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LOW FROUDE NUMBER STILLING BASIN DESIGN

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16. ABSTRACT

Hydraulic model investigations were performed to supplement existing data and to develop general design criteria for low Froude number stilling basins. A generalized basin design for Froude numbers from 2.5 to 5.0 was developed from model tests and existing low Froude number designs. The recommended design is a relatively short stilling basin with chute blocks, baffle piers, and a dentated end sill.

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SI METRIC

UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

CONTENTS

FIGURES

INTRODUCTION

The hydraulic jump has been used as an energy dissipation device for many spillways, outlet works, and canal structures. Model studies have often been required to assure proper performance of particular structures. These studies require large investments in both time and money for each specific structure modeled.

Previous Studies

Several general studies have been made to investigate hydraulic jump stilling basins. One of the main objectives of these studies was to develop guidelines which could be used in the future to design hydraulic jump stilling basins and minimize the need for individual model tests. Some of these general studies are: "Hydraulic Design of Stilling Basins and Energy Dissipators, Engineering Monograph No. 25" [1]*, "Hydraulic Design Criteria" [2], "Development and Hydraulic Design, Saint Anthony Falls Stilling Basin" [3], and "Criteria for Design of Hydraulic Jump Type Stilling Basins With Horizontal and Sloping Apron" [4]. Other design guidelines are used in specific applications; however, the general studies are used more frequently for design of hydraulic jump stilling basins. An additional design was developed by Bhowmilk [5] for a low Froude number stilling basin downstream from a sluice gate.

"Hydraulic Design Criteria" was developed by the Corps of Engineers from many model tests of large flood control structures which had high heads and large unit discharges. As a result, the guidelines are not directly applicable to this study and will not be discussed further.

The SAF (Saint Anthony Falls) stilling basin was developed for canal and diversion structures on agricultural distribution systems and small streams which typically have low heads and small unit discharges. However, the SAF basin is so short that a significant amount of the energy dissipation must occur downstream from the end sill. The downstream channel can be allowed to erode until a stable scour hole occurs or suitable protection can be provided downstream from the stilling basin to minimize scour. Often these structures are located in lined canals where no damage occurs or on intermittent streams where a certain amount of erosion is tolerable. The SAF basin design criteria were established for flows with $4 \leq F_1 \leq 100$, where:

$$F_1 = \frac{V_1^2}{gD_1}$$

This range of F_1 is equivalent to the more conventional F (Froude number) varying between $2 \leq F \leq 10$, where:

$$F = \frac{V_1}{\sqrt{gD_1}}$$

The Bureau criteria in EM25 (Engineering Monograph No. 25) are a combination of field experience, model studies for specific projects, and generalized model tests. The monograph contains general design criteria for most types of stilling basins, energy dissipators, and associated appurtenances. The designs obtained by following these recommendations are usually conservative. Generally, model studies will not be required on structures that lie within the limitations specified in the monograph. However, model studies are usually necessary to verify a design when ideal conditions do not exist; for example, when incoming or outgoing flow is not symmetrical about the spillway centerline. The first five sections of the EM25 specify guidelines for hydraulic jump stilling basins for various conditions. For example, section 1 (Basin I) specifies the recommended design for a natural jump basin and section 5 (Basin V) specifies the recommended design for a sloping apron-type basin. Basin IV, (figs. 1 and 2)** was the recommended design for Froude numbers less than 4.5 that would minimize wave problems and dissipate the energy. Basin IV is fairly effective at low Froude number flows for small canals and for structures with small unit discharges. However, recent model tests have developed designs quite different from the Basin IV design, even though the Basin IV design was included in the initial tests.

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* Numbers in brackets refer to literature cited in the bibliography.

** All figures are at the end of this report.

Palmetto Bend Dam stilling basin [6] is an example of a low Froude number structure, modeled recently in the Bureau Hydraulic Laboratory, and the recommended design is quite different from a Basin IV design. The Basin IV design has large deflector blocks, similar to but larger than chute blocks, and an optional solid end sill; the Palmetto Bend design has no chute blocks, large baffle piers, and a dentated end sill.

Current Bureau Studies

The foregoing generalized designs have not been suitable for some Bureau applications and the increased use of low Froude number stilling basins has created a need for this information. This study was initiated to develop generalized criteria for the design of low Froude number hydraulic jump stilling basins. The criteria and guidelines from the previous studies were combined with the results of this study to formulate the design guidelines recommended for low Froude number stilling basins. However, it should be noted that a hydraulic jump stilling basin is not an efficient energy dissipator at low Froude numbers; that is, the efficiency of a hydraulic jump basin is less than 20 percent for $F<2.7$. Alternative energy dissipators, such as the baffled apron chute or spillway, should be considered for these conditions.

SUMMARY

This study was undertaken to consolidate the knowledge of low Froude number stilling basins, and to supplement this with model tests to develop design criteria for a stilling basin for Froude numbers between 2.5 and 5.0. The recommended design has chute blocks, baffle piers, and a dentated end sill. All data are presented in dimensionless form. The length is rather short, approximately three times D_2 (the conjugate depth after the jump). The size and spacing of the chute blocks, and baffle piers are a function of D_1 (incoming depth) and the Froude number. The dentated end sill is proportioned according to D_2 and the Froude number. The end sill is placed at or near the downstream end of the stilling basin. Erosion tests were not included in the development of this basin. Observations of flow patterns near the invert downstream from the basin indicated that no erosion problem should exist. However, if hydraulic model tests are performed to confirm a design based on this report, erosion tests should be included. Such tests should be made over a full range of discharges to determine whether abrasive materials will move upstream into the basin, in addition to determining erosion potential downstream from the basin.

LABORATORY MODEL DESCRIPTION

A flume 760 mm deep, 760 mm wide, and 11.6 m long was used for the study (fig. 3). An overflow crest was placed in the flume 330 mm above the floor. A 2:1 inclined chute connected the crest to the horizontal apron. The walls of the 8.5-m-long center section of the flume were clear plastic to allow visual observations from the side.

The permanent piping in the laboratory supplied the water to the flume from the pump, and the discharge was measured with venturi meters. The discharge was varied for each test to obtain the desired Froude number. The theoretical depth was 152, 68, and 24 mm for Froude numbers 2, 3, and 5 respectively; the q (unit discharge) for the same Froude numbers was 0.371, 0.165, and 0.058 $(m^3/s)/m$, respectively.

Depth measurements at the toe of the chute (section 1 of fig. 3) were not possible for all discharges because the tailwater covered the lower portion of the sloping chute when the chute blocks were in place. Measurements were made immediately upstream from the toe of the jump and were correlated to measurements at section 1 without any appurtenances in place so the proper depth at section 1 could be estimated with chute blocks in place.

TEST PROCEDURES

After reviewing the available data from references [1] through [5], preliminary tests were run for a natural hydraulic jump stilling basin (Basin I), a SAF stilling basin, and the Bureau low Froude number basin (Basin IV).

