Numerical values shown are suggested minimums.
CHUTE SPILLWAYS: CHANNELS; Definition of symbols and Formulas

Capacities of Channel Sections

<table>
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<th>N</th>
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<th>N cos θ</th>
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*Values of qMN are for values of θ = 8 ft. For other values of θ see table 2, ES-88.
†Values are for channels of θ to 1 slope.

DEFINITION OF SYMBOLS

N = Height normal to slope s0 of side-wall of channel in ft
Z = Vertical drop from crest of inlet to floor of outlet in ft
D = Vertical distance from crest of inlet to top of floor at entrance of vertical curve section in ft. This is zero for straight inlets
F = Vertical distance from upstream end to downstream end of channel in ft
J = Height of sidewalls of S AF above floor in ft
θ = Vertical drop of vertical curve section in ft
W = Width of vertical curve section in ft
n = Number of channel sections required
θ = Tan⁻¹ s0
s0 = Slope of floor of channel in ft/ft
Qc = Design discharge in cfs
Qfr = Required capacity without freeboard in cfs
Qmc = Capacity per foot width of channel without freeboard in cfs/ft

FORMULAS

F = Z + N cos θ - (J + θ + D)

Qfr = (1.20 + 0.003 Z) Qc

qMN = qMC
**CHUTE SPILLWAY: CHANNEL; Example**

**Example**

**Given:** A chute of width, \( W = 10 \) ft, has a design discharge, \( Q_r = 360 \) cfs, and a 5 to 1 slope. The chute has a vertical drop from the crest of the straight inlet to the floor of the outlet of \( Z = 47 \) ft. The vertical curve section has a vertical drop of \( y = 8 \) ft and the SAF cutlet has the dimension \( J = 15 \) ft.

The inlet will require no freeboard as a result of waves.

**Determine:**
1. The recommended required capacity of the chute: (i) \( Q_{fr} \) (ii) \( q_{fr} \)
2. The required height of the sidewalls, \( \overline{N} \), of the channel
3. The vertical drop, \( F \), required for the channel
4. The number of joints in the channel if they are spaced less than or equal to \( 9.5 \) ft (vertically) apart
5. The velocity and depth of flow with air entrainment and without air entrainment at the end of the channel section for the discharge \( Q_{fr} \)

**Solution:**

1. The recommended required capacity of the chute is
   \[
   Q_{fr} = (1.20 + 0.003 2) Q_r = 380 
   \]
   \[
   Q_{fr} = 509.6 \text{ cfs}
   \]
   \[
   q_{fr} = \frac{Q_{fr}}{W} = \frac{509.6}{10} = 50.96 \text{ cfs/ft}
   \]
2. (a) The required height of the sidewalls of the channel may be read from the table on sheet 2 as \( \overline{N} = 2.50 \) ft
   (b) The required height of the sidewalls of the channel may also be read on sheet 5 at the intersection of \( Q_{fr} = 309.6 \) cfs and \( W = 10 \) ft as \( \overline{N} = 2.50 \) ft
3. The vertical drop of the channel is given by the formula \( (D = 0) \)
   \[
   F = \overline{Z} - \overline{N} \cos \theta - (J + y)
   \]
   \[
   F = 47 + 2.50 - (15 + 8)
   \]
   \[
   F = 26.37 \text{ ft}
   \]
   Values of \( \overline{N} \cos \theta \) when \( \theta = \tan^{-1} 0.33333 \) are given in the table on sheet 2.
4. The number of joints is
   \[
   n = \frac{F}{\overline{N}} = \frac{26.37}{2.50} = 10.55
   \]
   Three joints are required.
5. The downstream end of the channel is located a vertical distance of \( y \) or \( 8 = 26.37 - 38.37 \) ft below the floor of the inlet. Read on ES-18 the intersection of \( x = 50.96 \) cfs and \( y = 38.37 \) ft for values
   \[
   c = 1.086 \text{ ft}
   \]
   \[
   \varphi = 1.33
   \]
   The velocity, \( v \), of the air-water admixture is
   \[
   v = \frac{3}{3} = \frac{50.96}{1.086} = 47.18 \text{ ft/see}
   \]
   The depth of water without air entrainment is
   \[
   d = 1.086 \text{ ft}
   \]
   The depth of air-water admixture, \( d_{aw} \), is
   \[
   d_{aw} = \overline{N} d = (1.33)(1.086) = 1.42 \text{ ft} \]
SAF OUTLETS

The criteria for the dimensions of the SAF outlet were developed by Fred W. Blaisdell\(^1\), Hydraulic Engineer, SCS, St. Anthony Falls Hydraulic Laboratory. These criteria are given as design formulas in ES-73, page 2.193, and ES-86, page 2.198. (See ES-73, page 2.193, for nomenclature.)

