CHAPTER 7

CHUTES

7-1. General.

A chute is a steep open channel which provides a method of discharging accumulated surface runoff over fills and embankments. A typical design is shown in figure 7-1. Frost penetration beneath the structure will be restricted to nonfrost-susceptible materials using procedures outlined in paragraph 2-6*b* and note 4 of paragraph 2-6*d*, since small increments of heave may seriously affect its drainage capacity and stability. The following features of the chute will be given special consideration in the preparation of the design.

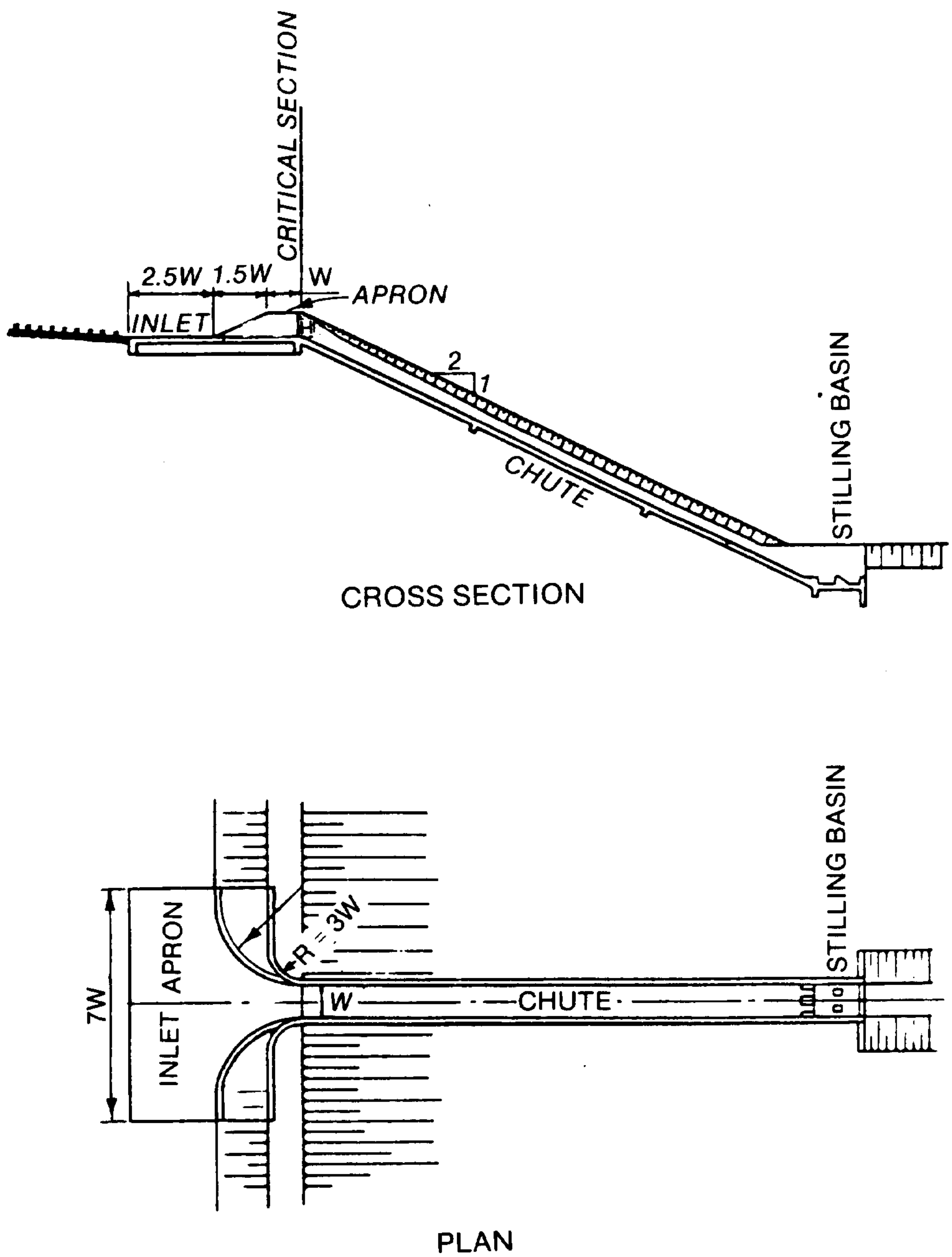


Figure 7-1. Details of typical drainage chute.