The designs for the Palmetto Bend and SAF stilling basins recommend that baffle piers and end sills be used. The SAF design recommends that chute blocks be used in addition to baffle piers and end sill. These designs were compared to Basins III and IV designs. The Basin III design, for a Froude number of 5, was similar to the SAF design and the Palmetto Bend design, both of which worked well. Therefore, a stilling basin was built according to the Basin III criteria for a Froude number of about 6.0, which performed very well. Data extrapolated from the Basin III design were used as the initial design for lower Froude number tests. The size and location of the chute blocks, baffle piers, and end sills were varied from this extrapolated design to obtain the best configuration for Froude numbers from 2.5 to about 6.0. The optimum size and placement of the chute blocks were established first, and then various sizes and locations for the baffle piers were tested. After the location and size of the baffle piers and chute blocks were determined, different sizes and shapes of end sills were tested near the end of the basin to determine the best size and location.

MEASUREMENTS AND CRITERIA FOR EVALUATION

The depths at sections 1 (toe of the chute) and 2 (downstream from the end sill) (fig. 3), the observed wave heights at section 2, and the discharge were recorded for each configuration tested. The Froude number, discharge, basin length, and the size and location of the appurtenances were also recorded. Observations of the velocity patterns, surface flow, eddy size and location were noted. These observations were combined with the data to form parameters used to evaluate the different configurations.

The parameters used to evaluate the performance of the various stilling basins tested were:

- basin length
- energy dissipation
- observed wave heights
- tailwater depth near D_2
- even distribution of flow throughout the basin with no stagnant or high-velocity flow areas.

The best stilling basin design had the shortest length with even flow distribution, minimum wave heights, maximum energy dissipation, and tailwater at or near D_2.

Basin Length and Flow Patterns

Both the length and the flow patterns in the basin are subjective observations and will vary from observer to observer. The *L* (length of basin) was taken as the longer of (1) the distance from the toe of the chute to the point at which the high-velocity jet leaves the floor, or (2) the distance from the toe of the chute to a point immediately downstream from the surface roller. These criteria were used for the length of the jump both in EM25 and in this study.

The distribution of flow was observed with particular attention to the velocity along the floor. The best flow pattern was the flow which had a stable jet that hit the baffle piers directly, resulting in:

- lower velocities along the floor
- the upstream toe of the jump locating near section 1 (fig. 3).
- a "smooth" water surface immediately downstream from the hydraulic jump.

Waves

Initially, wave characteristics were observed visually; comments about wave height, wave length, and surface roughness were written on the data sheets. Later, wave heights and wave lengths were scaled from oscillograph strip chart records of the waves and were used to evaluate each stilling basin configuration.

Efficiency

Specific energy at section 1 and section 2 (fig. 3) was determined by measuring the depth and discharge and computing *E* (specific energy) above the bottom of the flume from

$$E = D + \frac{q^2}{2gD^2} \qquad (1)$$

where

D = depth of flow
q = unit discharge
g = acceleration of gravity

Efficiency of the stilling basin is defined as the difference of specific energy between sections 1 and 2 divided by the energy at section 1.

$$\text{Efficiency} = \frac{E_1 - E_2}{E_1} = \frac{E_L}{E_1} \quad (2)$$

The vertical depth of water on the chute was measured by a point gage connected to an electronic device which gave an audible signal when the point gage contacted the water surface. This measured depth was corrected for the slope of the chute to obtain the depth normal to the floor of the chute at section 1. A stilling well and point gage were used to measure the water depth at section 2, and this depth was used as the tailwater.

PRELIMINARY TESTS

The initial tests were performed on a natural hydraulic jump stilling basin (Basin I) and on stilling basins designed according to the SAF and Bureau Basin IV criteria before tests were run to develop a low Froude number stilling basin. The eight Basin I tests were for Froude numbers from 2.7 to 6.0; the tests for the SAF and Basin IV designs were for a specific Froude number. The existing basins were tested to gain experience on performance of existing designs and to obtain data to compare with later tests.

Natural Basin Tests

The flow downstream from the Basin 1 design was quite smooth at low Froude numbers and the jump was maintained in the basin if the tailwater depth was at least equal to D_2. Sweepout occurred (the hydraulic jump moved downstream from the toe of the chute) in a natural basin when the tailwater was about 3 percent lower than D_2.

Two main disadvantages of using a Basin I design for low Froude number flows are: (1) the basin length, 6 D_2, and (2) the relatively high-velocity jet that exists along the floor may extend into and erode the downstream channel.

Preliminary test data included upstream and downstream depths, length of the jump, and discharge. These data were combined to form dimensionless ratios and are plotted as functions of the Froude number (fig. 4, 5, and 6) for the basins tested.

The efficiency is shown as a function of Froude number (fig. 4) and the data from the preliminary tests are in agreement with the computed theoretical maximum energy loss curve shown as a dashed line.

The ratio of L to D_2 is plotted (fig. 5) as a function of Froude number. The dashed line is the length recommended in EM25 for a natural hydraulic jump stilling basin, Basin I. The basin length data from the current tests for Basin I are shorter than the length recommended in EM25. The differences between these two data sets were most likely caused by the following:

(1) The front of the jump may have been maintained more completely on the sloping chute during this study than the previous studies, which would decrease the length of the hydraulic jump.

(2) The differences between observations made by different people may account for some of the difference between the current data and the dashed line because each set of data appears to be consistent within itself.

The curve for the conjugate depth ratio, $D_2/D_1 = \frac{1}{2}(\sqrt{1 + 8F^2} - 1)$, is a function of the Froude number and is plotted on figure 6. The data points are bounded by the curves which correspond to tailwater depths of 1.1 and 0.9 times D_2.

Tests that had ratios of TW (tailwater depth) to D_1 higher than those shown, (fig. 6) had very little energy dissipation even though the flow was very smooth. Tests with a high TW/D_1 were observed and the efficiencies computed; however, these data were not recorded because of the small amount of energy dissipation. If the tailwater depth was reduced below D_2, a rough wavy surface developed and eventually the hydraulic jump would sweep out of the stilling basin. The best conditions for energy dissipation and flow existed when the tailwater was at or slightly above D_2.

In summary, the following were characteristic of the natural básin (Basin I) design: (1) The length of the jump was about six times D_2 and tailwater was nearly equal to D_2 (2) The velocity was distributed uniformly over the depth except for the high-velocity jet near the floor. (3) Usually, minimal waves occurred downstream from the jump; however, surging waves occurred downstream when the high-velocity jet oscillated between the floor and the water surface. As a result, channel erosion is likely to occur for a Basin I design because higher velocity flow stayed close to the floor.

SAF Basin Test

A stilling basin was built and tested for a Froude number of 3.5 according to the SAF design criteria [3]. The upstream face of the hydraulic jump was very rough. Waves and large fluctuations in velocity occurred immediately downstream from the baffle piers and caused a rough wavy surface. The rough turbulent flow continued some distance downstream from the end sill and much of the energy dissipation occurred there. Consequently, the potential for scour downstream from an SAF stilling basin is high. Riprap or other protection must be provided unless a scour hole is permissible.

The length of the SAF stilling basin was shorter than the natural basin for the same Froude number (fig. 5), but higher waves were observed. The SAF basin is about 5 percent more efficient (fig. 4) than the other basins. However, the SAF basin is generally not more efficient than a natural hydraulic jump stilling basin. The increased efficiency shown was mainly caused by the inadvertently lower tailwater set during the SAF test. At section 1 most of the energy is velocity head, while at section 2 most of the energy consists of piezometric head. As a result, higher energy losses than normal were computed between sections 1 and 2 (fig. 6) because the tailwater was slightly less than D_2 for the test.