Function of SAF Outlet. The function of the SAF outlet is to convert, for all discharges equal to or less than the design discharge, supercritical velocities to subcritical velocities in a manner which will be nonerosive in erosible channels. Obviously, certain criteria will be required of the channels downstream from the outlet for its proper functioning. These requirements will be presented later.

Freeboard. The SAF outlet functions well for all discharges less than its capacity without freeboard. It will generally function quite well for greater discharges for short periods of flow. The freeboard recommended for SAF outlets is expressed in terms of the increased discharge \(f_r\). (See Eq. 2.1, page 2.7.) The recommended required capacity of the SAF outlet without freeboard is \(Q_{fr}\) as defined by Eq. 2.2, page 2.7.

Hydraulic Criteria. The criteria for the SAF outlet are expressed by a graph having the coordinates \(v_1\) and \(d_1\). (See ES-73.) These criteria are applicable for a range of Froude's numbers from 3 to 300. The coordinate \(d_1\) (entrance depth) is the fictitious depth of flow \(d\) as given by ES-78 and ES-86. As given by ES-78, the value of \(y\) is the vertical distance between the floors of the inlet and outlet of a chute spillway having a 3 to 1 slope. The depth of \(d_1\) for chutes having bottom slopes other than 3 to 1, 4 to 1, and 10 to 1 may be calculated by the general differential equation given in ES-78, page 2.145 or interpolated using the diagrams of ES-78. The effect of air entrainment can be neglected in the design of SAF outlet. The coordinate \(v_1\) is the entrance velocity as determined by ES-78 and the equation

\[
v_1 = \frac{Q}{d_1}\]

Knowing \(d_1\) and \(v_1\) make it possible to determine \(L_R\) and \(J\) from sheet 2 of ES-73. For Froude's numbers less than 20, the crest of the boil occurs in the stilling basin. For higher Froude's numbers, the crest occurs downstream from the endsill. The height \(J\) of the stilling basin sidewalls is sufficient to keep most splash in the basin. This height is not excessive in most cases.

The wingwalls can be used as retaining walls for earth. Their prime function, however, is to prevent eddies along each side of the downstream channel which would cause excessive scour. Wingwalls can be set parallel or perpendicular to the sidewalls if necessary, but the 45° angle with the chute axis is the preferred location in terms of hydraulic functioning.

Knowing \(d_1\) and \(v_1\) make it possible to determine the dimensions of the endsill \(s\) and the required tailwater height \(d_2\). The endsill is used to

deflect the bottom currents in the floor of the basin upward and off of the
stream bed. It is also used to deflect the bottom currents of the roller,
which are in an upstream direction, upward. This roller brings bed material
from downstream and deposits it against the endsill. Because of this, a toe-
wall of only nominal depth is required. The criterion of tailwater depth $d_2$
is a minimum requirement for the SAF outlet to function properly. When the
tailwater depth is too low, the roller is forced away from the endsill of
the outlet. When the tailwater is too great, the tailwater will flow in an
eddy upstream along the sidewalls to re-enter the stilling basin and the out-
let will not function properly. For those situations in which the tailwater
can fluctuate in depth for a discharge equal to the required capacity without
freeboard, the minimum tailwater depth will determine the elevation of the
endsill. (See below.) The sidewall height $J$ should be increased in amount
equal to the difference between the maximum and minimum tailwater depths
which may be expected for a discharge equal to the required capacity with-
out freeboard. The SAF outlet will operate satisfactorily for greater tail-
water depths than the $d_2$ provided the sidewall heights are sufficiently
great to prevent re-entrance of the tailwater over the top of the sidewalls
into the basin. The tailwater elevation at the endsill can be determined by
computing the water-surface profile from a point sufficiently far downstream
from the endsill for a discharge equal to the discharge $Q_{tr}$. (See Engineer-
ing Handbook, Section 5, Hydraulics.) The flow in this region is subcritical;
therefore, these calculations are made in an upstream direction. The SAF
outlet will not prevent erosion in the channel downstream from the SAF if the
channel is scouring. When a scouring condition exists, it should be realized
that the tailwater elevation will be lowered after a period of time because
the channel bottom is lowered as a result of erosion. Scouring can be con-
trolled by a gradient control structure downstream from the SAF outlet. The
minimum required tailwater elevation in terms of depth $d_2'$ above the SAF floor
can be attained in one of two ways:

