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K-TRAN Research Project KU-98-3

Hydraulic Performance of Set-Back Curb Inlets

by

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for

Kansas Department of Transportation
and the Cities of Leawood, Overland Park,
Olathe, Lenexa and Shawnee, Kansas

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16 Abstract

The objective of this study was to develop hydraulic design charts for the location and sizing of set-back curb inlets. An extensive program of hydraulic model testing was conducted to evaluate the performance of various inlet opening sizes. The grade and cross slope of the pavement was varied as was the water flow in an effort to determine the maximum flow which could be captured by the various inlets.

The street model was 50 feet (15.2 meters) long with a Type A curb on one side and a Type B curb on the other side.The grade was set at either 0.5%, 1%, 2%, 4%, 6%, 8%, 10% , or 12% and the cross slope was either 2% or 4%. The inlet opening was 10 inches (254 mm) high and the mouth opening length was set at either 4, 6, 8, 10, or 12 feet (1.2, 1.8, 2.4, 3.0, and 3.7 meters).

All combinations of cross slope, grade, curb type, and inlet opening were tested in an effort to determine the relationship between captured flow and total flow. The set-back curb inlets exhibit consistent hydraulic behavior over a wide range of conditions. Design charts were created and provide a sound basis for the location and sizing of set-back curb inlets.

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Curb inlet, hydraulic, set-back, storm sewer, design flow chart, cross slope, grade, model.	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

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PREFACE

This research project was funded by the Kansas Department of Transportation K-TRAN research program. The Kansas Transportation Research and New-Developments (K-TRAN) Research Program is an ongoing, cooperative and comprehensive research program addressing transportation needs of the State of Kansas utilizing academic and research resources from the Kansas Department of Transportation, Kansas State University and the University of Kansas. The projects included in the research program are jointly developed by transportation professionals in KDOT and the universities.

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The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or the policies of the State of Kansas. This report does not constitute a standard, specification or regulation.

ACKNOWLEDGMENTS

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1. Background and Objective

The cities of Overland Park, Leawood, Olathe, Lenexa and Shawnee in Kansas all use the same "set-back" curb inlets for street drainage. The standard design for these inlets, shown in Figures 1 and 2, was developed by the City of Overland Park. The inlet opening is set back one foot (0.3 m) from the back of the curb. The bottom of the inlet opening is 16 inches (406 mm) below the top of the curb. The length of the inlet opening can be 4, 6, 8, 10, or 12 feet (1.2, 1.8, 2.4 and 3.0 meters). The inlet opening is 10 inches (254 mm) in height. The steel inlet frame has a horizontal bar across the inlet opening to prevent large objects from entering the storm sewer, and vertical stiffener plates to support the bar. The transition from the upstream curb to the inlet opening is 10 feet (3.0 m) long. The transition from the inlet opening to the downstream curb is 5 feet (1.5 m) long.

Set-back inlets are used on streets with two types of curbs. These standard curbs are shown in Figure 3. The Type B curb has a steep face and a slightly depressed gutter. The top of the Type B curb is four inches (102 mm) above the edge of the pavement. The Type A curb, used in some residential areas, has a gentle slope. The top of the Type A curb is three inches (76 mm) higher than the edge of the pavement.

In 1995, the University of Kansas conducted limited hydraulic tests on one-third-scale models of standard set-back inlets for the cities of Overland Park, Lenexa, Olathe and Shawnee. Inlets with opening lengths of 4, 6, 8 and 10 feet (1.2, 1.8, 2.4 and 3.0 meters) were tested on streets with Type B and Type A curbs. The street was set at eight different grades (from 0.5% to 12%) and two different cross-slopes (2% and 4%). In these initial tests, we determined the largest discharge that each inlet could capture with no bypass under various conditions. This nominal capacity of the inlet was difficult to determine accurately. We observed that a set-back inlet can capture a discharge much larger than its nominal capacity with relatively little bypass. However, our test system was not designed to capture and measure the bypassed discharge.

The objective of this study was to develop hydraulic design charts for the location and sizing of set-back curb inlets. The project sponsors requested that these charts relate the captured discharge to the total discharge in the street, the grade and cross-slope of the street, and the type of curb. These practical design aids were developed through an extensive program of hydraulic model tests.

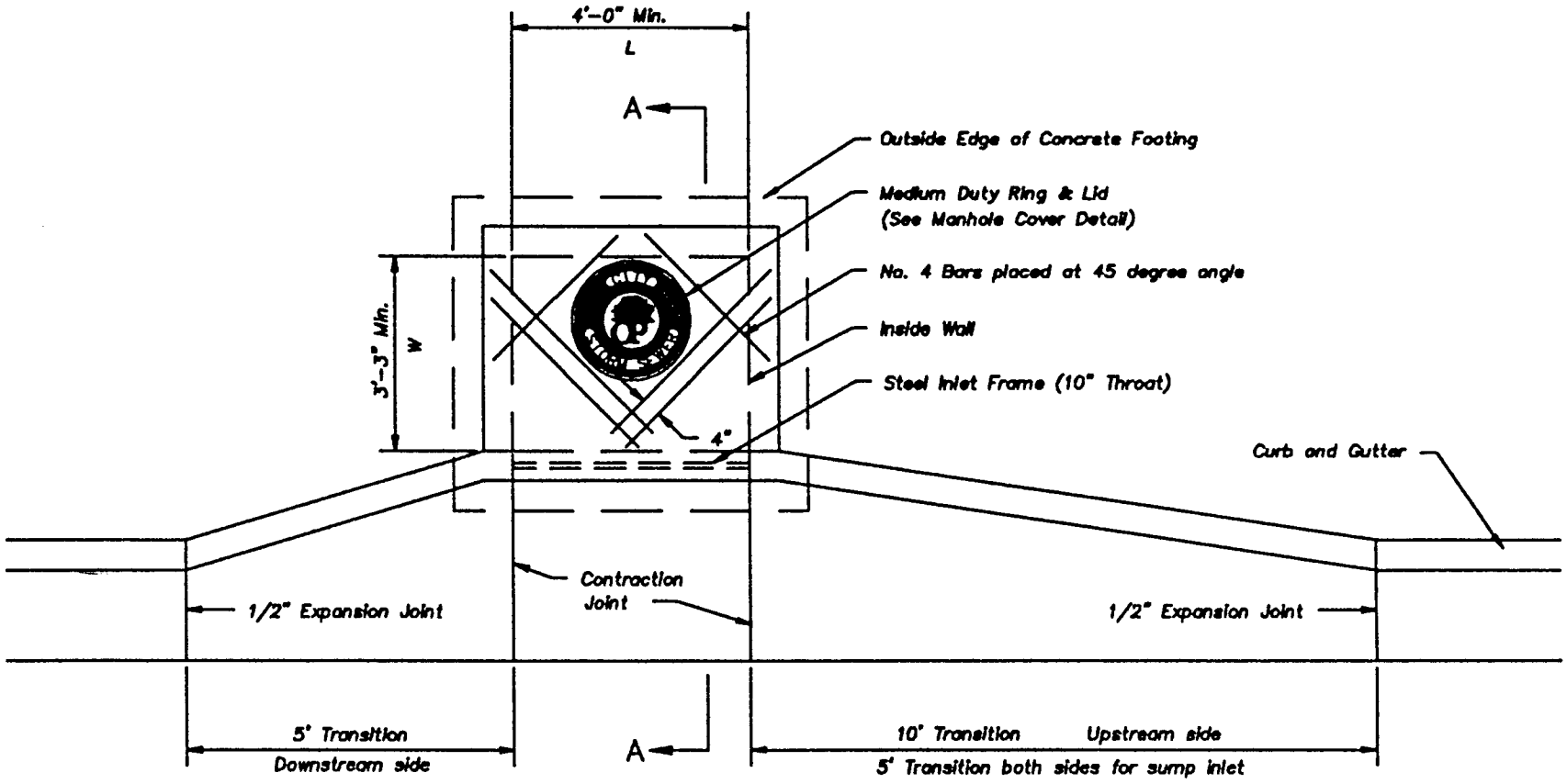


Figure 1. Plan view of set-back curb inlet (City of Overland Park)

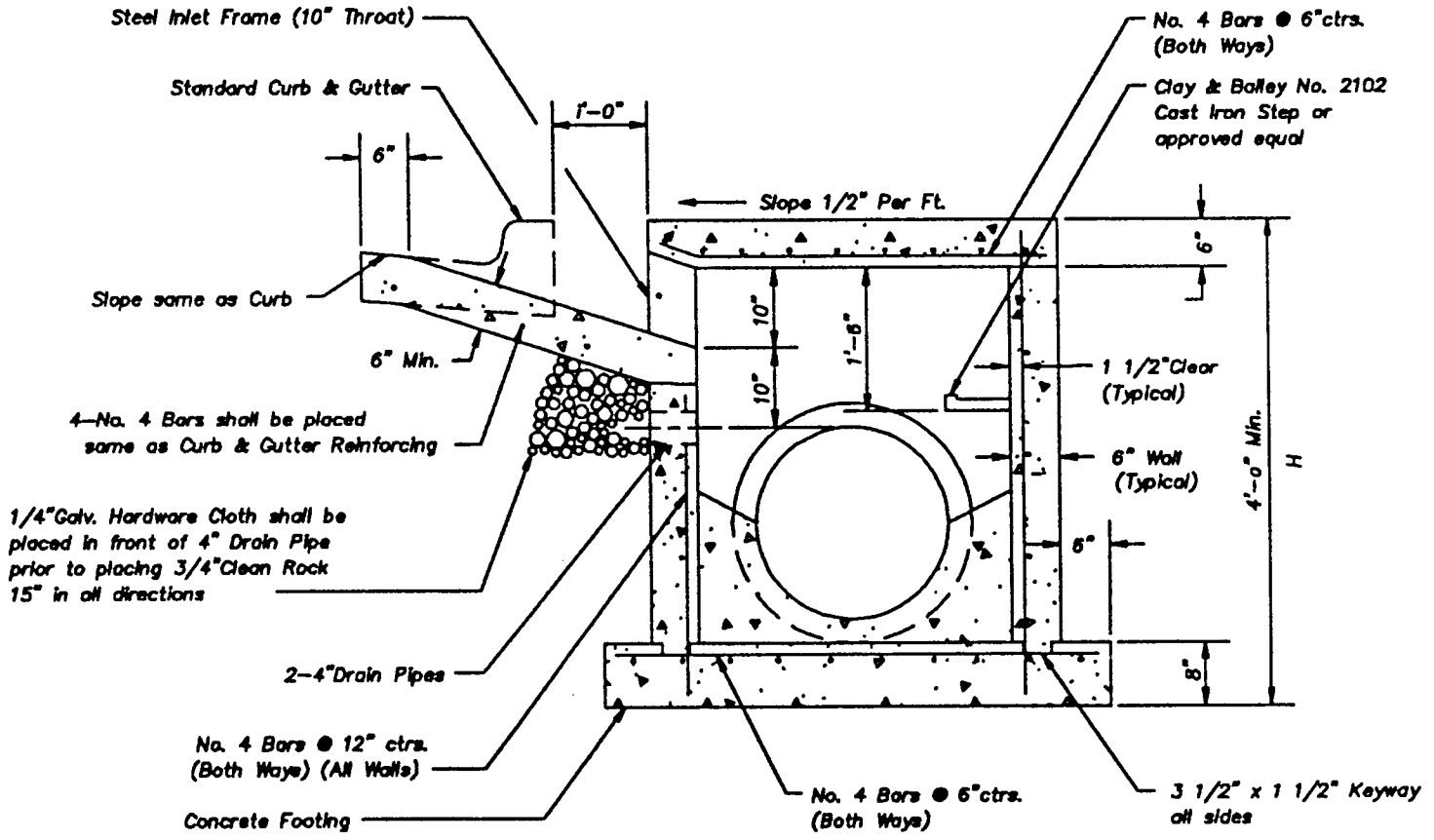
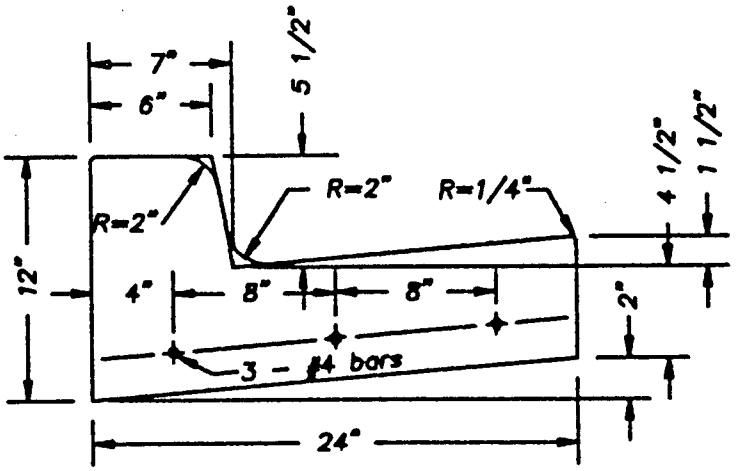
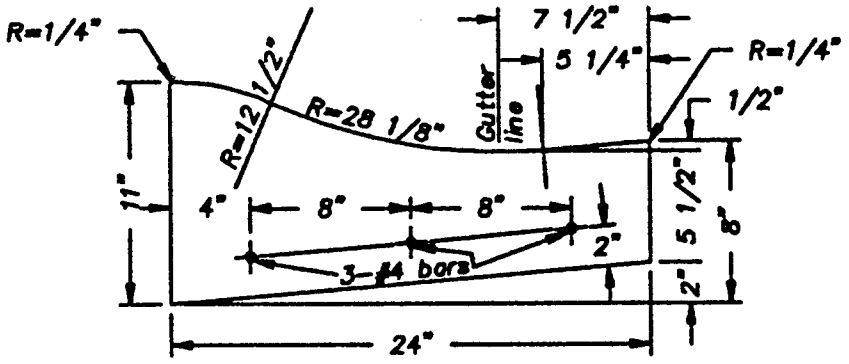