Bureau Type IV

Oversize deflector blocks on the chute and an optional solid end sill characterize the Bureau Basin IV. The recommended length of the stilling basin for this structure is the same as for stilling Basin I. Two data points were recorded from the tests of this structure. The upper data point on figure 5 is with the end sill and the lower point is without the end sill.

The flow approached critical depth across the solid end sill proportioned according to EM25. As a result the flow alternately accelerated, reducing the depth, then raised back up to the tailwater height immediately downstream from the end sill. This alternate decrease and increase in depth caused a very rough water surface downstream from the end sill, which required a longer stilling basin than would be required without the end sill. The water surface was not as rough and turbulent without the end sill. Apparently, the end sill was too high for the Froude number tested. The full conjugate depth was required to keep the jump from sweeping out of the basin. The efficiency of the type IV basin was slightly lower (fig. 4) than that for Basin I.

DEVELOPMENT TESTS

The development of a low Froude basin design started with the Basin III design and modified according to the results of model tests. Data obtained during these tests included basin length, upstream depth, tailwater depth, and discharge. These variables were used to create the dimensionless plots for the design criteria on figures 5, 6, and 8.

Basic Flow Patterns

Several different types of flow patterns were observed in the stilling basins. Without chute blocks the jet hit the floor at a downward angle, deflected off the basin floor, and almost jumped completely over the baffle piers, making them ineffective. When chute blocks (fig. 7) were placed at the toe of the chute, the jet was directed toward the vertical face of the baffle piers, which increased the energy dissipation. However, if the baffle piers were too close to the toe of the chute, rough turbulent flow occurred between the chute blocks and the baffle piers, and the jet was deflected upward along the upstream face of the baffle piers. This vertical flow caused a boil above the baffle piers and rough turbulent waves downstream. As the baffle piers were shifted downstream, a much smoother flow occurred and the downstream waves diminished. At the other extreme, when the baffle piers were too far downstream they were ineffective, and the jet-like flow from the chute blocks oscillated between the water surface and the floor of the stilling basin immediately upstream from the baffle piers.

Baffle piers that were too high caused a secondary jump to occur downstream from them. If the baffle piers were too short, there was insufficient energy dissipation. Placing the baffle piers downstream from the openings in the row of chute blocks produced a smoother flow than when the baffle piers were not offset. As a result, the width and spacing of the baffle piers and chute blocks must be the same to obtain the exact offset.

Changes in tailwater significantly affected the flow downstream from the baffle piers. If the tailwater depth was much below the conjugate depth, a high-velocity jet existed along the floor but did not increase the efficiency above the dashed line of figure 4. These high velocities decreased as the tailwater approached the conjugate depth and most of the kinetic energy in the flow was dissipated by turbulence in the tailwater. Maximum energy dissipation resulted when the tailwater was equal to D_2. Energy dissipation decreased as the tailwater was raised above D_2. As a result of the above, a tailwater slightly above the conjugate depth is preferred to a low tailwater condition at the sacrifice of a slight decrease in efficiency.

Either a solid or dentated end sill is often used to lift the high-velocity flow away from the floor of the channel downstream from the end sill and to increase the stability of the hydraulic jump. End sills that were too high caused rough flow and waves downstream. Small end sills generally allowed more erosion because the water flowed over the end sill, turned downward, and eroded the channel downstream from the basin.

Rougher flow occurred with a solid end sill than with a dentated end sill of the same height. The dentated end sills tended to improve the mixing of the higher energy water with the surrounding water and produced a better velocity distribution downstream from the end sill. Also a dentated end sill reduced the tendency for the flow to hit the channel floor, consequently, a dentated end sill is recommended instead of a solid end sill to minimize erosion and provide a smoother flow downstream for a wider range of conditions.

RECOMMENDED DESIGN

This design was developed from the tests of the current study and from design criteria that have been used successfully in previous applications. The recommended design is a relatively short stilling basin (L equals approximately 3 D_2), with chute blocks, baffle piers, and dentated end sill (fig. 7).

Chute Blocks and Baffle Piers

The recommended height and width of both the baffle piers and the chute blocks are equal to D_1 and 0.70 D_1, respectively. The recommended spacing between these piers or blocks is equal to the width, that is, $S = W = 0.70\ D_1$.

The following relationship can be used to obtain N (the total number of blocks and spaces):

$$N = \frac{\text{Width} - 2kW}{W} \qquad (3)$$

where

k = fractional width of block equal to side clearance, $0.375 \leq k \leq 0.50$
Width = total width of stilling basin
W = 0.70 D_1

The N obtained should be rounded to the nearest odd number and then adjusted values of either or both W and k can be computed.

The baffle piers should be placed in line with the openings between the chute blocks to increase their effectiveness and to decrease the waves. The clear space between the sidewall and the chute blocks should not be less than 0.375 W nor greater than 0.50 W. Usually, no baffle piers will be placed within 1.375 W of the sidewall. However, if the blockage (summation of the widths of baffle piers divided by the width of the channel) is less than 0.40, then partial sections of the baffle piers could be placed along the sidewall to obtain approximately 0.50 blockage. Any configuration with less than four baffle piers will need partial baffle piers placed along the sidewalls to obtain the necessary blockage. Blockage should be kept between 0.45 to 0.55. When more than four baffle piers were tested, no difference in performance was noted when partial side piers were in place, thus the partial side piers would usually not be needed.

The location of the chute blocks and baffle piers is shown in figure 7. The distance from the chute blocks to the baffle piers (X in fig. 8) varies from 1.3 to about 0.7 times D_2 as the Froude number varies from 2.5 to 5.6.

End Sill and Basin Length

The dimension L_1(the distance from the toe of the chute to the upstream side of the end sill) may be obtained from figure 8. L_1 plus the length of the end sill is somewhat shorter than L for Froude numbers greater than 3 and almost equal to L for Froude numbers less than 3. The additional length beyond the end sill was required for acceleration and deceleration of the flow. However, the distance L_1 plus the length of the end sill might be slightly longer than L for Froude numbers less than 2.7. The stilling basin must be extended to include the end sill for the latter.

The end sill is approximately 0.2 D_2 high. The width of the dentates and spacing between the dentates are both equal to approximately 0.15 D_2. This width may be adjusted to obtain an integer number of dentates across the end sill. Generally, dentates should be placed against the sidewalls of the stilling basin.

The recommended L shown as the ratio L/D_2, (fig. 5) is very close to the value 3, for all Froude numbers shown and could be used instead of the value obtained from the curve. Suitable scour protection will generally be needed downstream from the end of the stilling basin in highly erodible channels.

Tailwater Depth

A tailwater depth of D_2 maintained the jump at the intersection of the horizontal apron and the chute. However, sweepout did not occur for the recommended design when the tailwater was 0.8 of D_2. The TW (tailwater depth) should be maintained at or slightly higher than D_2 (five percent or less). The additional depth increases the factor of safety against sweepout and decreases the flow velocity.

Energy Dissipation

The energy loss ratio (E_L/E_1) is shown (fig. 4) as a function of the Froude number. These data are in agreement with the theoretical curve for higher Froude numbers and are slightly below this curve for lower Froude numbers. The energy loss in a hydraulic jump stilling basin is less than 20 percent for Froude numbers less than 2.7; therefore, it may be better to use another type of energy dissipator. For example, a baffled apron spillway is a more efficient energy dissipator for Froude numbers below three.