1. Proper determination of the elevation of the SAF outlet floor
   with respect to the nonerosive channel bottom.

2. Construction of a structure downstream from the SAF outlet to
   fix the tailwater elevation.

The criteria for chute and floor blocks and their placement are given
on sheet 1 of ES-73. Pitting of concrete due to cavitation will occur at
the floor and chute blocks when the entrance velocity $v_1$ is greater than
65 ft/sec. When such a condition occurs, these blocks can be designed of
a shape to eliminate cavitation. The purpose of these blocks is to remove
energy from the water and help create turbulence to effectively cause energy
dissipation.

The basin having diverging sidewalls appears to be slightly more effec-
tive than the basin with parallel sidewalls.

All odd dimensions read from ES-73 should be increased to the next even
number to simplify construction.

---
1Thomas, H. A., and Hopkins, Cavitation on Baffle Piers, Proceedings
of the Second Hydraulic Conference, Iowa, June 1942.
ES-86, page 2.202, gives the capacity without freeboard $q_{mo}$ of SAF outlets for various values of $d_1$, $J$, and $L_B$. For a given required capacity without freeboard, a study of ES-78 and ES-86 will show an increase in the width of the chute will decrease $q_{mo}$, $d_1$, $J$, and $L_B$. The corresponding values for required tailwater depth $d_2$ and height of endsill $s$ is given on page 2.203. These values are also listed in tabular form on pages 2.199 to 2.201.
**HYDRAULIC DESIGN CRITERIA AND CHARTS FOR SAF STILLING BASIN**

**DETAILS OF LAYOUT FOR FLOOR AND CHUTE BLOCKS**

1. Height of floor and chute blocks is \( d_1 \).
2. Width and spacing of floor and chute blocks approximately \( \frac{3d}{4} \).
3. No floor block should be placed closer to sidewall than \( \frac{3d}{8} \).
4. Floor blocks occupy between 40 and 55 percent of stilling basin width at blocks.
5. Chute blocks to be staggered with floor blocks.
6. A portion of a chute block or a whole chute block may be adjacent to a sidewall.
7. Space between sidewall and first chute block is not to be greater than approximately \( \frac{3d}{4} \).
8. Blocks are to be symmetrical about stilling basin center line.

**DESIGN FORMULAS**

\[
3 \leq F_r \leq 300
\]

1. \( F_r = \frac{v}{g \cdot d_1} \) (Froude's number, dimensionless number)
2. \( d_1 = \frac{2}{3} \left(-1 + \sqrt{8F_r + 1}\right) \)
3. \( d_1 = 1.4 d_1, F_r^{0.45} \)
4. \( L_0 = \frac{4.5 d_1}{g \cdot 0.38} \)
5. \( J = \frac{d_1}{3} + d_1 \)
6. \( s = 0.07 d_1 \)
7. \( z \geq 3\sqrt{F_r} \)

**DEFINITION OF SYMBOLS**

- \( F_r \) = Froude's number
- \( v \) = Entrance velocity of water to SAF stilling basin - FT./SEC.
- \( d_1 \) = Entrance depth of water to SAF stilling basin - FEET
- \( L_0 \) = Length of SAF stilling basin - FEET
- \( J \) = Height of sidewalls of SAF stilling basin - FEET
- \( s \) = Height of transverse end sill of SAF stilling basin - FEET
- \( d_2 \) = Required height of tailwater over SAF stilling basin - FEET
- \( d_2 \) = Sequent depth of flow to depth \( d_1 \) - FEET
- \( \gamma \) = Acceleration due to gravity - 32.16 FT./SEC.²
- \( W_1 \) = Width of SAF stilling basin at downstream end of chute blocks - FEET
- \( W_2 \) = Width of SAF stilling basin at upstream end of floor blocks - FEET
- \( W_3 \) = Width of SAF stilling basin at downstream end - FEET
- \( z \) = Divergence of sidewall (ratio)

**REFERENCE**


**U.S. DEPARTMENT OF AGRICULTURE**

SOIL CONSERVATION SERVICE

ENGINEERING DIVISION-DESIGN SECTION

**STANDARD DRAWING NO.**

ES-73

**SHEET 1 OF 3**

**DATE:** 3-23-53

**REVISION:** 4-10-54
The General Layout Drawing

Numerical values shown are suggested minimums.