Figure 2. Sectional view of set-back curb inlet (Section A-A in Figure 1)



TYPE "B" CURB



TYPE "A" CURB

Figure 3. Standard curbs (City of Overland Park)

2. Experimental Set-Up

Hydraulic model studies of the standard set-back curb inlets were conducted in the hydraulics laboratory at the University of Kansas. A new test apparatus was designed and constructed for this project. All features were modeled at one-quarter scale. The model street is 50 feet (15 m) long and 5 feet (1.5 m) wide, with a Type B curb on one side and a Type A curb on the other side. It is supported on a lightweight box beam. The downstream end of the beam is hinged to the floor of the laboratory. The grade of the street is adjusted by raising or lowering the upstream end of the beam with a chain hoist. The cross-slope of the street is also adjustable. Water can be directed to either curb. The distance from the upper end of the street to the start of the inlet transition is 30 feet. High-density polyurethane foam panels form the street surface. We constructed separate models of the four inlets and the upstream and downstream transitions to the Type B and Type A curbs. The model curbs, gutters, inlets and transitions are constructed of wood and plaster. All surfaces are painted. A commercial non-skid product was mixed into the paint to increase the roughness of the surfaces.

Water is supplied by the recirculating system that serves the two large flumes in the hydraulics laboratory. A flexible conduit 2.5 inches (64 mm) in diameter delivers water to a stilling basin attached to the upstream end of the street. This line is fed from a constant-head tank on the roof of the laboratory. The discharge is controlled with a ball valve. The water spills out of the stilling basin into the gutter and street. The water captured by the inlet is directed to a wooden box with a 90° V-notch weir at the downstream end. The water that bypasses the inlet is directed to an identical weir box at the downstream end of the street. The captured and bypassed discharges are measured with these weirs. The water level in the weir box is measured in a stilling well with a point gage. The corresponding discharge is computed from the well established head-discharge relationship for a 90° V-notch weir (Bos, 1989). Each weir box contain several baffles that distribute the flow uniformly and minimize surface waves. Discharges at heads below 0.1 foot (0.03 m) were determined volumetrically with a graduated cylinder and a stopwatch. The outflows from the weir boxes are directed to a sump pit. Water is pumped continuously from the sump pit to the constant-head tank.

3. Test Program

We tested each combination of inlet and curb at all combinations of eight street grades and two cross-slopes. The eight grades were 0.5%, 1%, 2%, 4%, 6%, 8%, 10% and 12%. The two cross-slopes were 2% (1/4 inch per foot) and 4% (1/2 inch per foot). At each setup, the objective was to determine the relationship between the captured discharge and the total discharge (the sum of the captured and bypassed discharges). The total discharge was controlled with the ball valve on the inflow line. Initially, flow was established at a discharge that was captured entirely. This discharge was measured at the weir box. The flow was then increased slightly by repositioning the valve. When the water levels in the weir boxes stabilized, the captured discharge and the bypassed discharge (if any) were measured. This process was repeated until the flow overtopped the curb upstream of the inlet.

4. Model-Prototype Relations

The flow pattern in the vicinity of an inlet is determined primarily by two factors: gravity and inertia. The turning of the flow into the inlet is driven by gravity and resisted by inertia. The Froude number is the dimensionless number that indicates the relative importance of gravity and inertia. Within the inlet itself, frictional resistance is relatively insignificant. The flow in the gutter and street is generally supercritical, unless the street grade is nearly flat. Supercritical flow is controlled from upstream. Therefore, the flow pattern in the vicinity of the inlet depends on the velocity and depth in the gutter and street upstream of the inlet. The upstream flow in the gutter and street is generally almost uniform, meaning that the gravitational driving force and the frictional resistance are almost in balance.

Model-prototype relations for geometrically similar inlets can be developed from a dimensional analysis. The discharge captured by a model of a particular design depends primarily on the size of the model, the depth and velocity of the flow upstream of the inlet, and the density and specific weight of the fluid. This relationship can be expressed as

$$Q_c = f\,(L,\ y_o,\ V_o,\ \rho,\ \gamma) \qquad (1)$$

in which Q_c is the captured discharge, L is a characteristic length dimension, y_o and V_o are the depth

and velocity of uniform flow in the gutter and roadway upstream of the inlet, and ρ and γ are the density and specific weight of the fluid. Dimensional analysis leads to the relationship

$$\frac{Q_c}{\sqrt{g\,L^5}} = f\left(\frac{y_o}{L}, \frac{V_o}{\sqrt{g\,L}}\right) \tag{2}$$

Geometric similarity requires equal values of y_o/L in the model and prototype. If the Froude numbers of the uniform flows are also equal, then the captured discharges are related as follows:

$$\frac{Q_{c,m}}{Q_{c,p}} = \left(\frac{L_m}{L_p}\right)^{5/2} \tag{3}$$

(Henderson, 1966) in which the subscripts m and p indicate model and prototype. This scaling law, which follows from Eq. 2, also applies to the total discharge, Q_t (the sum of the captured and bypassed discharges), provided that the same conditions are satisfied:

$$\frac{Q_{t,m}}{Q_{t,p}} = \left(\frac{L_m}{L_p}\right)^{5/2} \tag{4}$$

In our tests, the length ratio L_m/L_p was 1/4, and the discharge ratios $Q_{c,m}/Q_{c,p}$ and $Q_{t,m}/Q_{t,p}$ were 1/32.

5. Calibration of the Model

The model was calibrated by adjusting the roughness of the surface. The objective was to achieve equal Froude numbers in the model and prototype for uniform flows at geometrically scaled depths, so that discharges could be scaled with Eqs. 2 and 3. This condition is met when the Manning friction factors for the model and prototype, n_m and n_p, are related as follows (Henderson, 1966):

$$\frac{n_m}{n_p} = \left(\frac{L_m}{L_p}\right)^{1/6} \tag{5}$$

For a one-quarter-scale model, Eq. 5 requires that $n_m = 0.79\ n_p$. For full-scale gutters and streets, Manning friction factors typically range from 0.013 to 0.016, depending on condition (Chow, 1959).

In the model calibration tests, a constant discharge was established and measured, and the cross-section of the flow (depth versus distance from edge of pavement) was measured at a locations where the flow was approximately uniform. The Manning n for the model was computed from the measured quantities. In repeated tests, the Manning n value of the model was found to be 0.010, which corresponds to a prototype Manning n of 0.013.

6. Analysis of Experimental Data

The graphs in Appendix A show the relationship between the captured discharge and the total discharge for all conditions tested. The plotted discharges are equivalent prototype discharges. For any given set of conditions (curb type, inlet length, street grade and cross-slope), the relationship between the captured discharge and the total discharge can be approximated satisfactorily by an equation of the form

$$Q_c = \begin{cases} Q_t & \text{for } Q_t \le Q_o \\ Q_o + (Q_a - Q_o)\left\{1 - \exp\left[-\left(\dfrac{Q_t - Q_o}{Q_a - Q_o}\right)\right]\right\} & \text{for } Q_t > Q_o \end{cases} \quad (6)$$

in which Q_o and Q_a are constants. The constant Q_o represents the largest discharge that is captured completely, and the constant Q_a represents the upper limit on the captured discharge, which is approached asymptotically with increasing total discharge. For each set of conditions, a least-squares optimization procedure was used to fit Eq. 6 to the experimental data. This procedure yielded best-fit values for Q_o and Q_a. An analysis these values for each combination of curb type and cross-slope revealed the following general trends:

1. The relationship between Q_o and the length of the inlet opening, L_o, is approximately linear.
2. The relationship between Q_a and L_o is approximately linear.
3. The relationship between log Q_o and log S_o is approximately linear (S_o = street grade in percent)
4. The relationship between log Q_a and log S_o is approximately linear.
5. The linear relationship between log Q_o and log S_o and the linear relationship between log Q_a and log S_o have approximately the same slope.

These findings indicate that, for a particular curb type and street cross-slope, Q_o and Q_a vary with inlet length and street grade according to the formulas

$$Q_o = (a + b \cdot L_o)\ (S_o)^x \quad (7)$$

$$Q_a = (c + d \cdot L_o)\ (S_o)^x \quad (8)$$

in which a, b, c, d and x are constants. The best-fit values of these constants for each combination of curb type and street cross-slope (S_x) were determined by least-squares regression. Tables 1 and 2 show these results in U. S. customary units and metric units.

TABLE 1. Values of Coefficients and Exponent in Equations 7 and 8 for U. S. Customary Units

Curb type	S_x, %	a	b	c	d	x
B	2	1.0	0	3.2	1.7	-0.5
B	4	1.5	0.5	2.6	1.9	-0.5
A	2	-0.4	0.1	3.5	0.8	-0.7
A	4	-0.3	0.3	4.3	2.5	-0.8

TABLE 2. Values of Coefficients and Exponent in Equations 7 and 8 for Metric Units

Curb type	S_x, %	a	b	c	d	x
B	2	0.30	0	0.98	0.52	-0.5
B	4	0.46	0.15	0.79	0.58	-0.5
A	2	-0.12	0.03	1.07	0.24	-0.7
A	4	-0.09	0.09	1.31	0.76	-0.8

Eqs. 6 through 8, with the coefficients and exponents in Tables 1 and 2, can be used to generate Q_c-Q_t curves for any combination of conditions within the ranges tested. Q_c-Q_t curves for the experimental conditions were developed in this manner and are plotted alongside the experimental data on the graphs in Appendix A. In general, the curves developed from Eqs. 6 through 8 fit the experimental results reasonably well. The smooth curves tend to overestimate the discharge captured by short inlets on very steep slopes at high total discharges. The experimental data show that, under these conditions, the captured discharge actually decreases with increasing total discharge. However, this anomaly only occurs at interception ratios below 50%, so it is of little practical importance.