a. The berm at the edge of the fill will have sufficient freeboard to prevent overtopping from discharges in excess of design runoff. A minimum height of wall of one and one-half times the computed depth of flow is suggested. Turfed berm slopes will not be steeper than 1V to 3H because they cannot be properly mowed with gang mowers.

b. A paved approach apron is desirable to eliminate erosion at the entrance to the chute. A cutoff wall should be provided around the upstream edge of the apron to prevent undercutting, and consideration should be given to effects of frost action in the design. Experience has shown that a level apron minimizes erosion of adjacent soil and is self-cleaning as a result of increased velocities approaching the critical section.

7-2. Design.

a. The entrance to the chute can be level or a drop can be provided as shown in figure 7-2. The advantage of providing the drop is to reduce the depth of headwater upstream. The dimensions of the structure can be determined from a known discharge and allowable head or width of chute by using the charts provided in figure 7-3. The curve with D=O is for a level approach to a drop. The following equation can be used to determine the discharge at given head and chute width when no drop is provided.

$$Q = 3.1\, W\, H^{1.5} \qquad \text{(eq 7-1)}$$

All of the curves shown in figure 7-3 were developed with the radius of an abutment equal to three times the width of the chute. If it becomes necessary to increase the radius of the abutments because of upstream embankments or other reasons, as will probably be the case for smaller chutes, the equation for D = 0 should be used for design since the radius of the abutments will have little effect on the discharge.