Design Example

The following calculation describes the design of a stilling basin according to the recommendations of this report. The resulting structure is shown (fig. 9) with dimensions.

Design of stilling basin for: q = 62.77 (m³/s)/m, D_1 = 2.74 m, and a basin width of 112.8 m.

$$F = \frac{q}{g^{1/2}\ D^{3/2}} = \frac{62.77}{(9.8)^{1/2}\ (2.74)^{3/2}} = 4.42$$

Basin dimensions:

$$D_2 = \frac{D_1}{2}\left(\sqrt{1+8F^2}-1\right) =$$

$$\frac{2.74}{2}\left(\sqrt{1+8\,(4.42)^2}-1\right) = 15.8 \text{ m}$$

$$TW = 1.05\,D_2 = 1.05\,(15.8) = 16.60 \text{ m}$$

1. $L \simeq 3.1\ D_2$ (from fig. 5) = 3.1 (15.8) = 49m
2. $X \simeq 0.97\ D_2$ (from fig. 8) = 0.97 (15.8) = 15.30m
3. $L_1 \simeq 2.24\ D_2$ (from fig. 8) = 2.24 (15.8) = 35.40m
4. Design of chute blocks and baffle piers
   a. height = D_1 = 2.74 m
   b. $W = 0.7D_1$ = 1.92 m tentative value*
   c. The number of blocks and spaces

Compute (N) from equation (3).

$$N = \frac{112.8 - 2(0.375)\ 1.92}{1.92} = 58$$

By rounding up to the nearest odd number, $N = 59$; adding $2k$ (where k = 0.5) for side clearance,

*Consequently, the adjusted width,

$$W = \frac{\text{width}}{N + 2k} = \frac{112.8}{60} = 1.88 \text{ m}$$

(either W or k could have been adjusted)

   d. The top of the baffle piers (fig. 7) = $0.2D_1$ = 0.2 (2.74) = 0.55 m
5. Design of end sill
   a. height = $0.2D_2$ = 3.16 m
   b. $W = 0.15D_2$ = 2.37 m tentative value**
   c. The number of blocks and spaces N = 49 (from eq. 3, where k = zero) similar to the calculation shown for the baffle piers and chute blocks.

**Consequently, the adjusted width,

$$W = \frac{112.8}{49} = 2.302$$

Dentates should be placed against either sidewall.

   d. Therefore, the sill will have 49 blocks and spaces, each 2.302 m wide.
   e. The top of the end sill piers = 0.2 times the end sill height = 0.2 (3.16) = 0.63 m.

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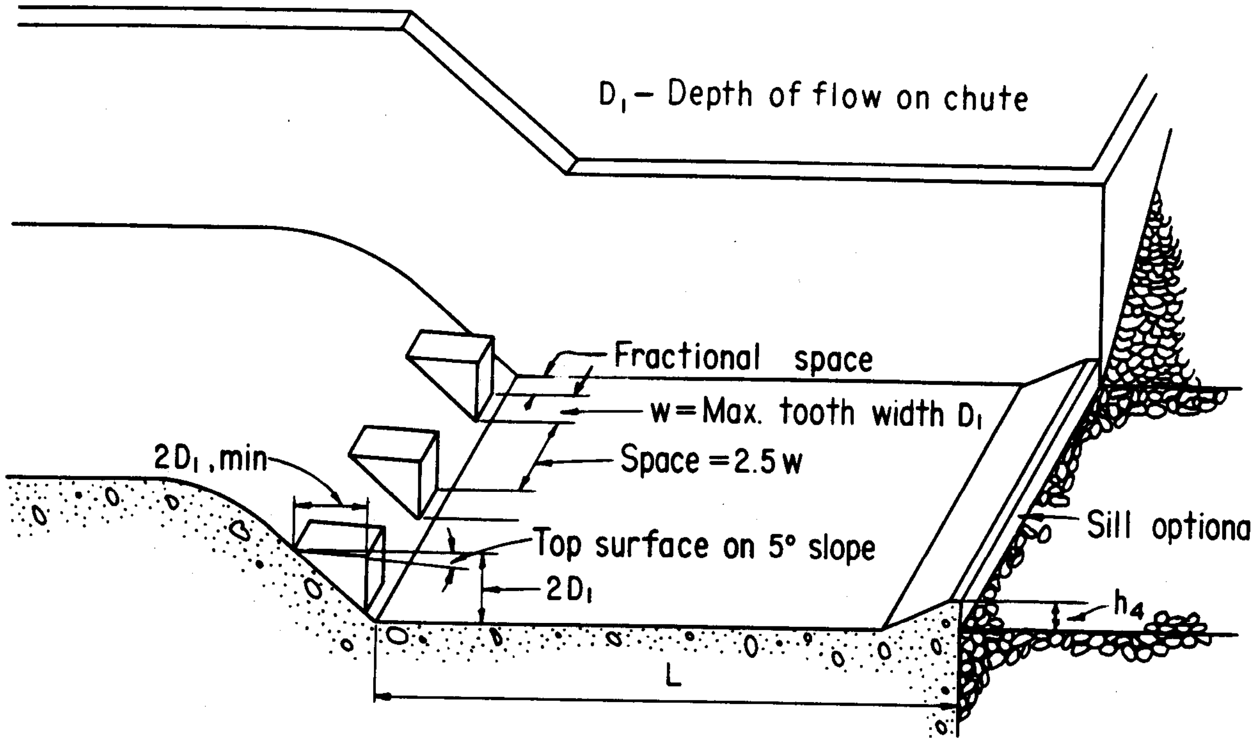

Figure 1.—Proportions for Froude numbers 2.5 to 4.5 (Basin IV).