The hydraulic efficiency of a curb inlet depends strongly on the cross-slope of the street and the cross-sectional geometry of the curb and gutter. Curb inlets work best on streets with large cross-slopes, deep gutters and steep curbs. On such streets, the flow is already concentrated near the curb when it reaches the inlet opening. On streets with small cross-slopes and shallow gutters, the flow can spread out across the pavement a considerable distance from the curb. The greater the spread of the flow, the longer the inlet needed to capture it. Figure 4 compares the performance of identical inlets on identical streets with different types of curbs. The inlet can capture much more water on the street with the Type B curb than on the street with the Type A curb. Figure 5 compares the performance of identical inlets on streets with cross-slopes of 2% and 4%. The inlet can capture much more water on the street with the steeper cross-slope.

Appendices B and C contain hydraulic design charts for the set-back curb inlets in U. S. customary units and metric units. These charts show the relationship between the interception ratio (Q_c/Q_t) and the total discharge for all possible combinations of the two curb types, the two cross-slopes, nine street grades, and five inlet lengths. These charts were developed from Equations 6 through 8 and the coefficients and exponents in Tables 1 and 2.

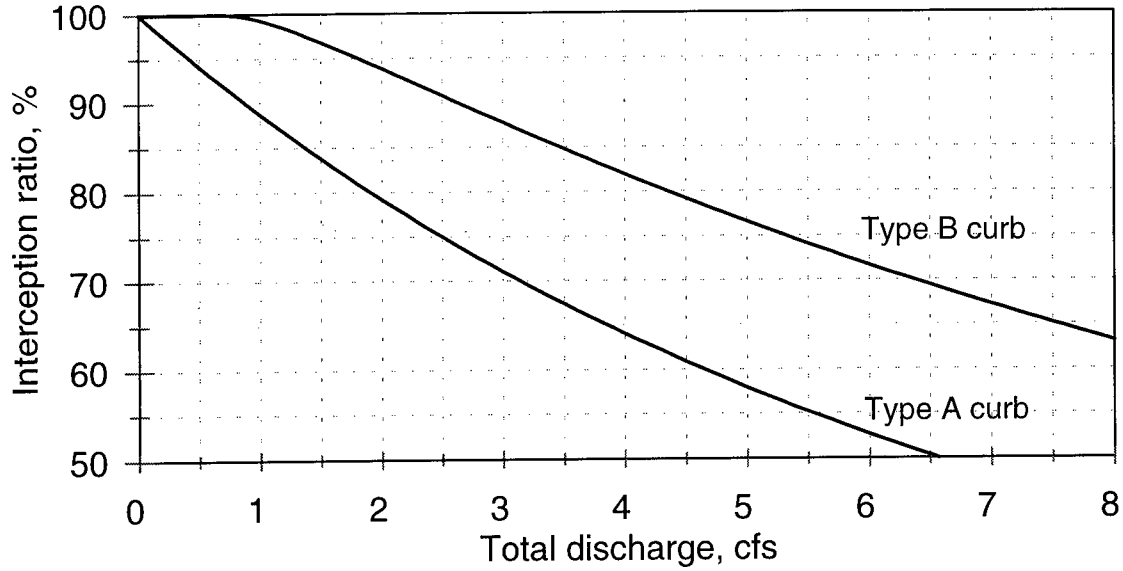


Fig. 4. Effect of curb type on inlet performance. Inlet length = 4 ft (1.2 m); street grade = 2%; street cross-slope = 4%.

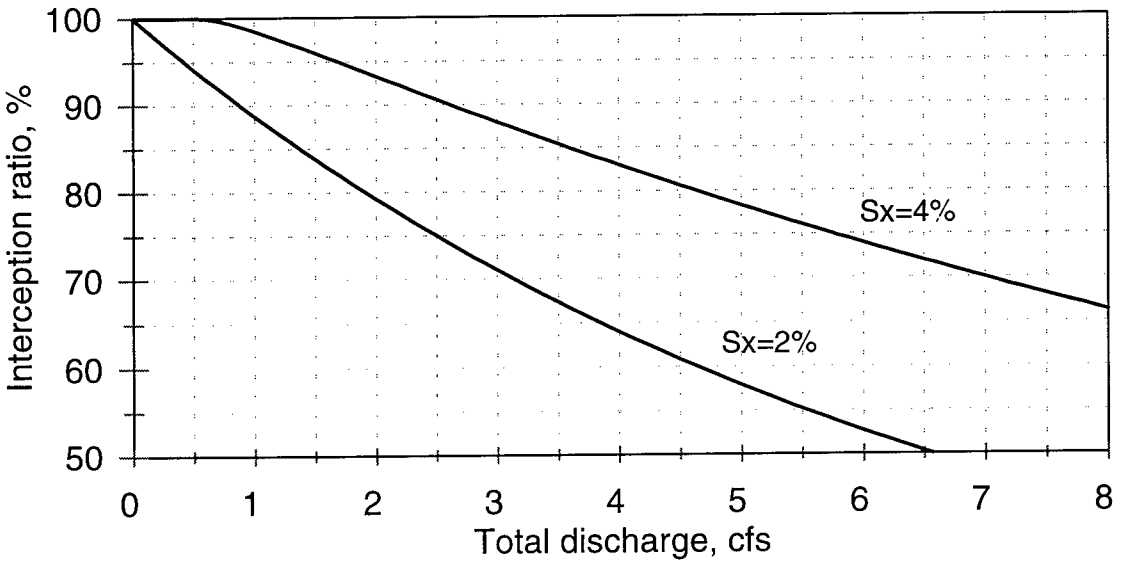


Fig. 5. Effect of street cross-slope on inlet performance. Inlet length = 4 ft (1.2 m); street grade = 2%; Type A curb.

7. Conclusions

Set-back curb inlets exhibit consistent hydraulic behavior over a wide range of conditions. The relationship between the captured discharge and the total discharge in the street is approximated satisfactorily by Eq. 6 for all conditions of practical interest. Eqs. 7 and 8 relate the values of the constants in Eq. 6 to the inlet length and the street grade. Tables 1 and 2 provide values of the constants in Eqs. 7 and 8 for two curb types and two cross-slopes. The hydraulic efficiency of a curb inlet depends strongly on the cross-slope of the street and the cross-sectional geometry of the curb and gutter. Curb inlets work best on streets with large cross-slopes, deep gutters and steep curbs. The design charts in Appendices B and C compare the hydraulic performance of inlets of five different lengths for 36 combinations of street grade, cross-slope and curb type. These charts provide a sound basis for the location and sizing of set-back curb inlets.

8. References

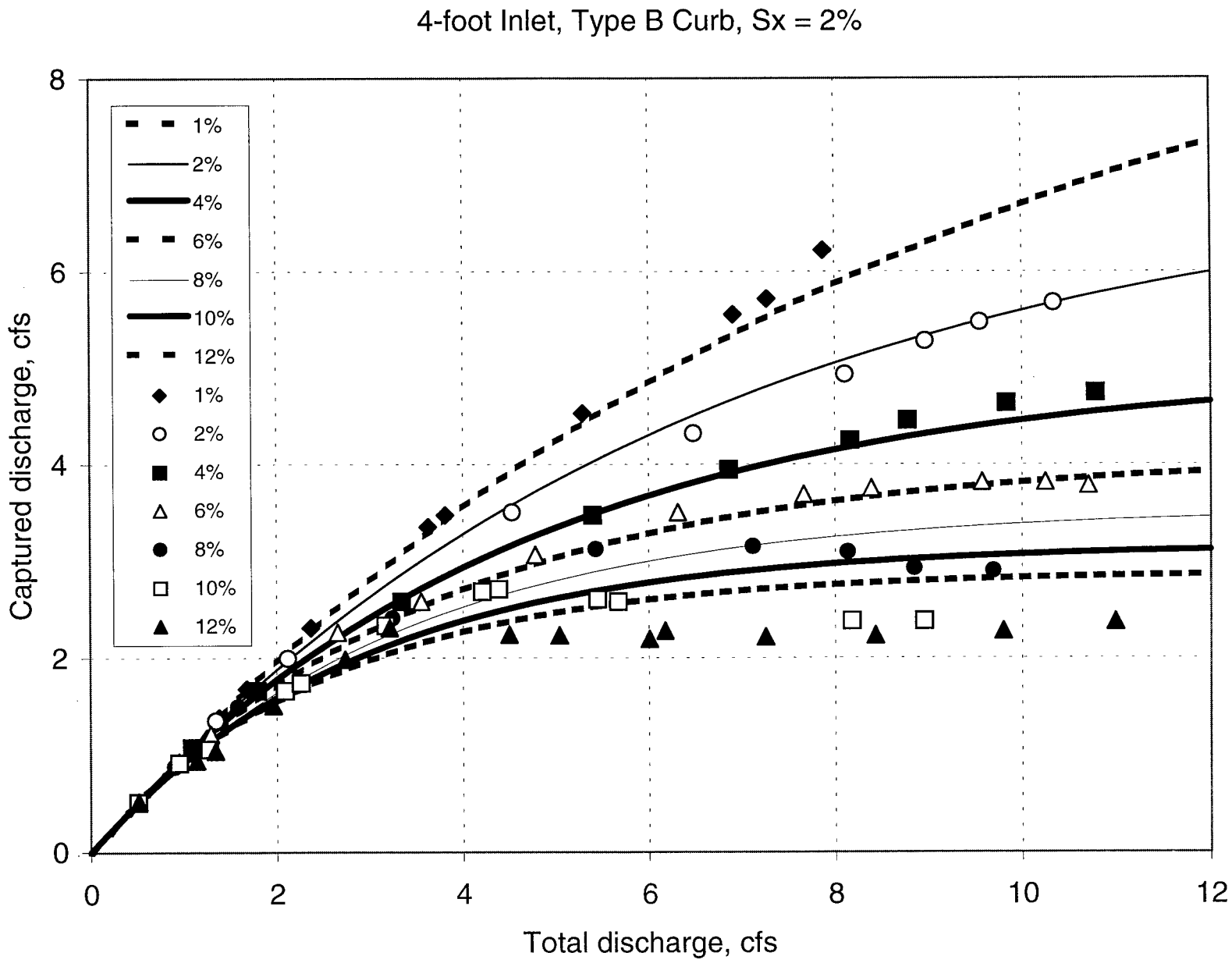
Bos, M. G. (1989). *Discharge Measurement Structures*, pp. 161-169.