4

ALTERNATE JOINT DETAIL

HALF-PLAN

SIDEWALL

FLOOR OF BASIN

CHUTE BLOCKS

END SILL

FOOTING

FOOTING

L_B

L_B

3/4 d_i

3/4 d_i

ARTICULATED JOINT

WINGWALL

SECTION ALONG CENTERLINE

NOTE -

Hydraulic Criteria and Formulas are given by ES-73, or by sheets 2, 6, and 7 of this drawing.

Capacities for this structure are given on sheets 2 through 7 of this drawing.

The backfill will be limited to one of the following heights, whichever is least:

1. Top of sidewall and wingwall.
2. 3/4 d_i above the floor of the basin.
3. 5 feet above the floor of the basin.

ISOMETRIC VIEW

REFERENCE:

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION-DESIGN SECTION

STANDARD DWG. NO.
ES-86

SHEET 1 OF 8 SHEETS

DATE 3-30-54

Revised 10/77
CHUTE SPILLWAYS: SAF OUTLETS;
Definition of symbols and Formulas

DEFINITION OF SYMBOLS

- $F_1$ = Froude's number $= \frac{v_1^2}{gd_1}$ at entrance of SAF basin (dimensionless number)
- $J$ = Height of sidewalls of SAF above floor in ft
- $L_B$ = Length of SAF basin (including end sill) in ft
- $d_1$ = Height of floor and chute blocks above floor of SAF basin in ft
- $d_1$ = Entrance depth of water without air to SAF basin in ft
- $s_1$ = Height of transverse end sill above floor of SAF basin in inches
- $d_2$ = Required height of tailwater above floor of SAF basin in ft
- $y_1$ = Entrance velocity of water to SAF basin in ft/sec
- $W$ = Width of SAF outlet in ft
- $Q_r$ = Design discharge in cfs
- $Q_{fr}$ = Recommended required capacity without freeboard of SAF outlet in cfs
- $Q_{mo}$ = Capacity without freeboard of SAF outlet in cfs
- $Q_{so}$ = Capacity of SAF outlet in cfs
- $q_r$ = Design discharge per foot width in cfs/ft
- $q_{fr}$ = Capacity without freeboard of SAF outlet per foot width in cfs/ft
- $s_0$ = Slope of bottom of channel in the SAF outlet ft/ft
- $N$ = Perpendicular height of sidewalls above channel floor at upstream end of SAF outlet in ft
- $g$ = Acceleration due to gravity--32.16 ft/sec²

DESIGN FORMULAS

$3 \leq F_1 \leq 300$

1. $F_1 = \frac{v_1^2}{gd_1}$
2. $d_2 = \frac{d_1}{2} (-1 + \sqrt{5 F_1} + 1)$
3. $d_2' = 1.4 \frac{d_1 y_1^{0.45}}{F_1}$
4. $L_B = \frac{4.5 d_2}{F_1}$
5. $J = \frac{d_2}{d_1} + d_2'$
6. $s = 0.07 d_2$

$Q_{fr} = (1.20 + 0.0032) Q_r$

The backfill will be limited to one of the following heights, whichever is least:
1. Top of sidewall and wing-wall.
2. $\frac{d_1}{2}$ above the floor of the basin.
3. 5 feet above the floor of the basin.

REFERENCE

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO. ES-86
SHEET 2 OF 8
DATE: February 1954