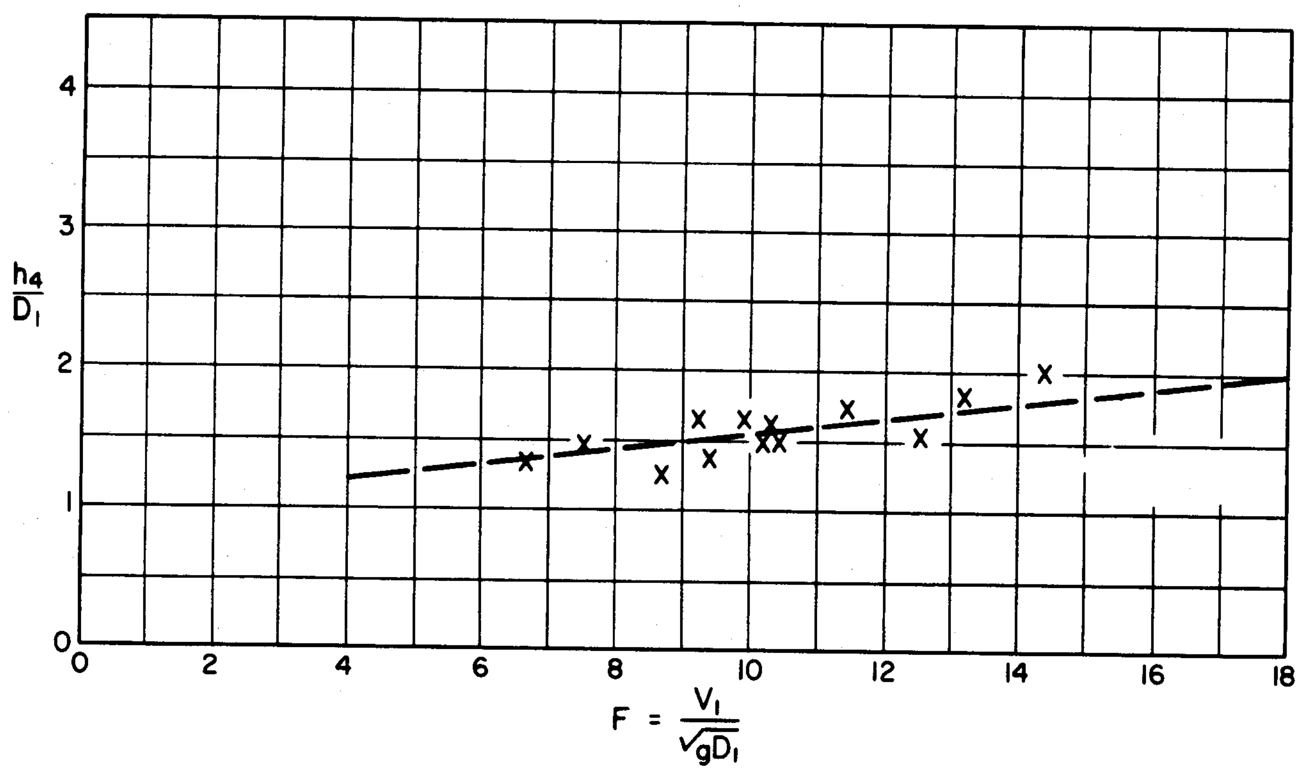

Figure 2.—Height of end sill (Basin IV).

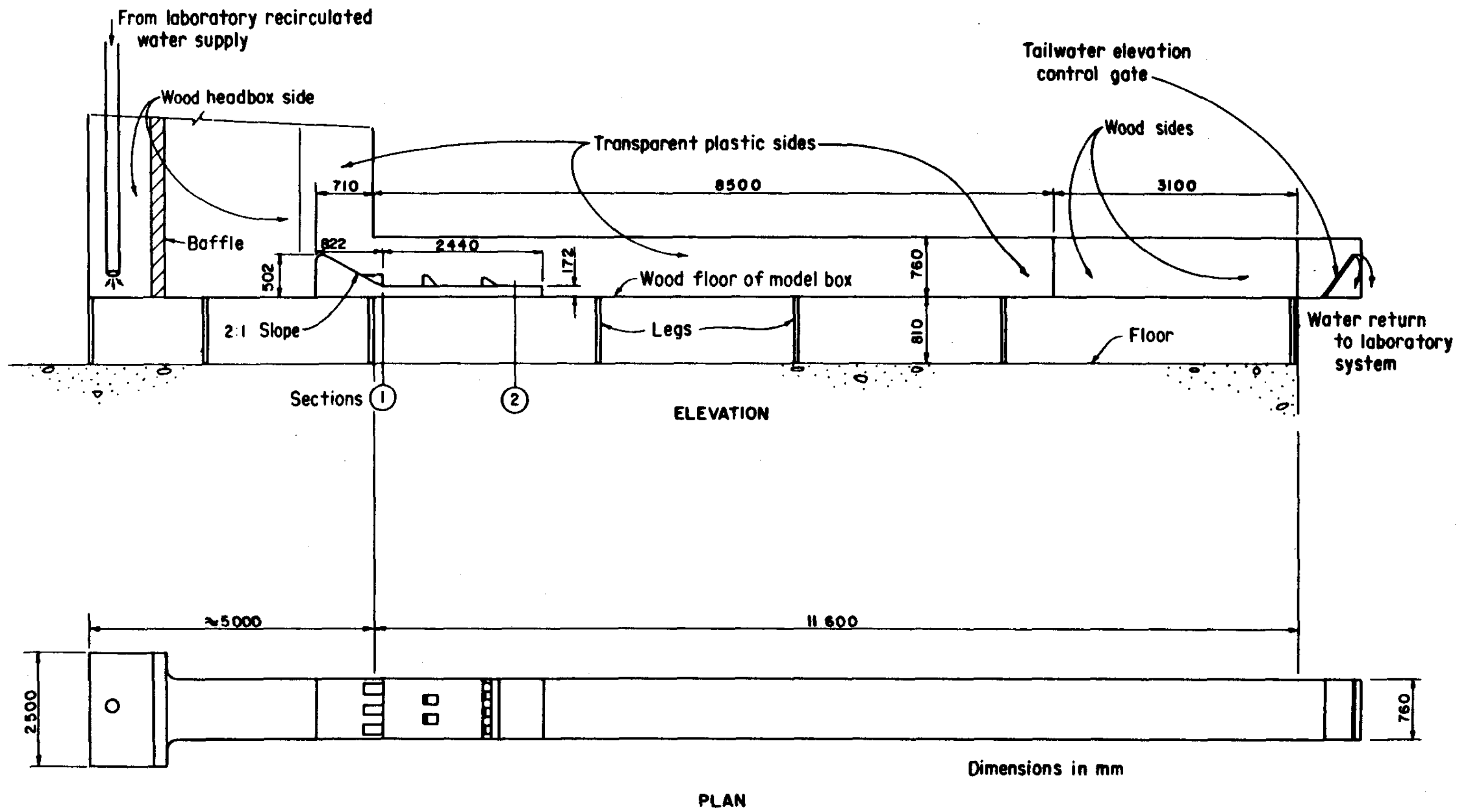

Figure 3.—Laboratory test facility for modeling hydraulic jump stilling basins.