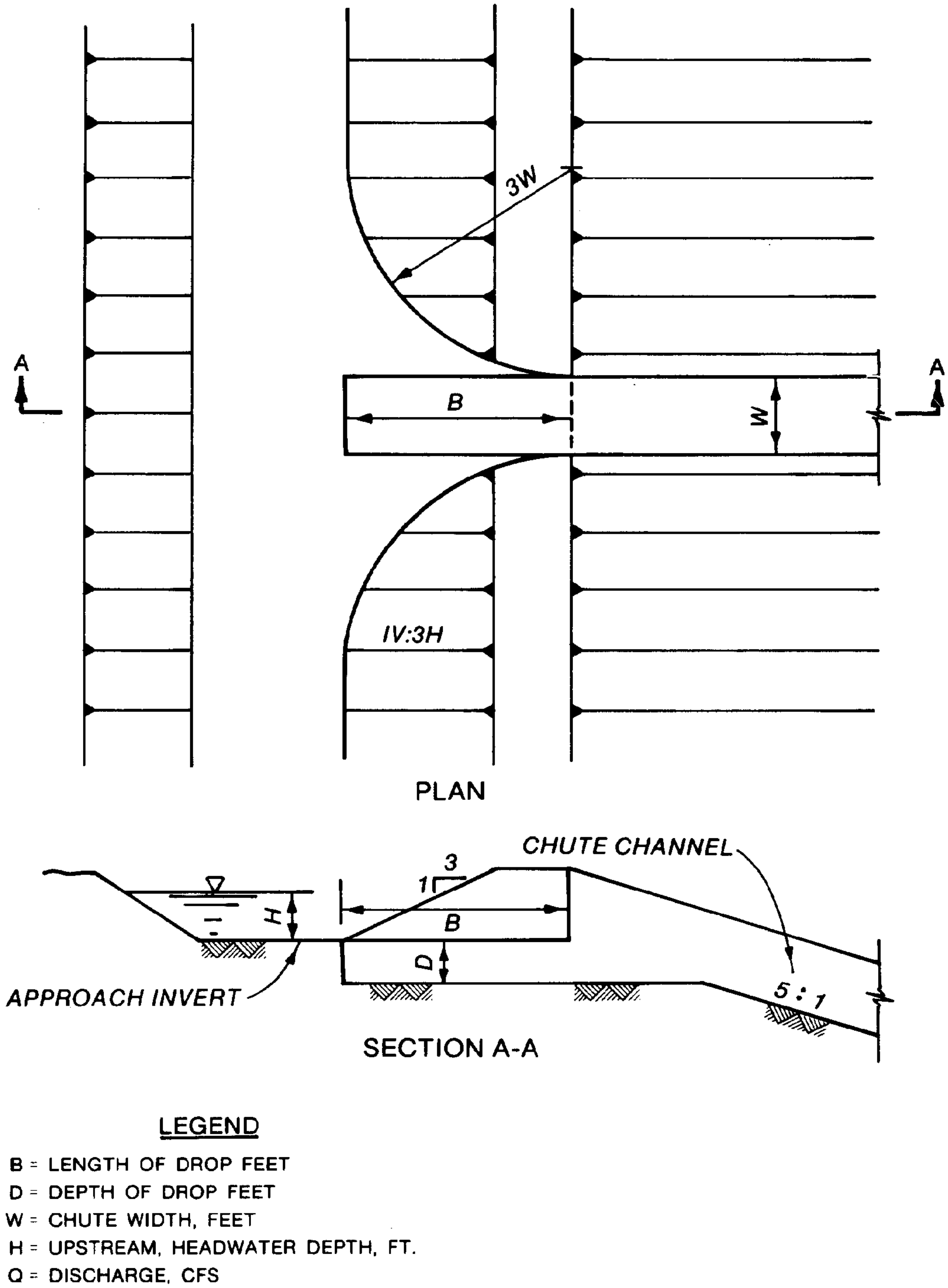


Figure 7-2. Details of typical drop intake.