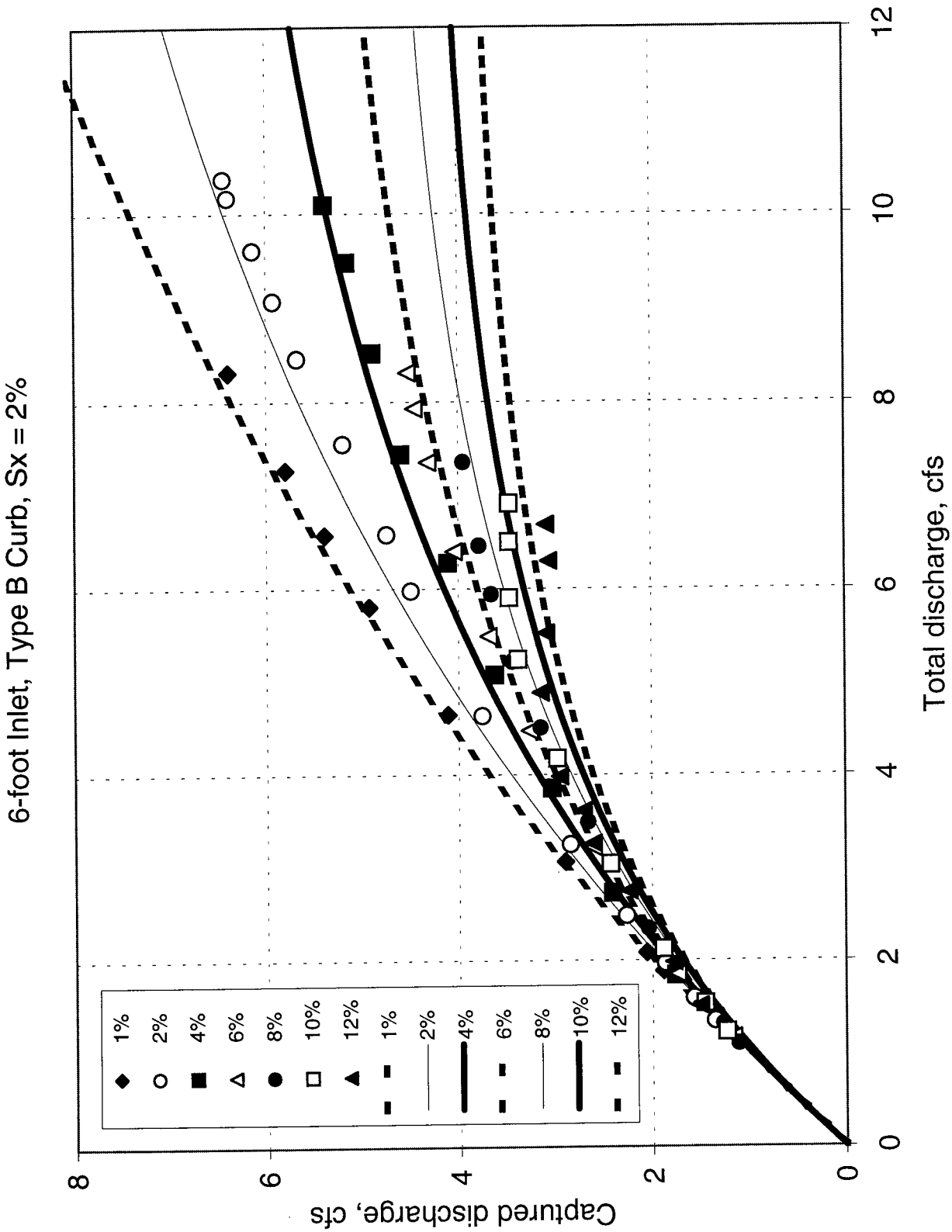
Henderson, F. M. (1966). *Open Channel Flow*, Macmillan Co., pp. 491-493

Chow, V. T. (1959). *Open-Channel Hydraulics*, McGraw-Hill Co., p. 111.

Appendix A

Graphs of Experimental Data and Fitted Curves


4-foot Inlet, Type B Curb, Sx = 2%
Captured discharge, cfs
Total discharge, cfs
0
2
4
6
8
10
12
1%
2%
4%
6%
8%
10%
12%
1%
2%
4%
6%
8%
10%
12%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2
4
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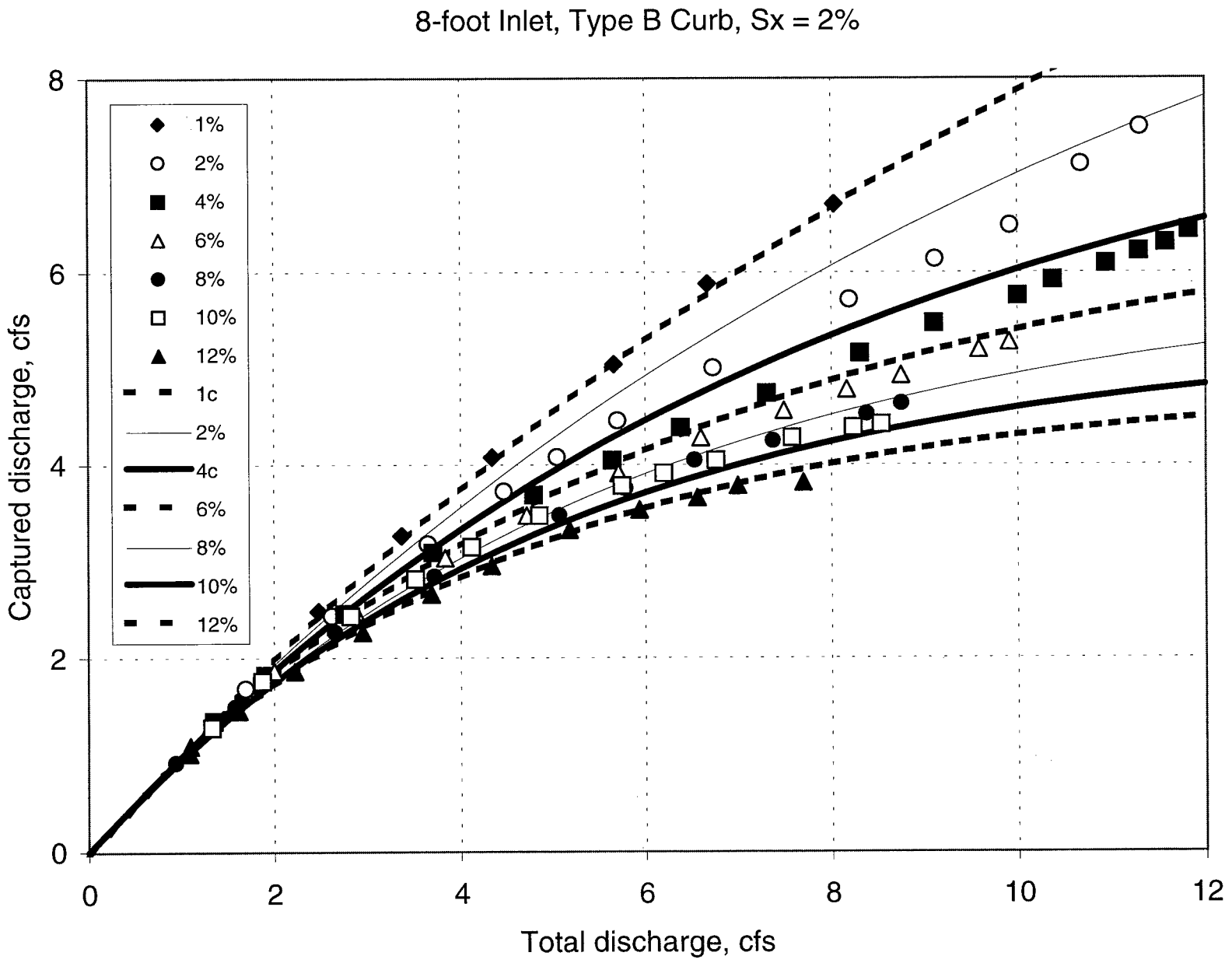
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Total discharge, cfs
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2
4
6
8
10
12
1%
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6%
8%
10%
12%
1c
2%
4c
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8%
10%
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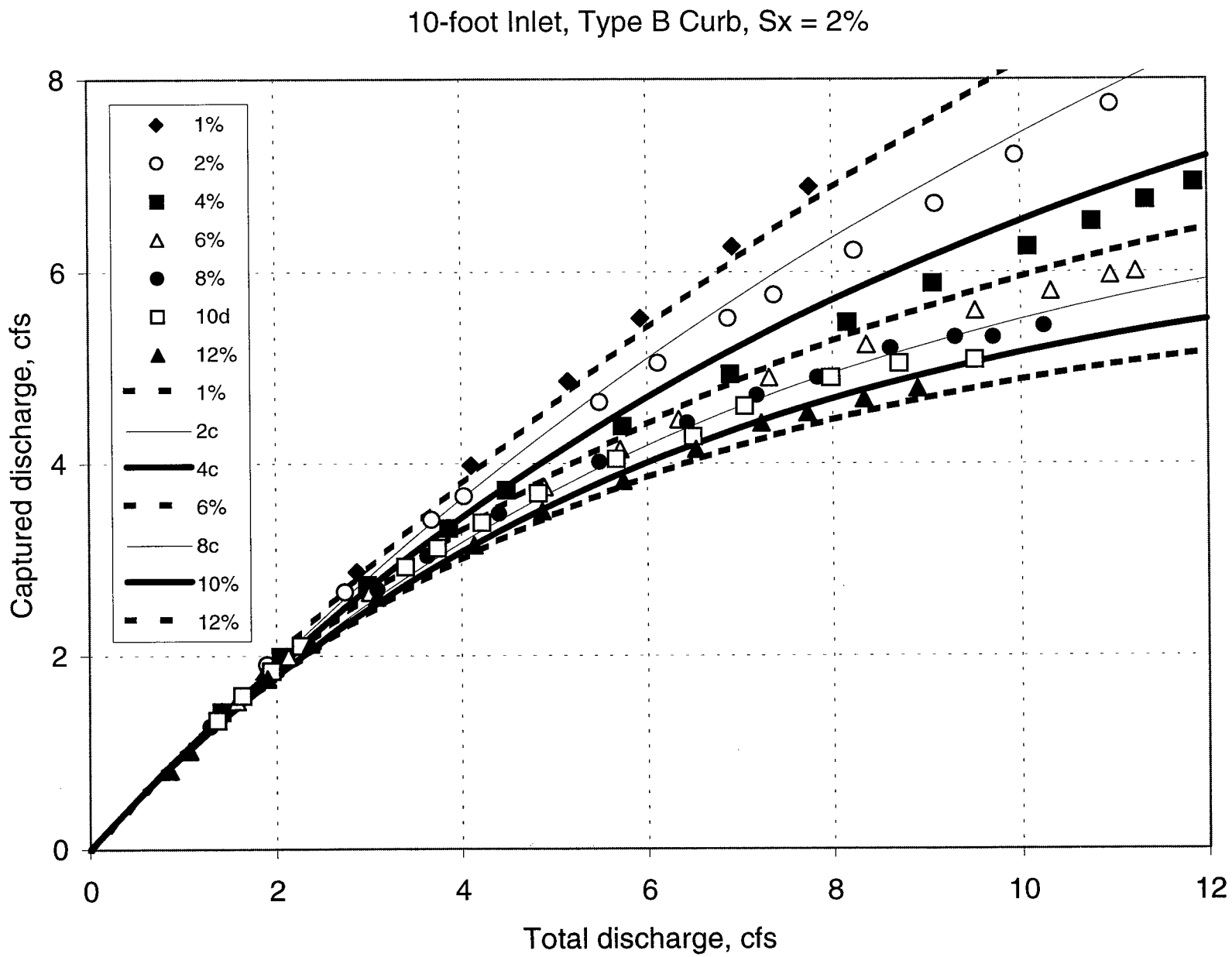
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Captured discharge, cfs
Total discharge, cfs
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4
6
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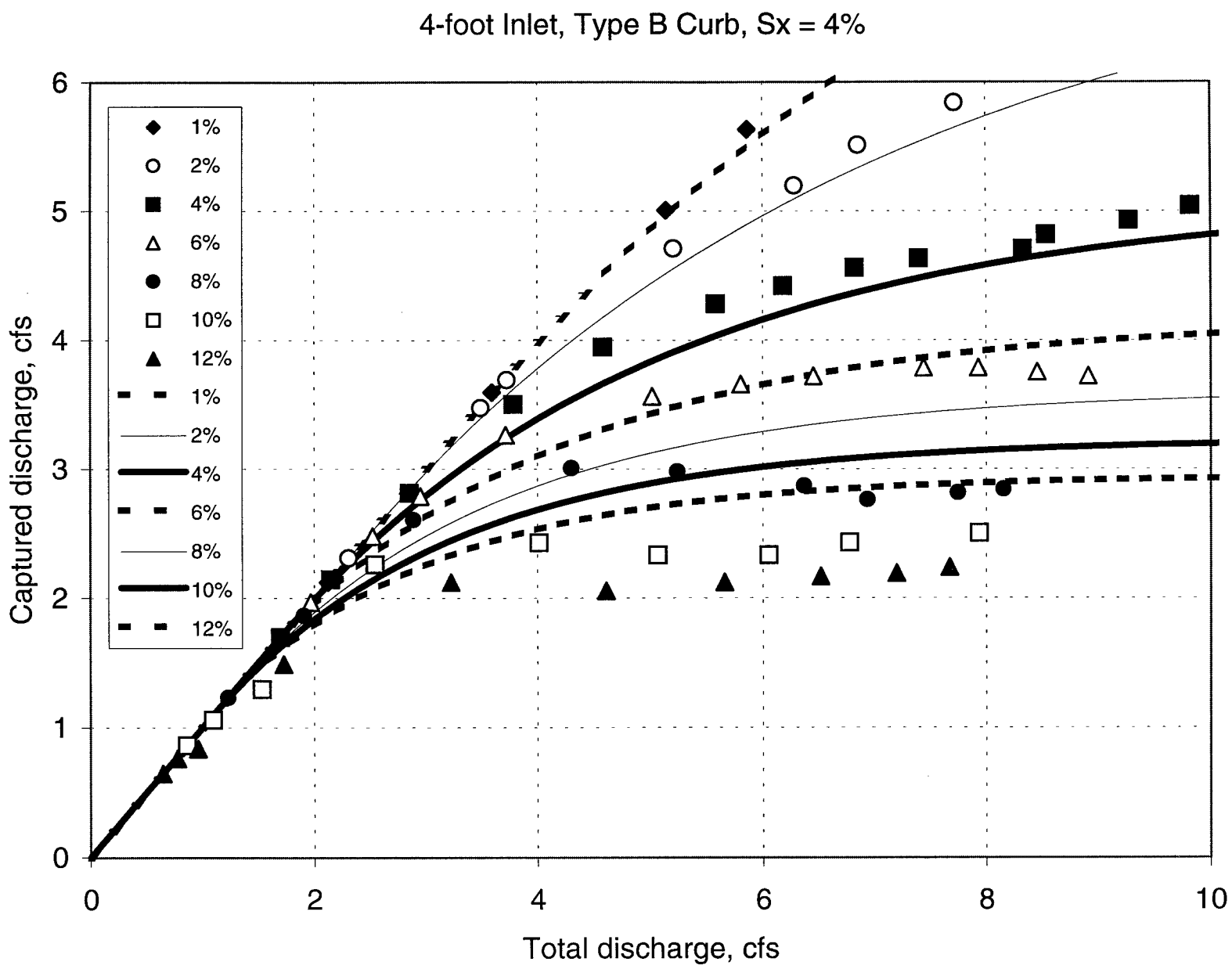
8c
10%
12%