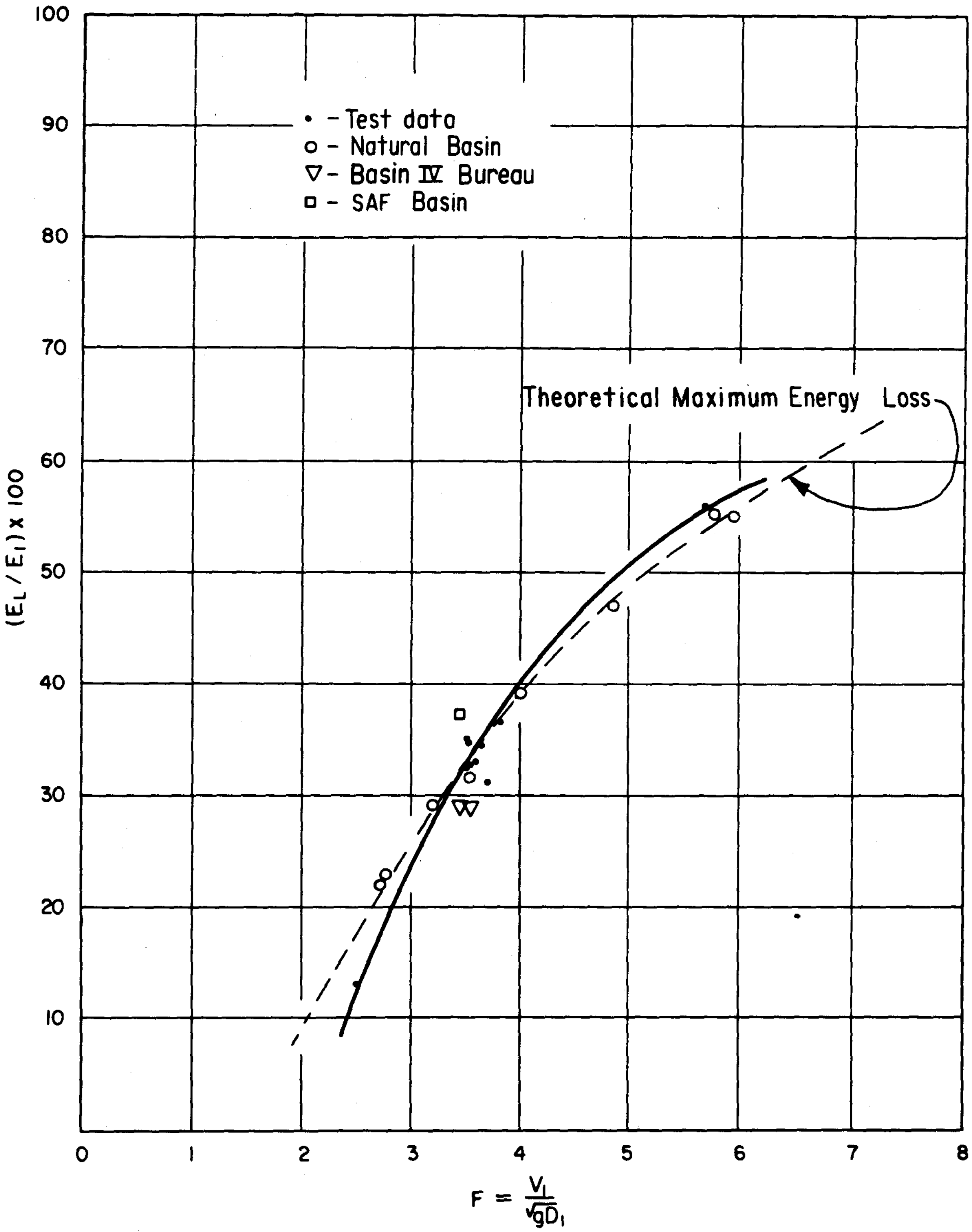

Figure 4.— Energy loss compared to incoming energy.

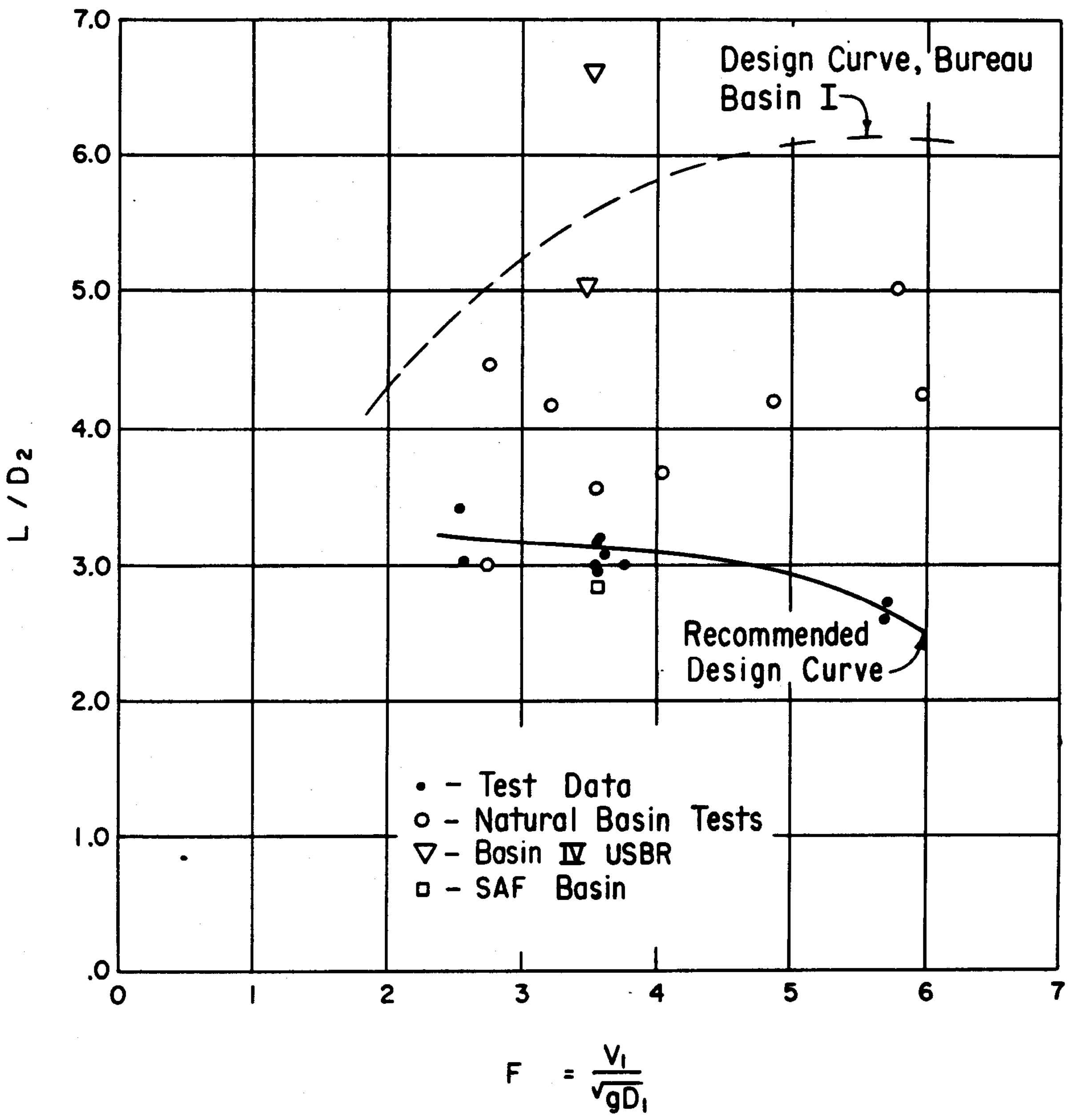

Figure 5.—Dimensionless length of stilling basin.