Revised 10/77
### CHUTE SPILLWAYS: SAF OUTLETS

**Dimensions and Capacities**

| J | Lp | N | f0 | t1 | b | g | 0.125 | 0.250 | 0.500 | 1.000 | 2.000 | 3.000 | 4.000 | 5.000 | 6.000 | 7.000 | 8.000 | 9.000 | 10.000 |
| 3.0 | 3.0 | 2.00 | 2.00 | 0.00 | 0.310 | 6.173 | 12.773 | 25.146 | 50.184 | 100.407 | 200.304 | 300.201 | 400.198 | 500.195 | 600.192 | 700.189 | 800.186 | 900.183 | 1000.180 |
| 3.5 | 3.5 | 2.00 | 2.00 | 0.00 | 0.368 | 7.656 | 15.173 | 30.201 | 60.264 | 120.301 | 240.301 | 360.301 | 480.301 | 600.301 | 720.301 | 840.301 | 960.301 | 1080.301 | 1200.301 |
| 4.0 | 4.0 | 2.00 | 2.00 | 0.00 | 0.430 | 9.490 | 18.960 | 37.804 | 75.564 | 151.208 | 302.301 | 453.301 | 604.301 | 755.301 | 906.301 | 1057.301 | 1200.301 | 1350.301 | 1500.301 |
| 4.5 | 4.5 | 2.00 | 2.00 | 2.00 | 0.576 | 13.824 | 27.648 | 55.289 | 110.118 | 220.235 | 440.248 | 660.248 | 880.248 | 1100.248 | 1320.248 | 1540.248 | 1760.248 | 1980.248 | 2200.248 |
| 5.0 | 5.0 | 2.00 | 2.00 | 2.00 | 0.712 | 18.140 | 36.260 | 72.520 | 145.110 | 290.220 | 580.440 | 870.650 | 1160.860 | 1451.070 | 1741.280 | 1981.490 | 2221.700 | 2461.910 | 2702.120 |
| 5.5 | 5.5 | 2.00 | 2.00 | 2.00 | 0.848 | 22.456 | 44.904 | 89.808 | 179.616 | 359.232 | 718.464 | 1077.696 | 1436.928 | 1796.160 | 2155.392 | 2514.624 | 2873.856 | 3233.088 | 3593.320 |
| 6.0 | 6.0 | 2.00 | 2.00 | 2.00 | 0.984 | 26.772 | 53.544 | 107.088 | 214.176 | 428.352 | 856.704 | 1285.056 | 1713.408 | 2141.760 | 2570.112 | 2999.464 | 3428.816 | 3858.168 | 4287.520 |
| 6.5 | 6.5 | 2.00 | 2.00 | 2.00 | 1.120 | 31.088 | 62.104 | 124.208 | 248.416 | 496.832 | 993.664 | 1490.496 | 1987.328 | 2484.160 | 2981.008 | 3477.840 | 3974.688 | 4471.536 | 4968.384 |
| 7.0 | 7.0 | 2.00 | 2.00 | 2.00 | 1.256 | 35.404 | 73.736 | 147.472 | 294.944 | 589.888 | 1179.776 | 1769.664 | 2359.552 | 2949.440 | 3539.328 | 4129.216 | 4719.104 | 5308.992 | 5898.880 |
| 7.5 | 7.5 | 2.00 | 2.00 | 2.00 | 1.392 | 39.720 | 106.464 | 212.928 | 425.856 | 851.712 | 1703.424 | 2555.232 | 3407.040 | 4258.848 | 5109.656 | 5960.464 | 6811.272 | 7662.080 | 8512.888 |
| 8.0 | 8.0 | 2.00 | 2.00 | 2.00 | 1.528 | 44.036 | 139.192 | 278.384 | 556.768 | 1113.536 | 2227.072 | 3340.608 | 4454.144 | 5567.680 | 6681.216 | 7794.752 | 8908.288 | 10021.824 | 11135.360 |
| 8.5 | 8.5 | 2.00 | 2.00 | 2.00 | 1.664 | 48.352 | 171.920 | 343.760 | 687.520 | 1375.040 | 2750.080 | 4125.120 | 5490.160 | 6855.200 | 8220.240 | 9585.280 | 10950.320 | 12315.360 | 13680.400 |
| 9.0 | 9.0 | 2.00 | 2.00 | 2.00 | 1.800 | 52.668 | 204.648 | 407.536 | 815.072 | 1630.144 | 3260.288 | 4890.432 | 6520.576 | 8150.720 | 9780.864 | 11411.008 | 13041.152 | 14671.296 | 16301.440 |
| 9.5 | 9.5 | 2.00 | 2.00 | 2.00 | 1.936 | 56.984 | 237.376 | 471.328 | 942.656 | 1885.312 | 3770.624 | 5655.936 | 7541.248 | 9426.560 | 11311.872 | 13207.184 | 15102.496 | 16997.808 | 18893.120 |
| 10.0 | 10.0 | 2.00 | 2.00 | 2.00 | 2.072 | 61.300 | 270.104 | 535.120 | 1070.240 | 2140.480 | 4280.960 | 6421.440 | 8561.920 | 10702.400 | 12842.880 | 14983.360 | 17123.840 | 19264.320 | 21404.800 |