4-foot Inlet, Type B Curb, Sx = 4%
Captured discharge, cfs
Total discharge, cfs
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2
3
4
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6
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2
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6
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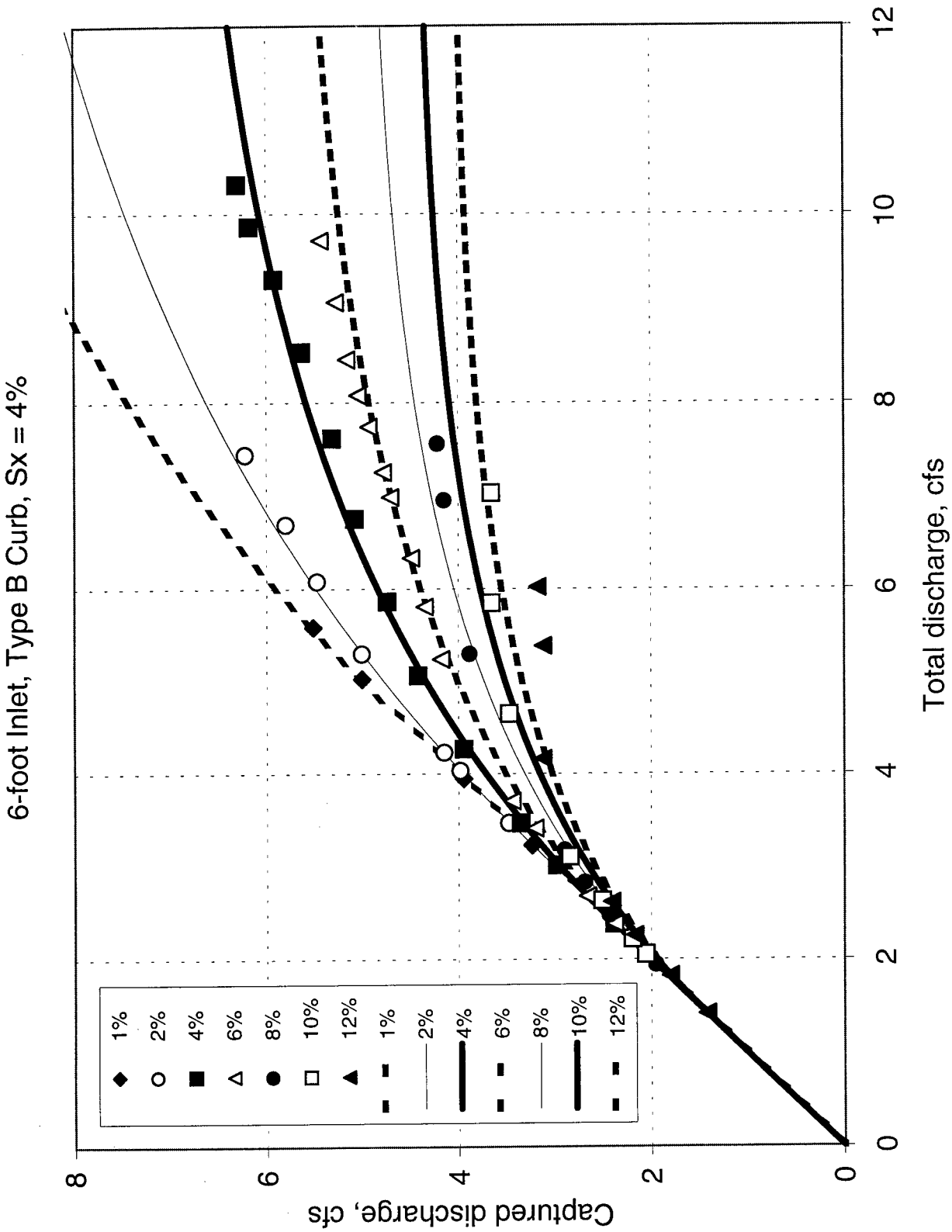
6-foot Inlet, Type B Curb, Sx = 4%
Captured discharge, cfs