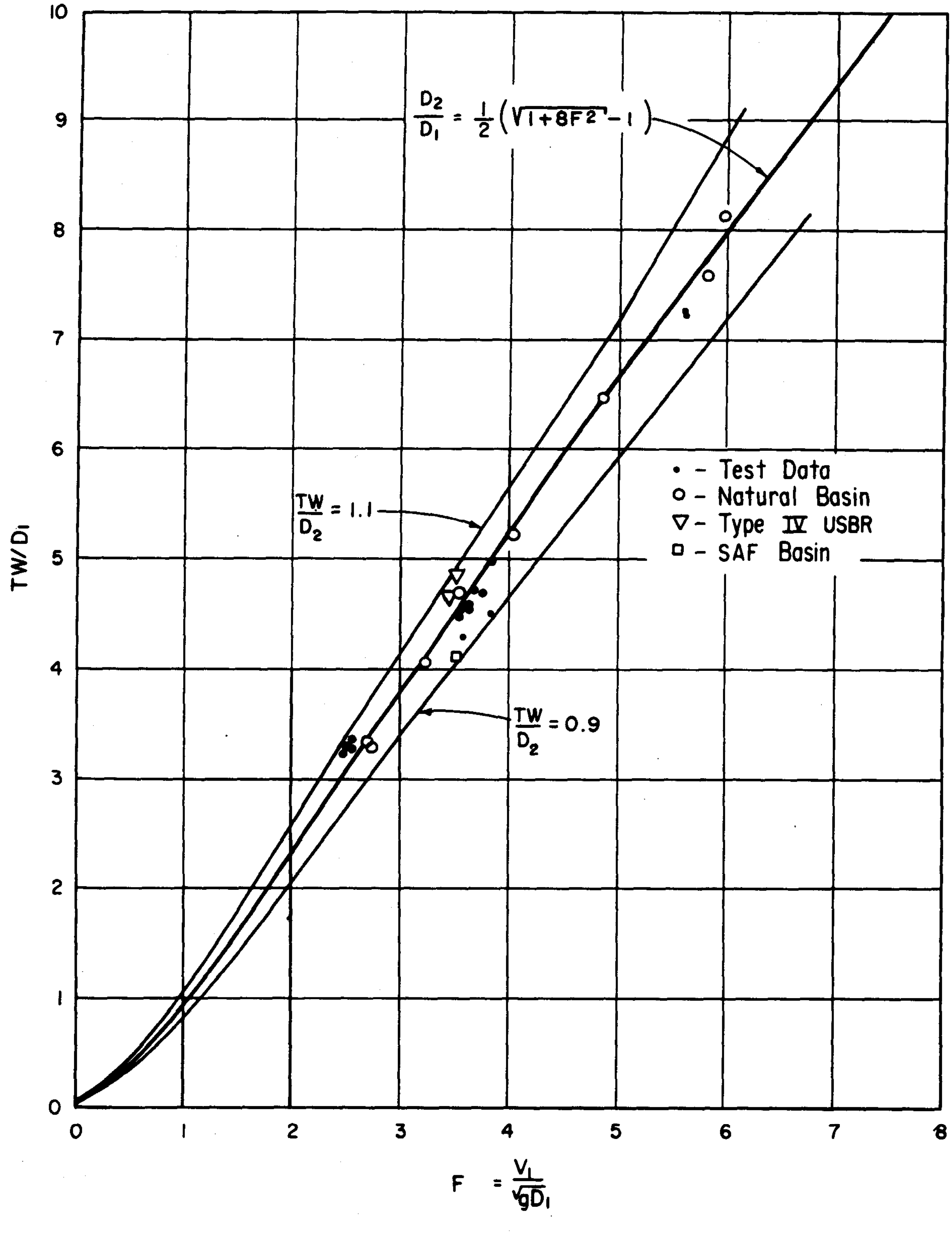

Figure 6.—Ratio of tailwater to inflow depth.

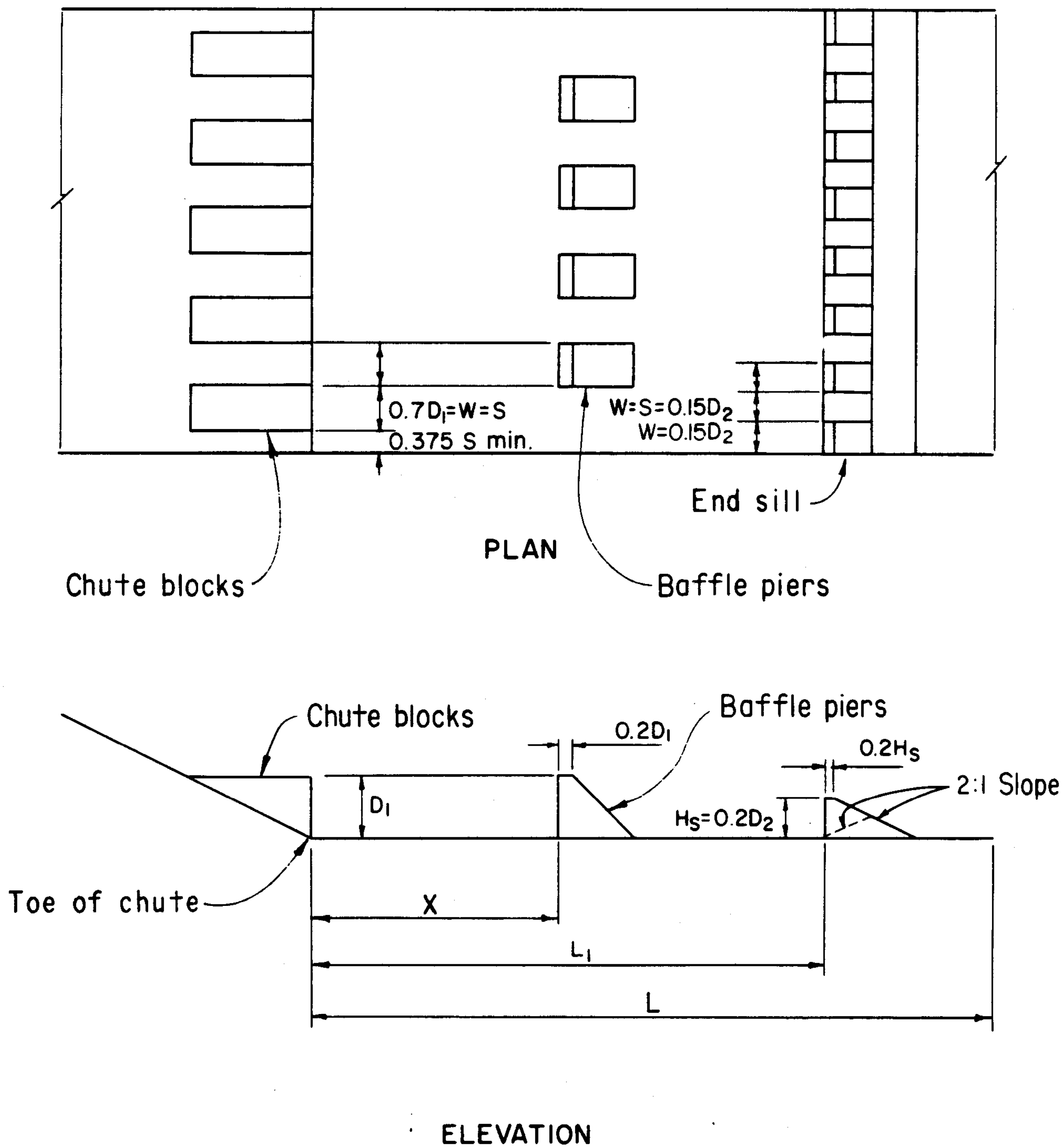

Figure 7.—Recommended stilling basin ($2.5 \leq F \leq 5.0$).