**REFERENCE:**

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION- DESIGN SECTION

**STANDARD DWG. NO.**

ES-86

**SHEET 3 OF 8**

DATE 9-6-54

Revised 10/77
### CHUTE SPILLWAYS: SAF OUTLETS

**Dimensions and Capacities**

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**REFERENCE:**

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION- DESIGN SECTION

**STANDARD DWG. NO.**

ES-86

**SHEET 4 OF 8**

**DATE**

9-8-54

Revised 10/77
### CHUTE SPILLWAYS: SAF OUTLETS

#### Dimensions and Capacities

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SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

**STANDARD DWG. NO.:** ES-86

**SHEET 5 OF 8**

**DATE:** 9-8-54

Revised 10/77
CHUTE SPILLWAYS: SAF OUTLETS

Capacities without freeboard for various dimensions

J in feet
L_e in feet

REFERENCE

This diagram was developed by Paul O. Doubt, Engineering Design Section.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION DESIGN SECTION

STANDARD DWG. NO.
ES-86

SHEET 6 OF
DATE 3-2-54

Revised 10/77
CHUTE SPILLWAYS: SAF OUTLETS
Tailwater requirement and end sill height.

REFERENCE


This diagram was developed by Paul D. Doubt, Engineering Design Section

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION DESIGN SECTION

STANDARD DWG. NO.
ES-86

SHEET 1 OF 1
DATE 2-25-54
CHUTE SPILLWAYS: SAF OUTLETS; Example

EXAMPLE

Given: A chute having a straight inlet, a bottom slope of 3 to 1 and a vertical drop of 2 = 50 ft from the crest of inlet to the floor of the outlet. The design discharge is 200 cfs \( W = 8 \) ft \( J = 8 \) ft.

Determine: 1. Required capacity without freeboard.
2. The height of the channel sidewalls, \( N \), and entrance depth, \( d_1 \), of flow to SAF outlet without air entrainment.
3. Dimensions of SAF outlet.
4. Required depth of tailwater.

Solution: 1. The required capacity without freeboard, \( Q_{fr} \), is
   \[
   Q_{fr} = (1.20 + 0.003 \times 200) = 270 \text{ cfs}
   \]

   \[
   Q_{fr} = \frac{Q_{fr}}{w} = \frac{270}{8} = 33.75 \text{ cfs/ft}
   \]

2. The required height of channel sidewalls, \( N \), is read from table 3b of ES-88 as
   \( N = 2.00 \) ft

The entrance depth of flow without air entrainment, \( d_1 \), is obtained from ES-78. Interpolation for this depth between \( W = 6 \) and \( W = 10 \) from sheets 9 and 11 obtain
   \( d_1 = 0.659 \) ft

3. The dimensions of the SAF may be read from ES-73 or ES-86.
   a. The dimensions of the SAF as given on sheet 6 of ES-86 when \( q = 33.75 \) cfs/ft and \( d_1 = 0.659 \) ft is
      \( J = 11.5 \) ft; \( L_B = 7.5 \) ft

      The height of the end sill as given on sheet 7 of ES-86 when \( q = 33.75 \) cfs/ft and \( d_1 = 0.659 \) ft is
      \( s = 8 \) inches

      Since the value of \( d_1 \) is known, the size and spacing of floor and chute blocks can be determined from sheet 1 of ES-73.

   b. The dimensions of the SAF outlet may also be determined by ES-73.

      The entrance velocity to the SAF outlet is determined by the formula
      \[
      v_1 = \frac{q}{d_1} = \frac{33.75}{0.659} = 51.2 \text{ ft/sec}
      \]

      From sheet 2 of ES-73 when \( v_1 = 51.2 \text{ ft/sec} \) and \( d_1 = 0.659 \) ft

      read the dimensions
      \( J = 11.5 \) ft; \( L_B = 7.5 \) ft

      The height of the end sill is read from sheet 3 of ES-73 as \( s = 8 \) inches

4. The SAF outlet will not cause dissipation of the kinetic energy unless it has sufficient tailwater height. Serious erosion will occur in the erodible channel downstream from the SAF outlet whenever sufficient tailwater depth is not present. The required tailwater depth \( d'_t \) may be read from sheet 7 of ES-86 or sheet 3 of ES-73.
   \( d'_t = 8.1 \) ft