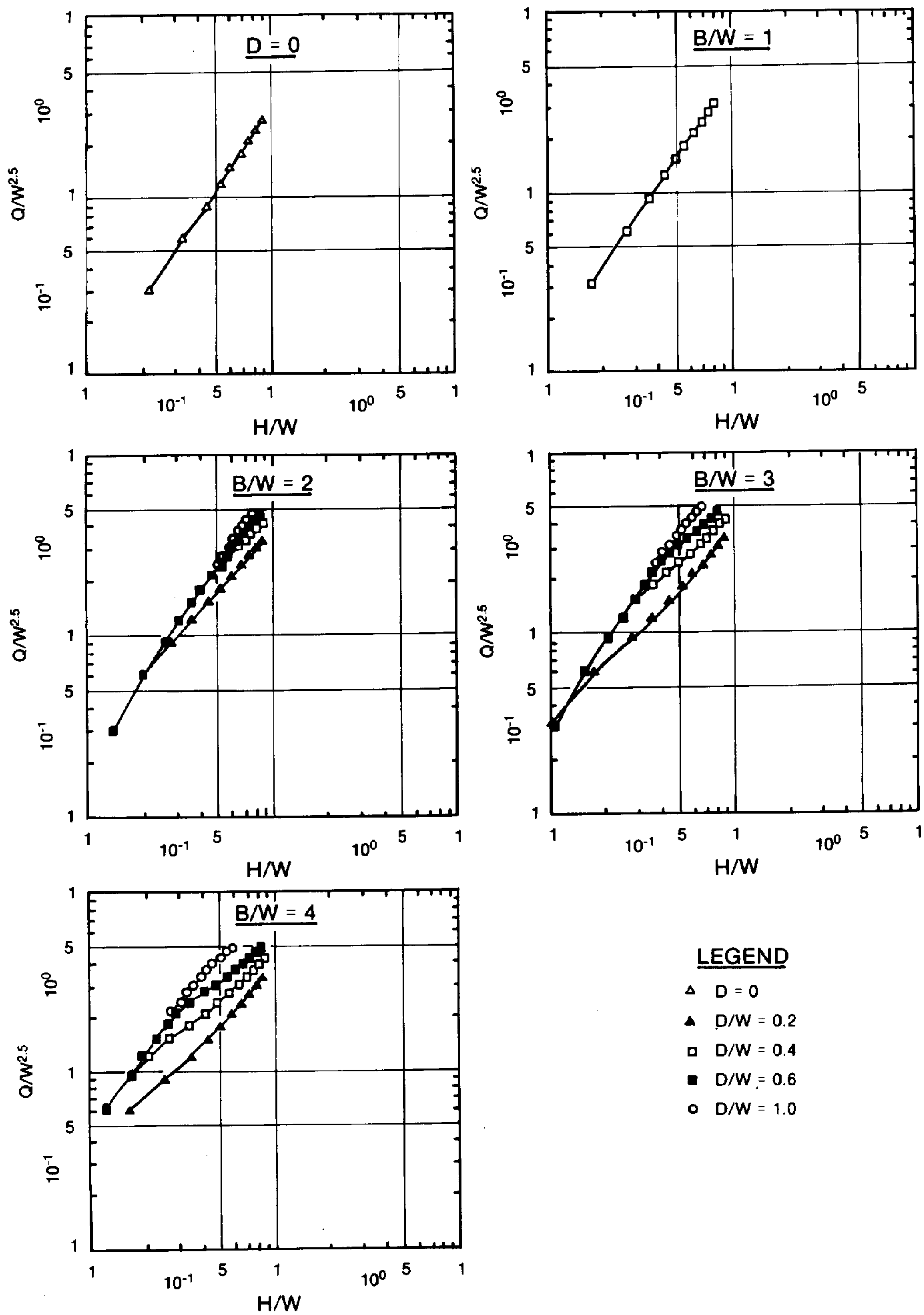


Figure 7-3. Drop structure calibration curves.

b. The depth of flow in the chute can be computed using Manning's equation

$$Q = \frac{1.486}{n} A S^{1/2} R^{2/3} \qquad \text{(eq 7-2)}$$

where:

Q=Discharge, cubic feet per second
n = Roughness factor
A=Area, square feet
S = Slope, feet per feet
R=Hydraulic radius, feet

Air becomes entrained in flow through steep chutes causing the depth of flow to increase which necessitates increasing the side-wall height. The chart in figure 7-4 can be used to determine the amount of air entrainment and thus the total depth of flow which is equal to the depth of air plus the depth of water.