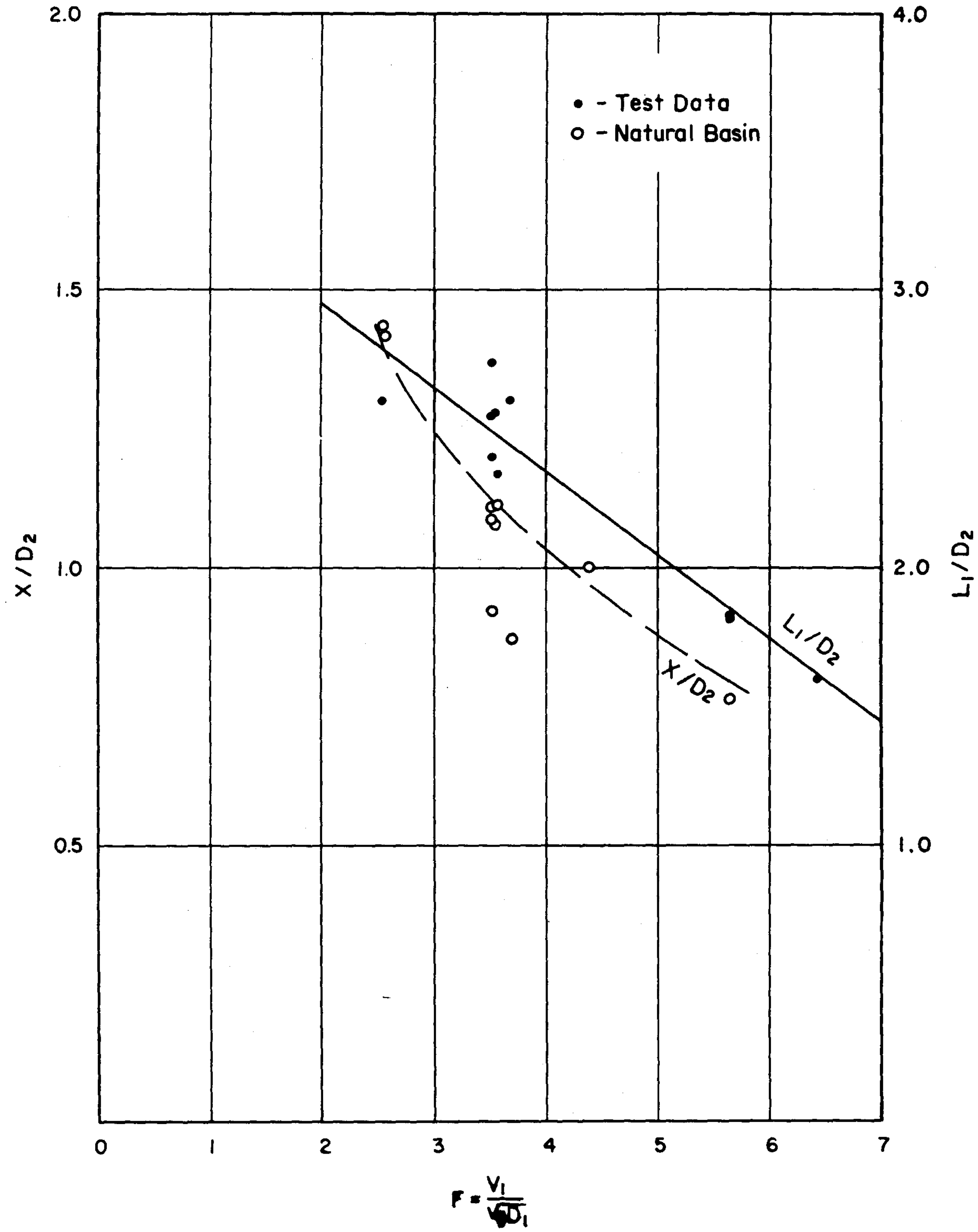

Figure 8.—Distance from toe of chute to baffle piers (*X*) and end sill (*L*).

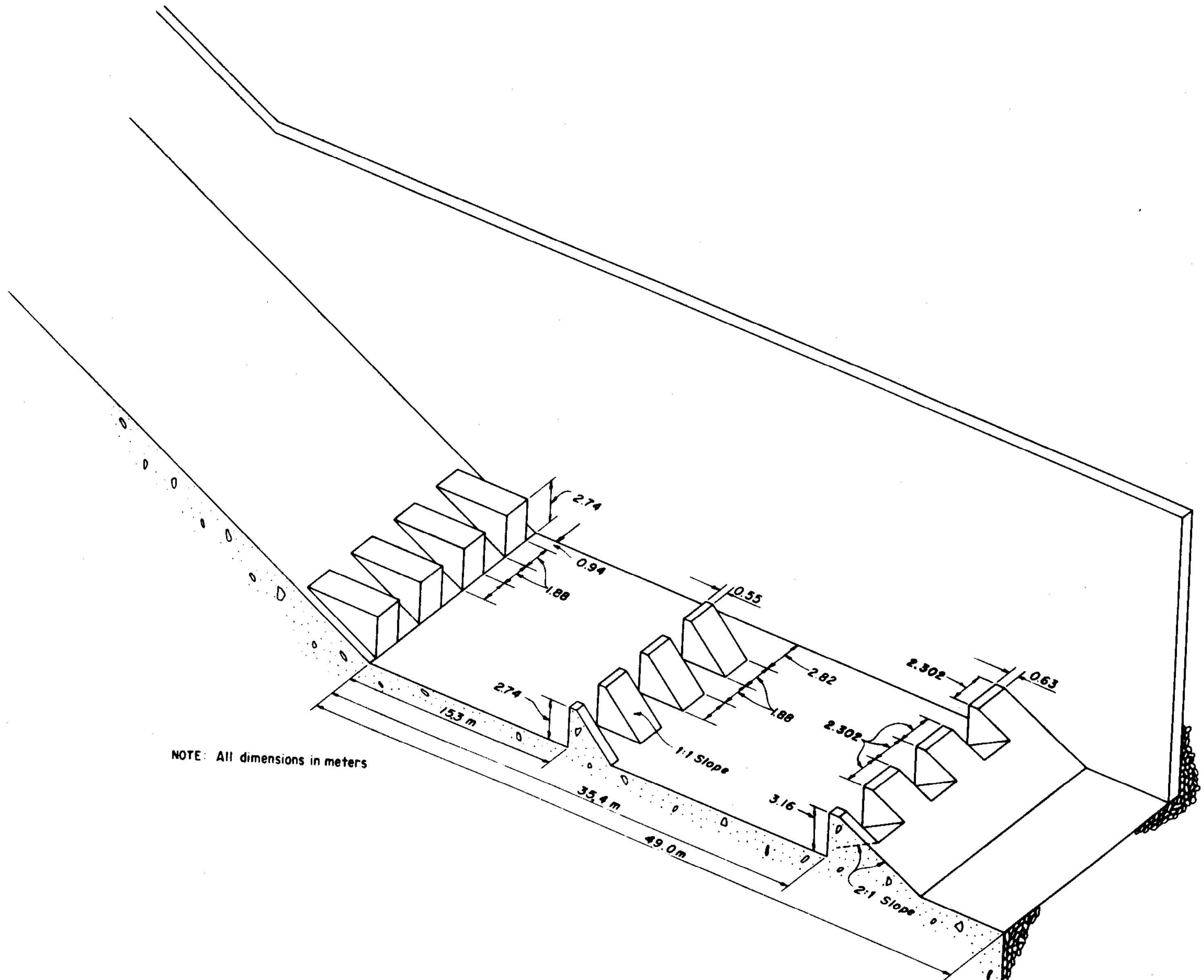

Figure 9.—Example of recommended design.

GPO 851-720