Total discharge, cfs
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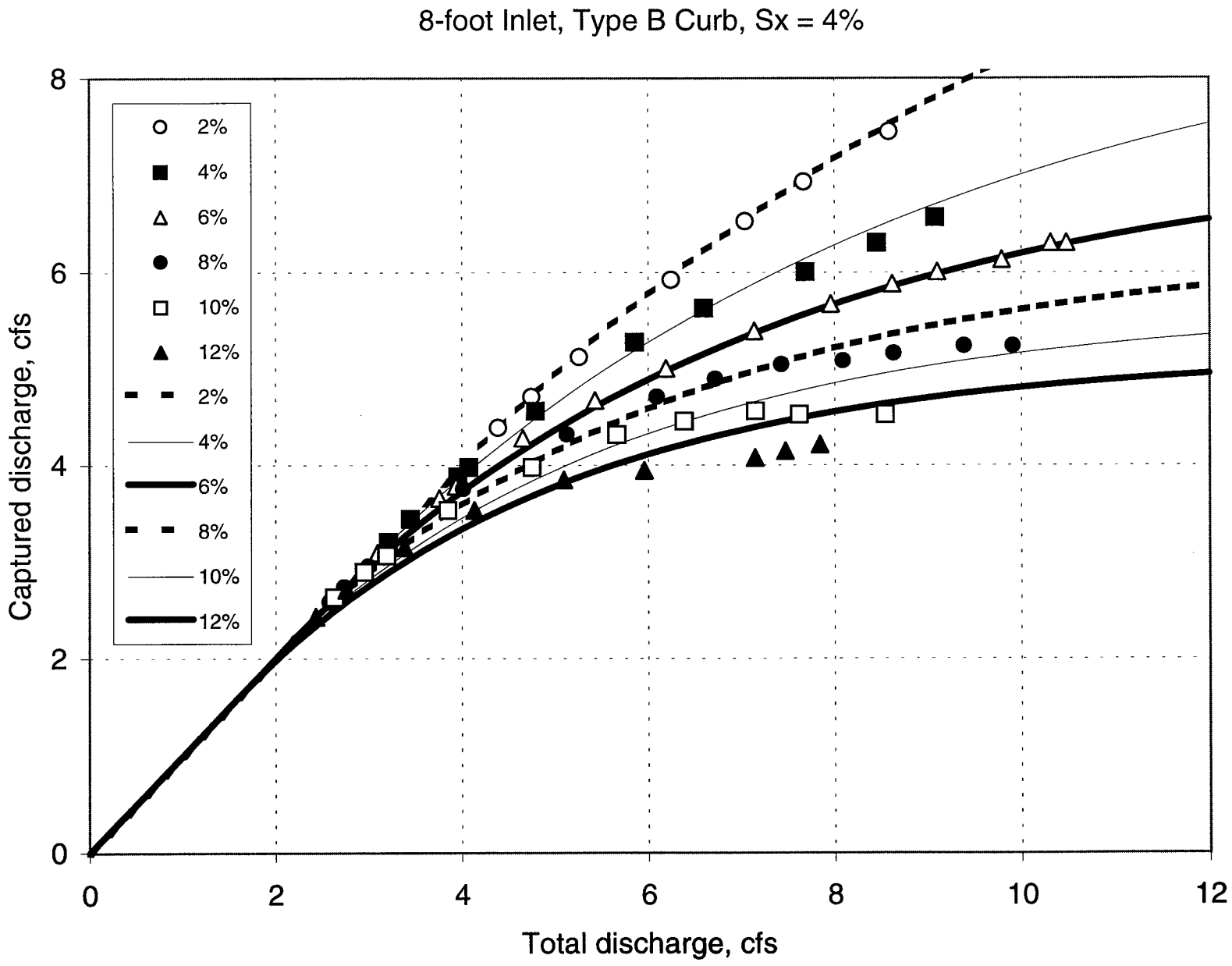
8-foot Inlet, Type B Curb, Sx = 4%
Captured discharge, cfs
Total discharge, cfs
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8
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12
2%
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4%
6%
8%
10%
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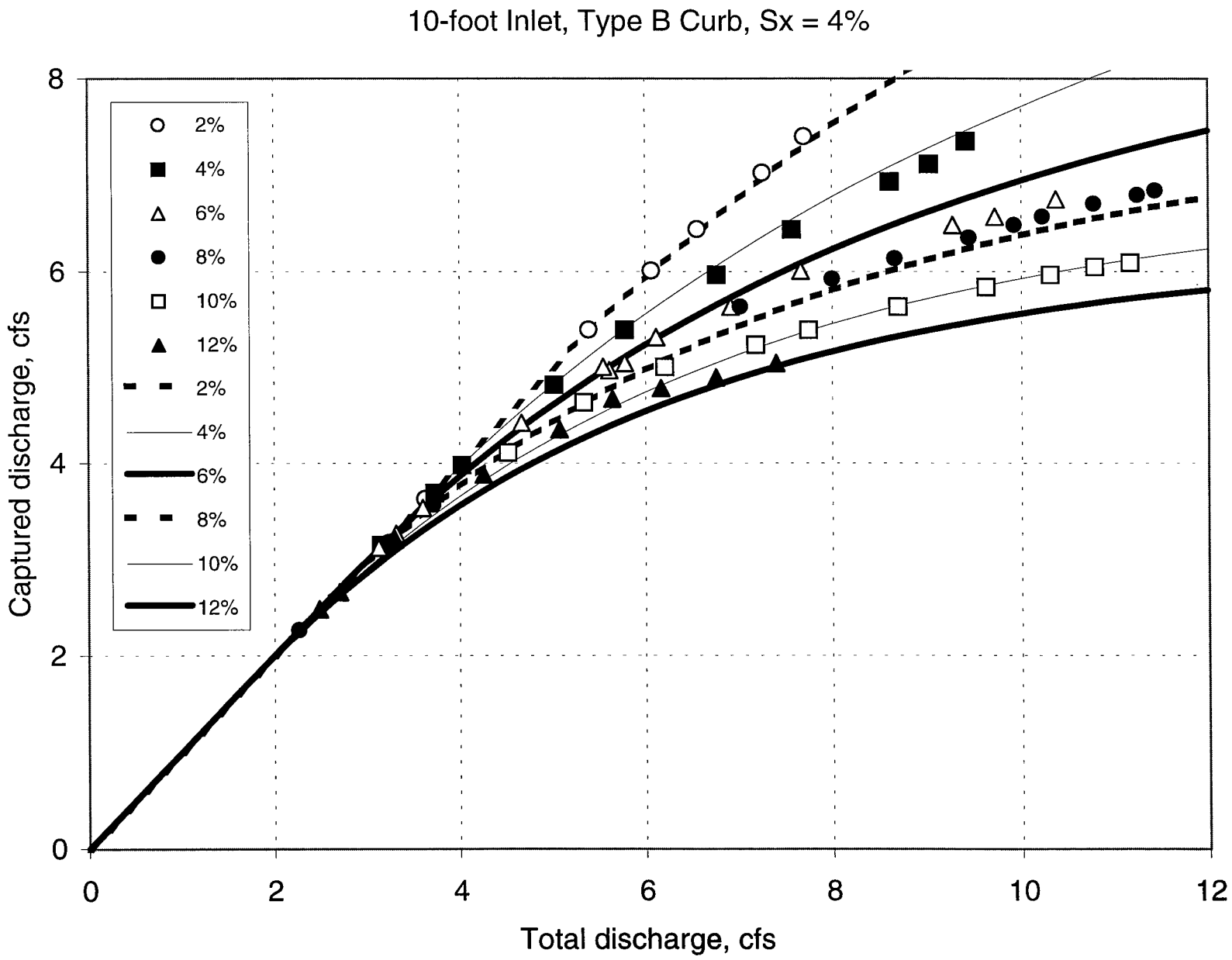
