34.6}{36.3} z \checkmark$$

$$P_w = \frac{2.85+4.06}{4} \left[\frac{10+10}{2} \left(\frac{2.85-4.06}{2.96-4.30} \right) + (10 + \frac{1.5(4.30)}{2.0}) 4.30 - (10 + \frac{1.5(2.96)}{2.0}) 2.96 \right] \checkmark$$

$$P_w = 26.5, 28.88 \checkmark$$

$$P_f = \frac{13(0.0235 + 0.013)}{4} \left[\frac{2.0(2.85)}{(10 + \frac{1.5(2.96)}{2.0})} 2.96 + \frac{2.0(4.06)}{(10 + \frac{1.5(4.30)}{2.0})} 4.30 \right] \checkmark$$

$$P_f = 13.46, 14.09 \checkmark$$

$$1069.5 + 127.0 = 788 + 217.5 + 75.7 + 56.0 + 34.6 z + 28.88 - 14.09$$

$$1107.2 + 132.2 = 825.7 + 217.5 + 75.7 + 56.8 + 36.3 z + 26.5 - 13.46$$

$$z = \frac{1.14}{1.40} \text{ say } 1.20 \rightarrow 1.21$$

$$\Delta y = z + c_1 - d_2 = 1.50 + 2.96 - 4.30 = 0.16$$

$$1.20 + 2.85 - 4.06 = 0.01 \rightarrow \text{OK}$$