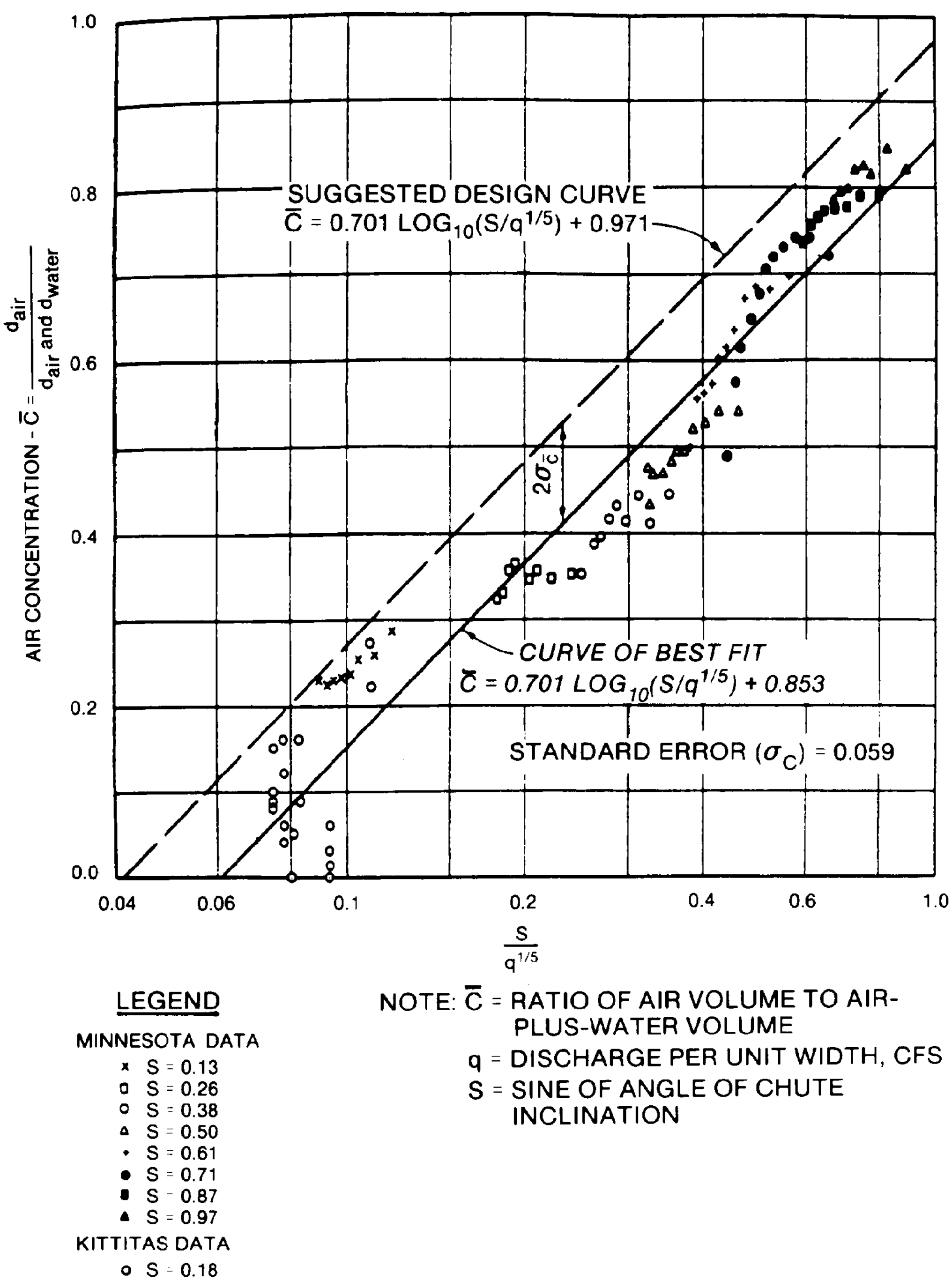


Figure 7-4. Air entrainment in chute flow.

c. Adequate freeboard is most important in the design of a concrete chute. The critical section where most failures have occurred is at the entrance where the structure passes through the berm. As indicated earlier, a minimum freeboard equal to one and one-half times the computed depth of flow is recommended. A minimum depth of 3 inches is suggested for the chute. Minor irregularities in the finish of the chute frequently result in major flow disturbances and may even cause overtopping of sidewalls and structural failure. Consequently, special care must be given to securing a uniform concrete finish and adequate structural design to minimize cracking, settlement, heaving, or creeping. A suitable means for energy dissipation or erosion prevention must be provided at the end of the chute.

7-3. Design problem.

a. Design a concrete chute to carry 25 cubic feet per second down a slope with a 25 percent grade. The allowable head is 1 foot and Manning's n is 0.014.

b. Solution one. Using equation 7-1 with no drop at the entrance, $Q=3.1W(H)^{1/5}$, with Q=25 cubic feet per second and H = 1 foot.

$$25=3.1W(1)^{1/5} \text{ or } W=8.06 \text{ feet} \qquad \text{(eq 7-3)}$$

Use W = 8 feet

Now

$$A=Wd=8d \qquad \text{(eq 7-4)}$$

and

$$R = \frac{\text{area}}{\text{wetted perimeter}} = \frac{8d}{W+2d} = \frac{8d}{8+2d} \qquad \text{(eq 7-5)}$$

Use Manning's equation (7-2) to determine depth of water:

$$Q = \frac{1.486}{n} A S^{1/2} R^{2/3} = \frac{1.486}{0.014} A(0.25)^{1/2} R^{2/3} = 25 \qquad \text{(eq 7-6)}$$

$$25 = \frac{1.486}{0.014} \times 8d \times (0.25)^{1/2} \times \left(\frac{8d}{8+2d} \right)^{2/3} \qquad \text{(eq 7-7)}$$

Solving for d by trial and error, the depth of water is d=0.186 foot. For use in figure 7-4, the size of the angle of the chute is equal to 0.243 and q=Q/W=25/8=3.125. Thus, $S/q^{1/5}$ equals 0.1935, which corresponds to a design air concentration $T = d_{air}/(d_{air}+d)=0.471$. Solving for d_{air} gives 0.166 foot. Then, the total depth of flow is depth of water plus depth of air, 0.352 foot. Wall height should be 1.5 times the total depth of flow or 0.528 foot. One should use 0.5 foot. This design is shown in figure 7-5.