10-foot Inlet, Type B Curb, Sx = 4%
Captured discharge, cfs
Total discharge, cfs
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2
4
6
8
10
12
2%
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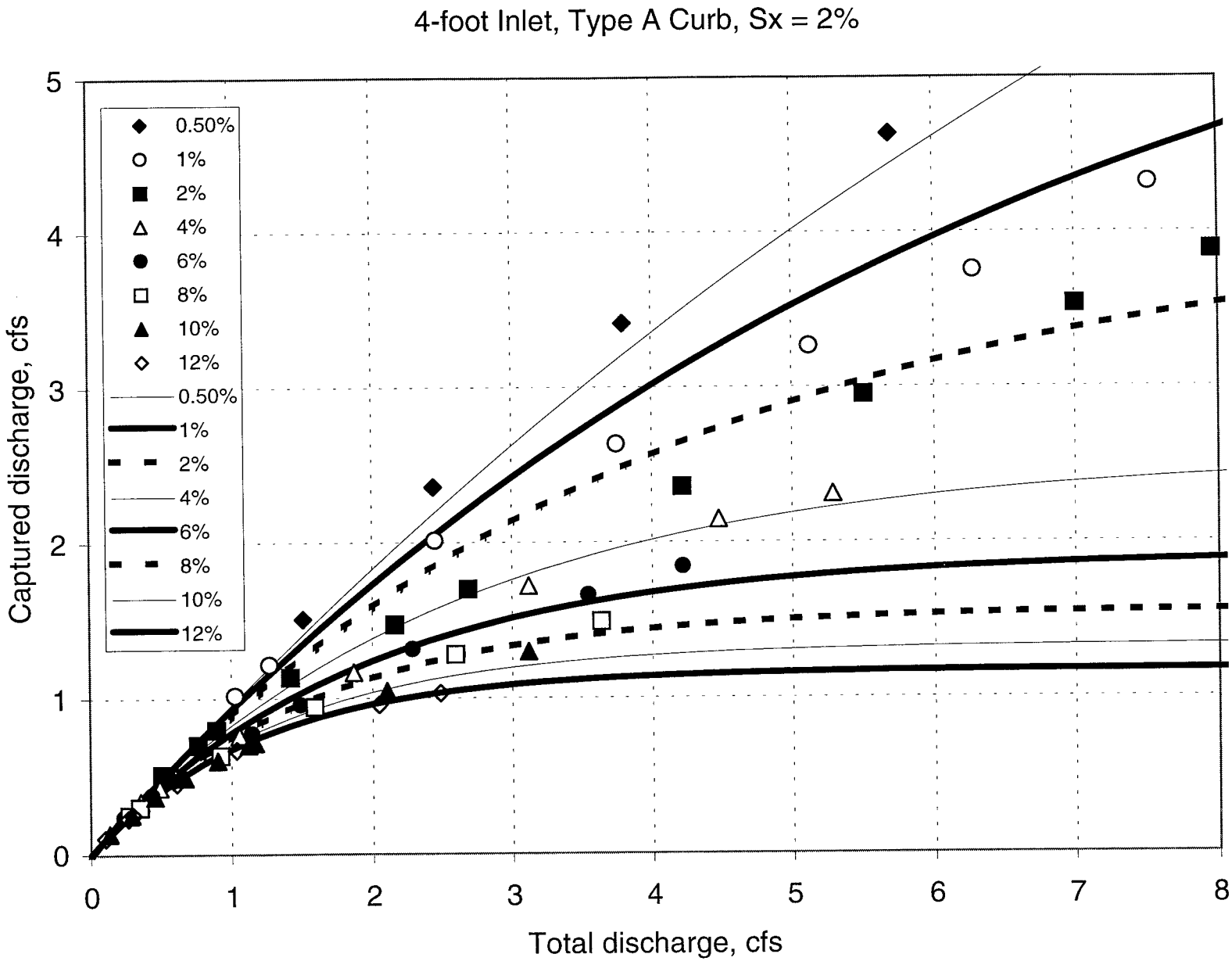
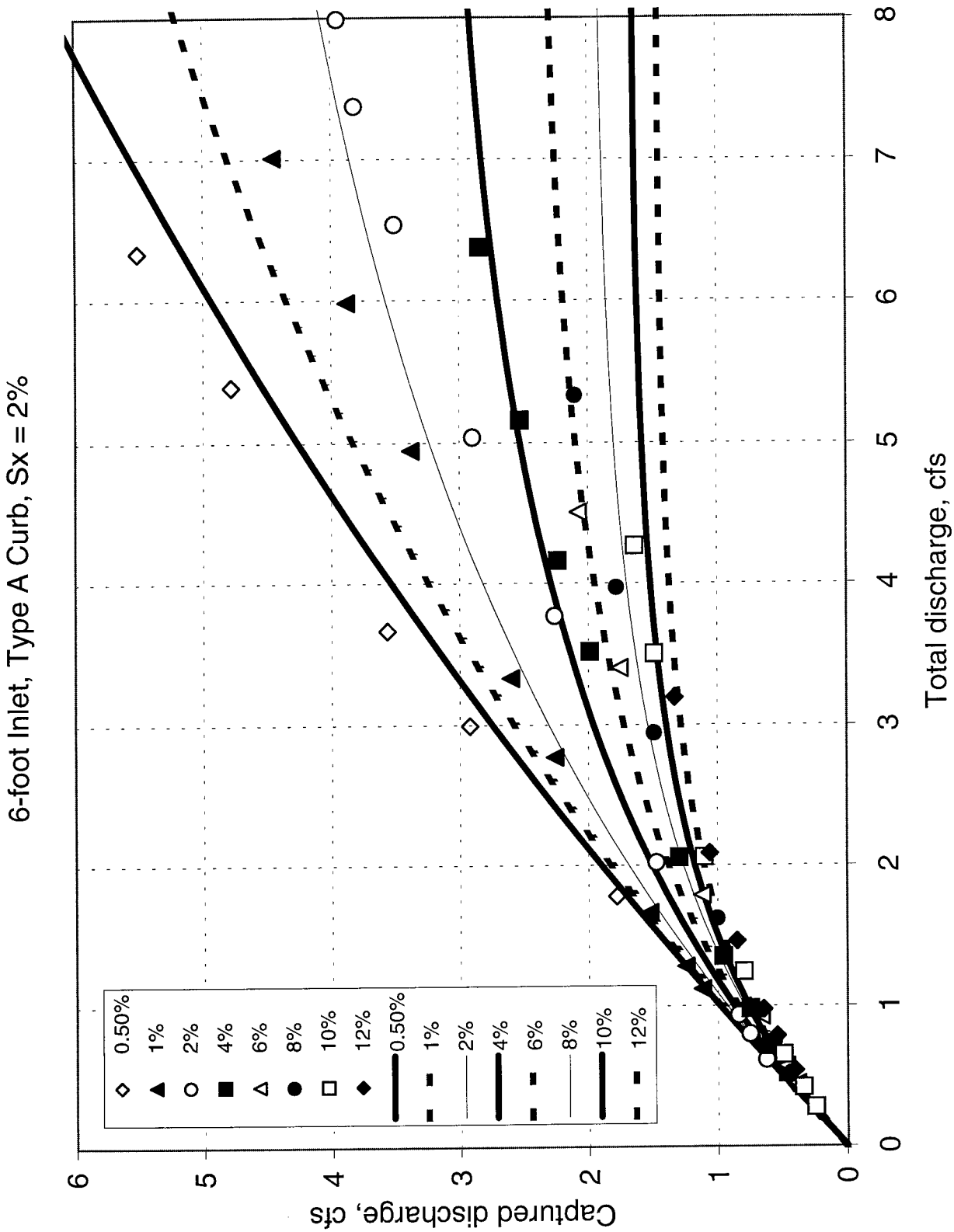
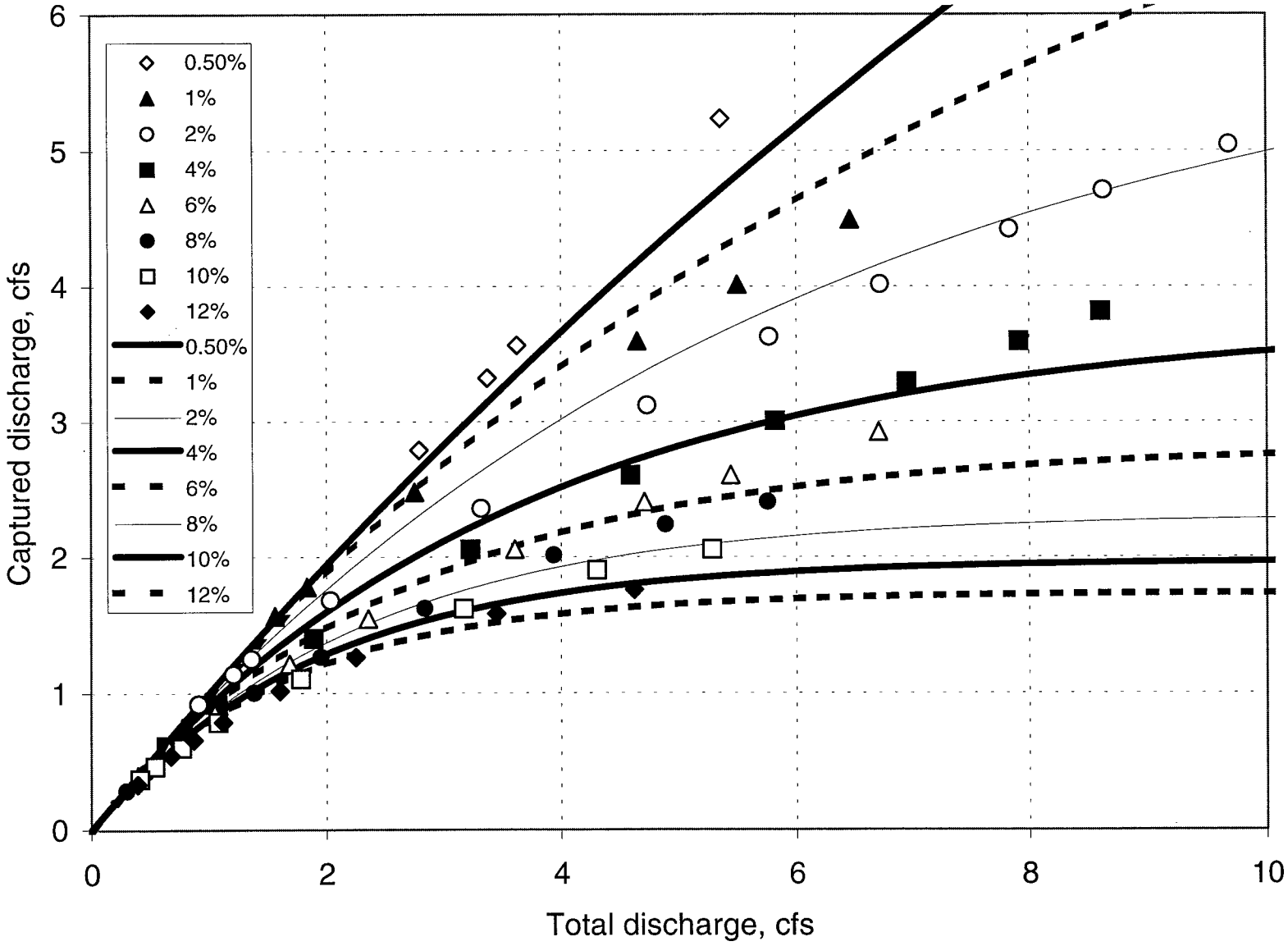
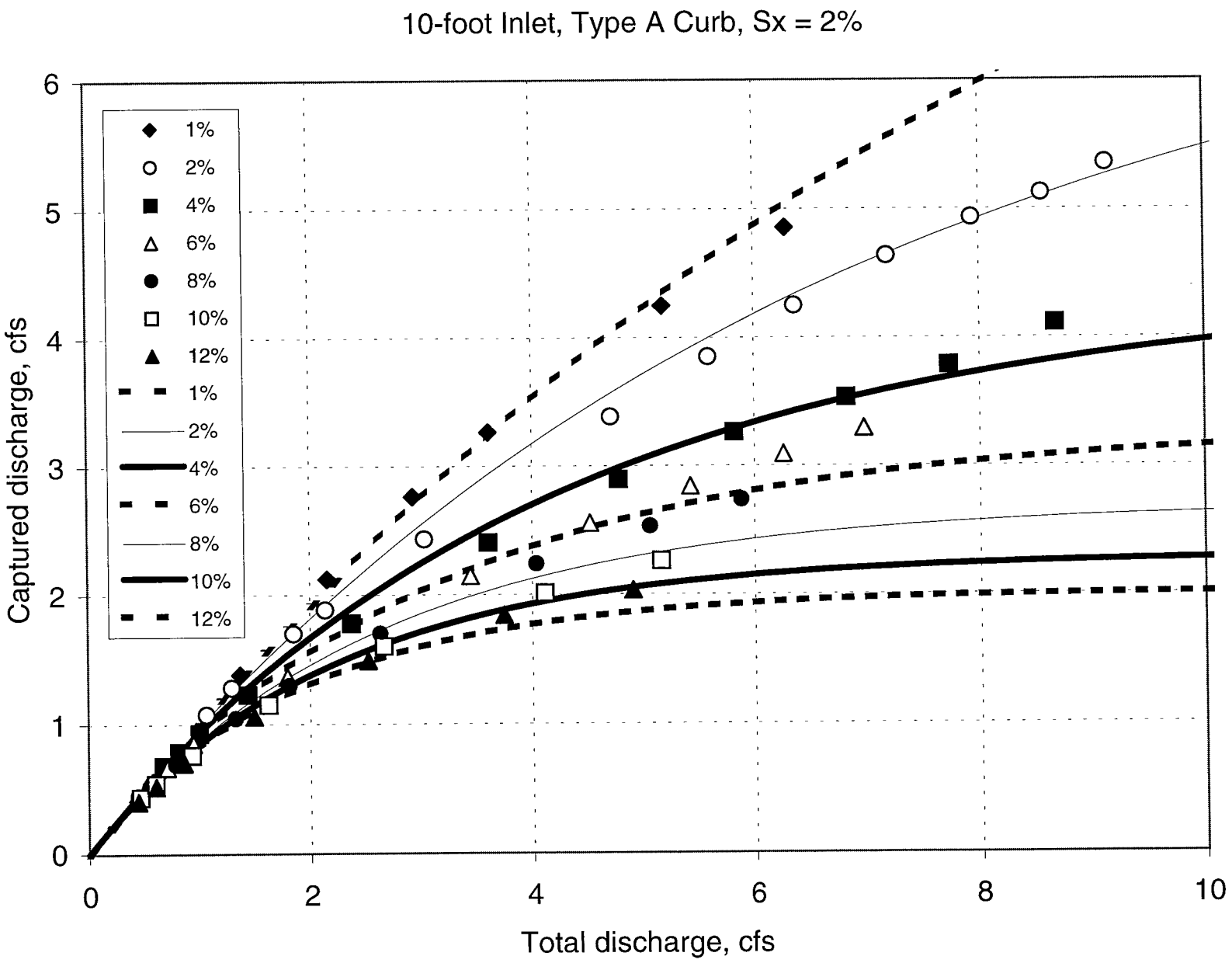
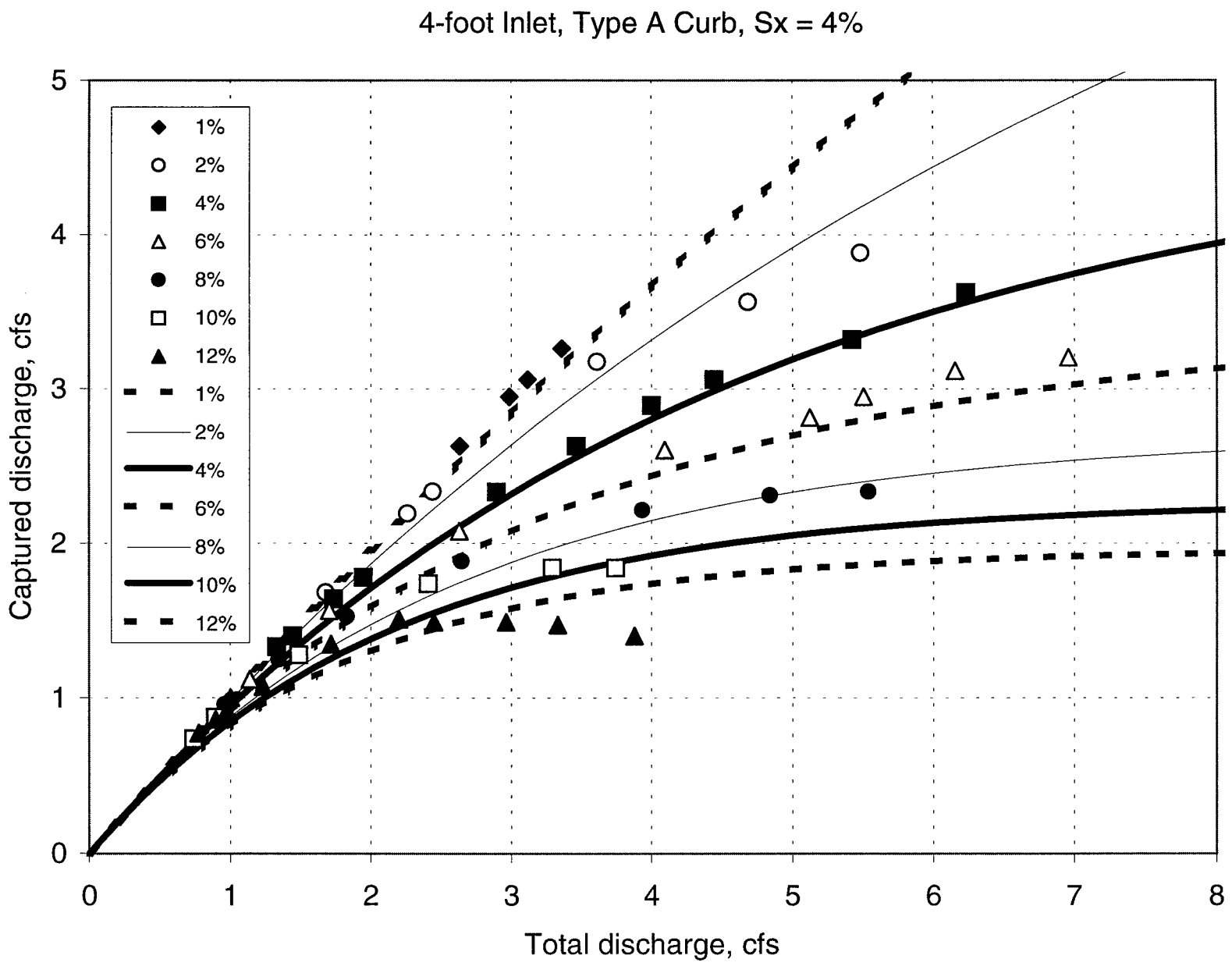
12%
2%
4%
6%
8%
10%
12%