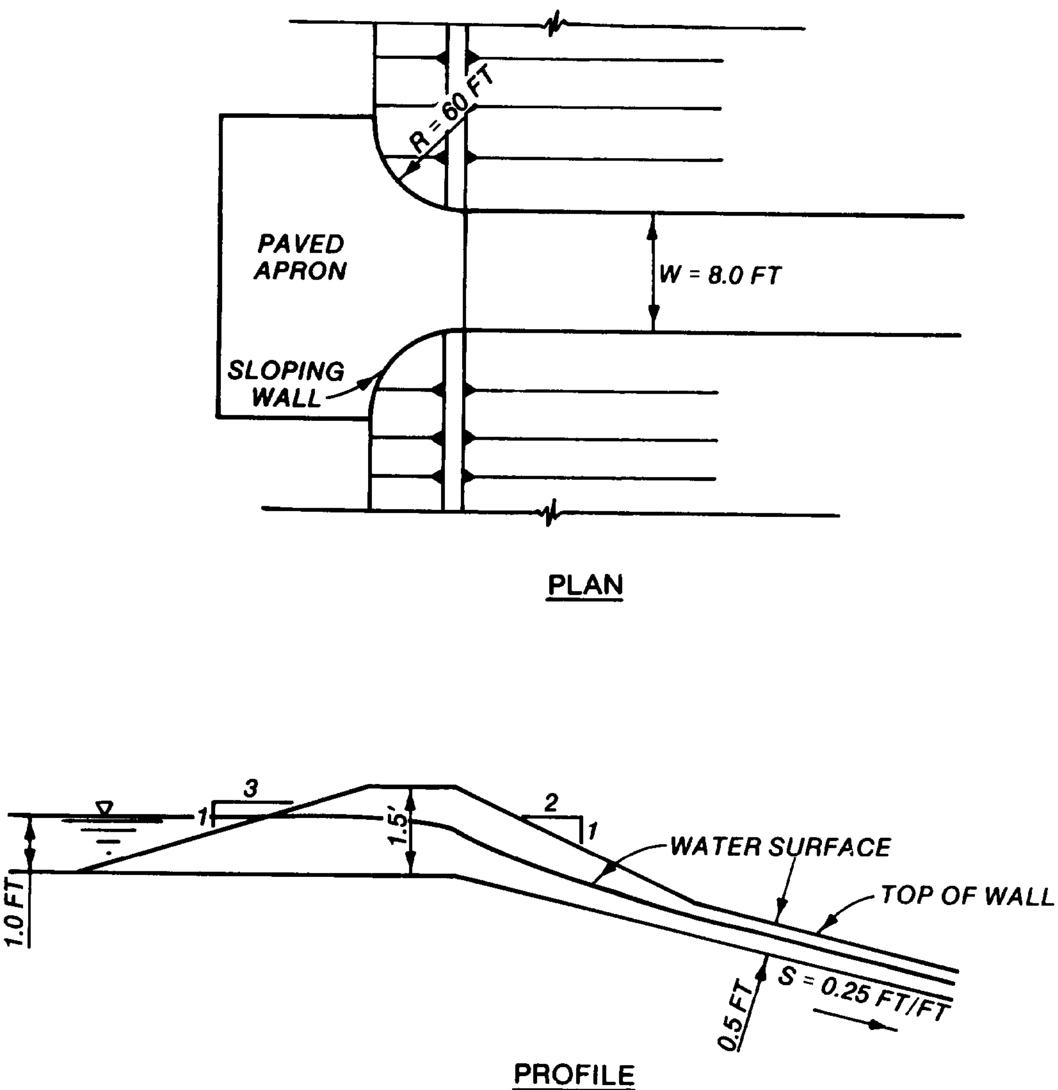
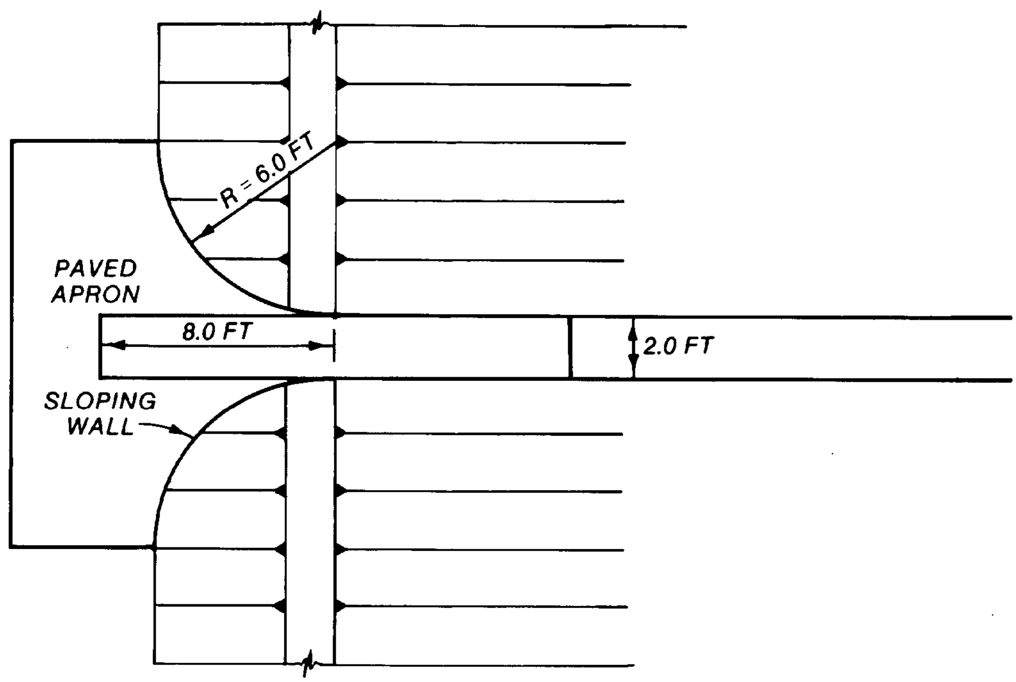
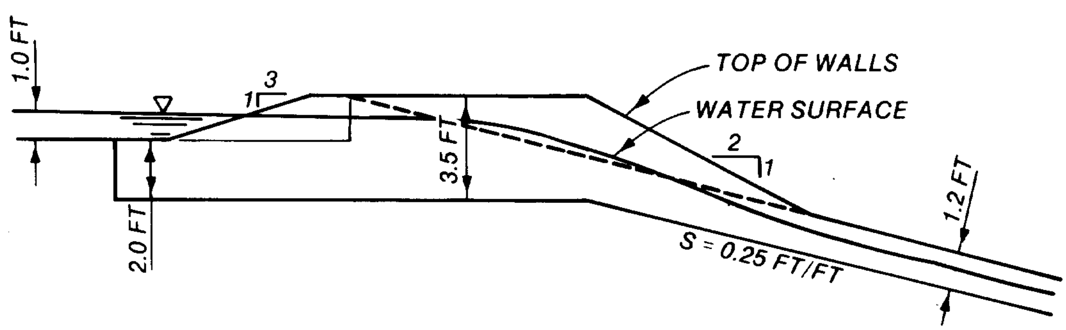


Figure 7-5. Design problem—solution one.

c. Solution two. A drop will he provided at the entrance. Therefore, a width of chute can he selected and the appropriate length and depth of drop determined from the curves in figure 7-3. For this design select a width of 2 feet. Then $H/W = \frac{1}{2} = 0.5$ and $Q/W^{5/2} = 25/(2)^{5/2} = 4.42$. From figure 7-3 find a curve that matches these values. This is found on the curve for D/w 1.0, on the chart for B/W=4. Therefore, B=8 feet and D=2.0 feet. Using Manning's equation (7-2) to determine depth of water as in the first solution, find d_w=0.493 foot. From figure 7-4, with q equals 12.5, sine of angle of slope equals 0.243 and d_w equals 0.493 foot, determine the depth of air to be 0.311 foot. Thus, total depth is 0.804 foot. Use 0.80 foot. Wall height is 1.5 times 0.80 foot, or 1.20 feet. This design is shown in figure 7-6.



PLAN



PROFILE

Figure 7-6. Design problem—solution two.