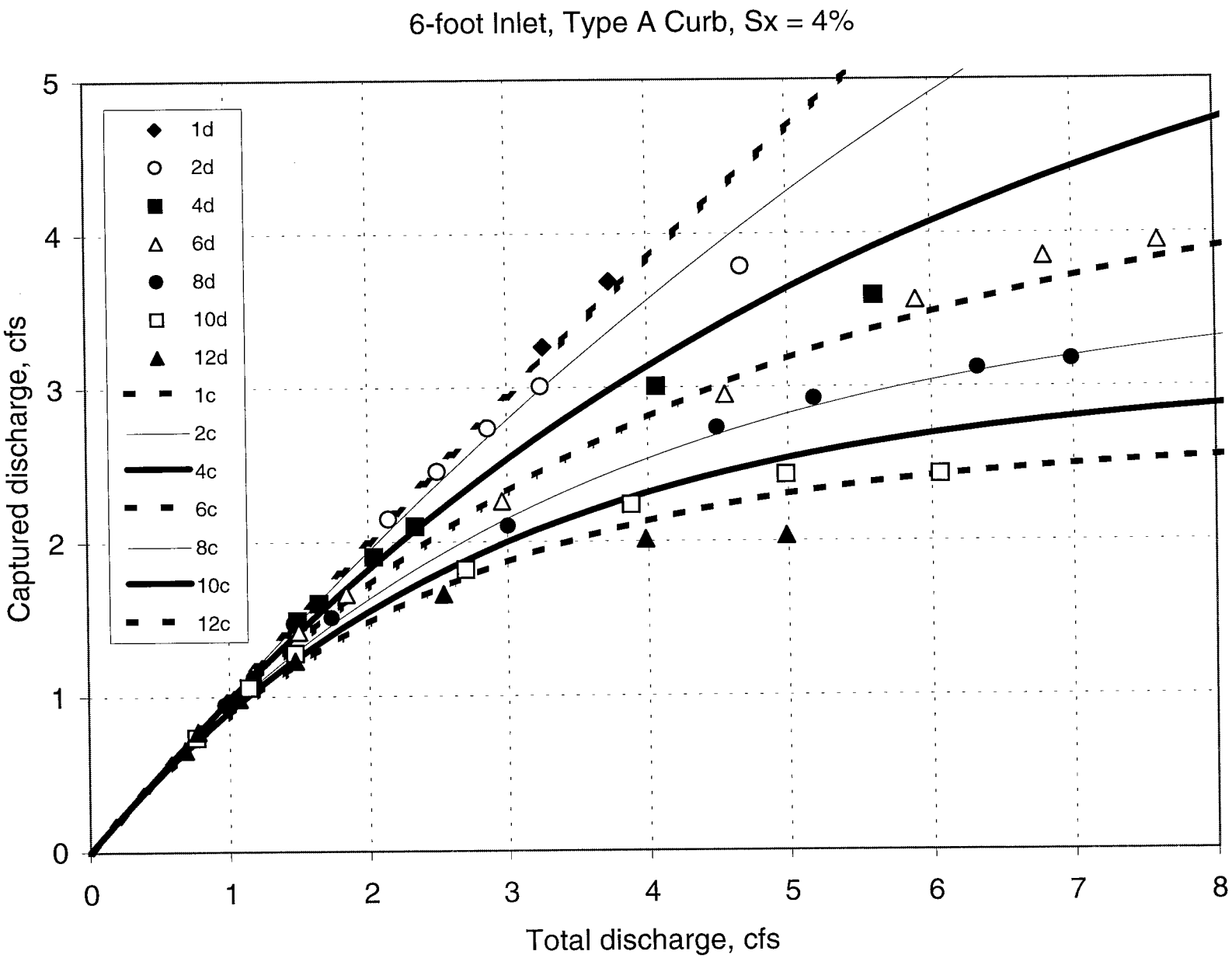

4-foot Inlet, Type A Curb, Sx = 2%
Captured discharge, cfs
Total discharge, cfs
0
1
2
3
4
5
6
7
8
0.50%
1%
2%
4%
6%
8%
10%
12%
0.50%
1%
2%
4%
6%
8%
10%
12%

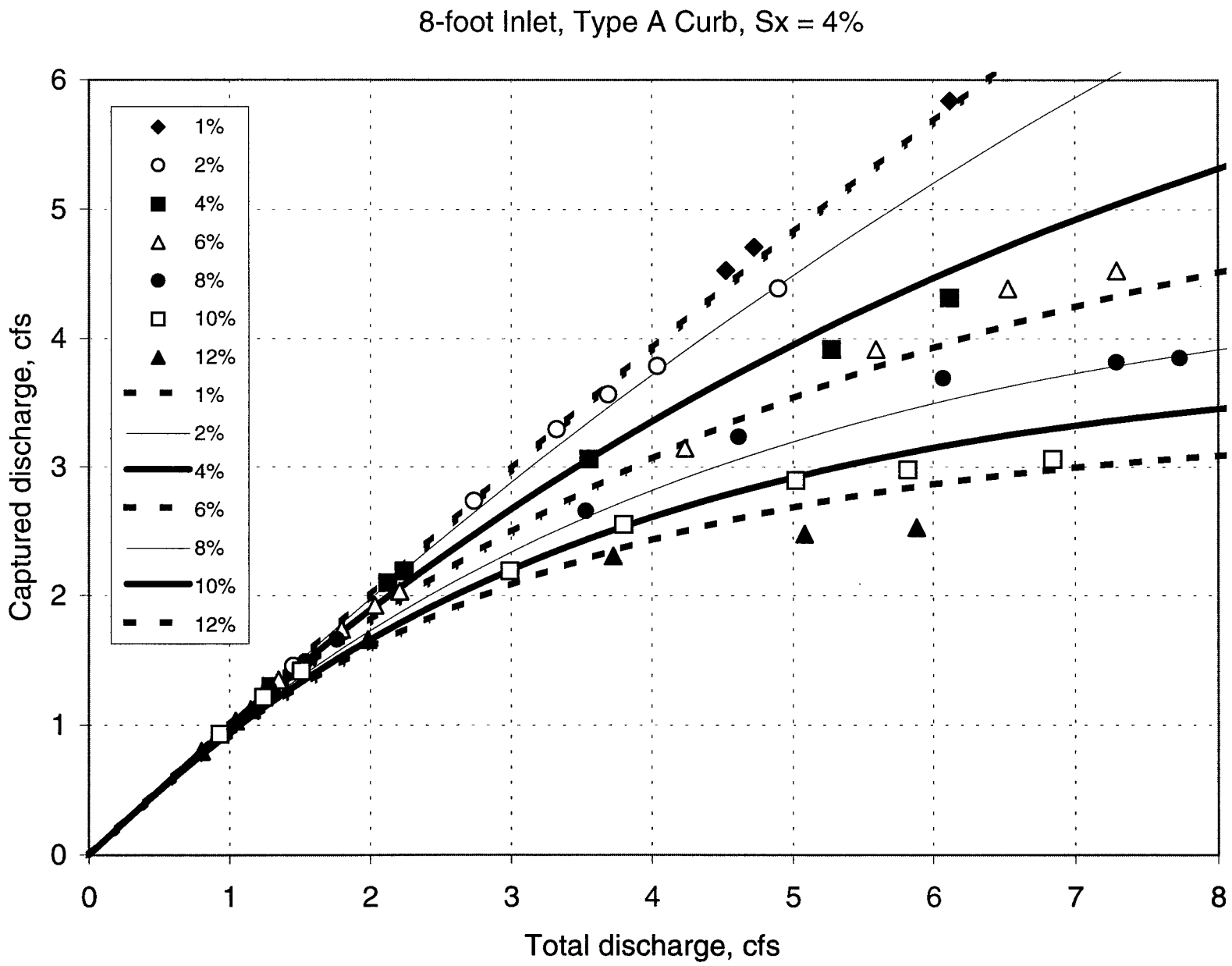

6-foot Inlet, Type A Curb, Sx = 2%
Captured discharge, cfs
Total discharge, cfs
0
1
2
3
4
5
6
7
8
0.50%
1%
2%
4%
6%
8%
10%
12%

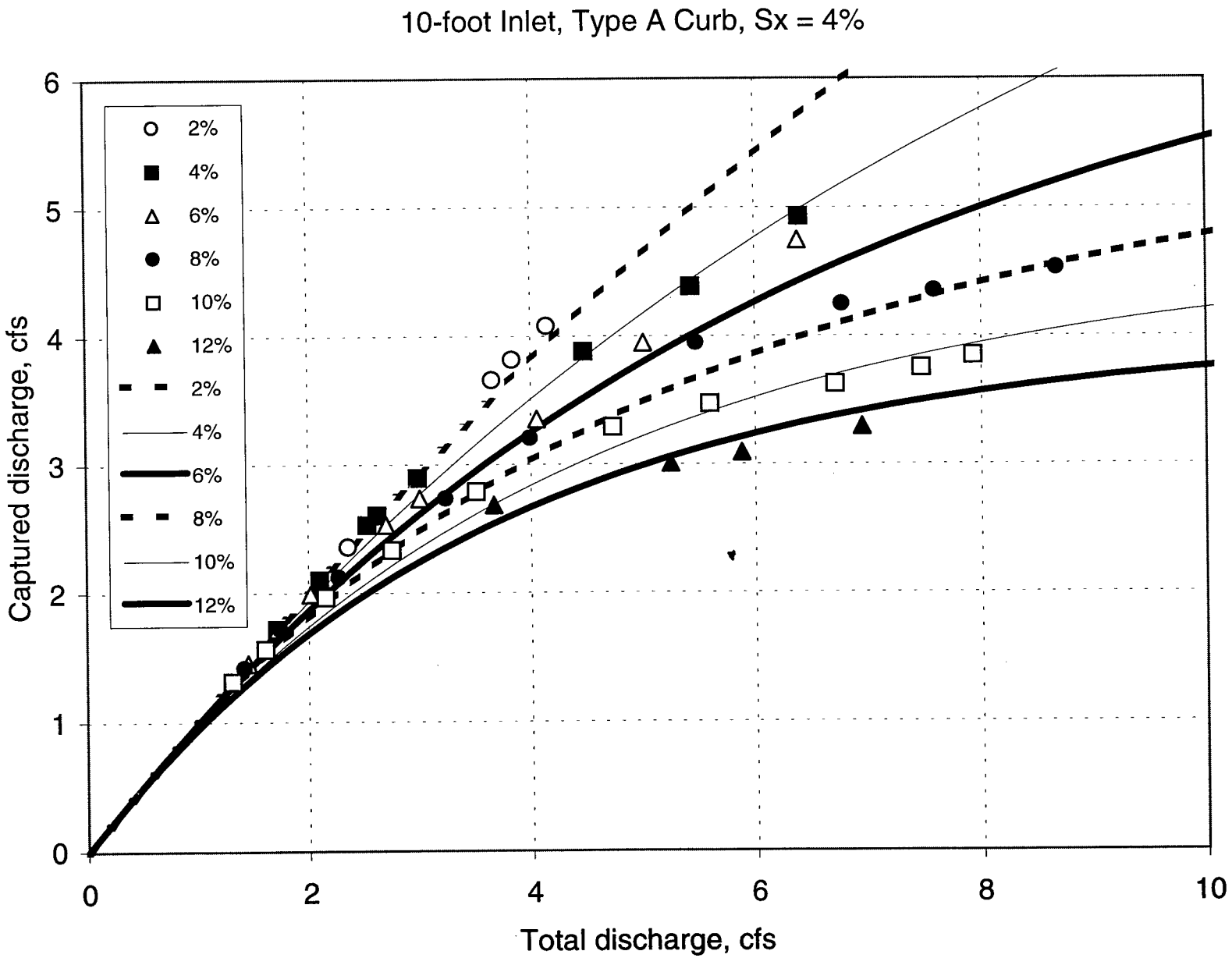

8-foot Inlet, Type A Curb, Sx = 2%
Captured discharge, cfs
Total discharge, cfs
0
1
2
3
4
5
6
0
2
4
6
8
10
0.50%
1%
2%
4%
6%
8%
10%
12%
0.50%
1%
2%
4%
6%
8%
10%
12%


10-foot Inlet, Type A Curb, Sx = 2%
Captured discharge, cfs
Total discharge, cfs
0
1
2
3
4
5
6
0
2
4
6
8
10
1%
2%
4%
6%
8%
10%
12%
1%
2%
4%
6%
8%
10%
12%


4-foot Inlet, Type A Curb, Sx = 4%
Captured discharge, cfs
Total discharge, cfs
0
1
2
3
4
5
6
7
8
1%
2%
4%
6%
8%
10%
12%
1%
2%
4%
6%
8%
10%
12%

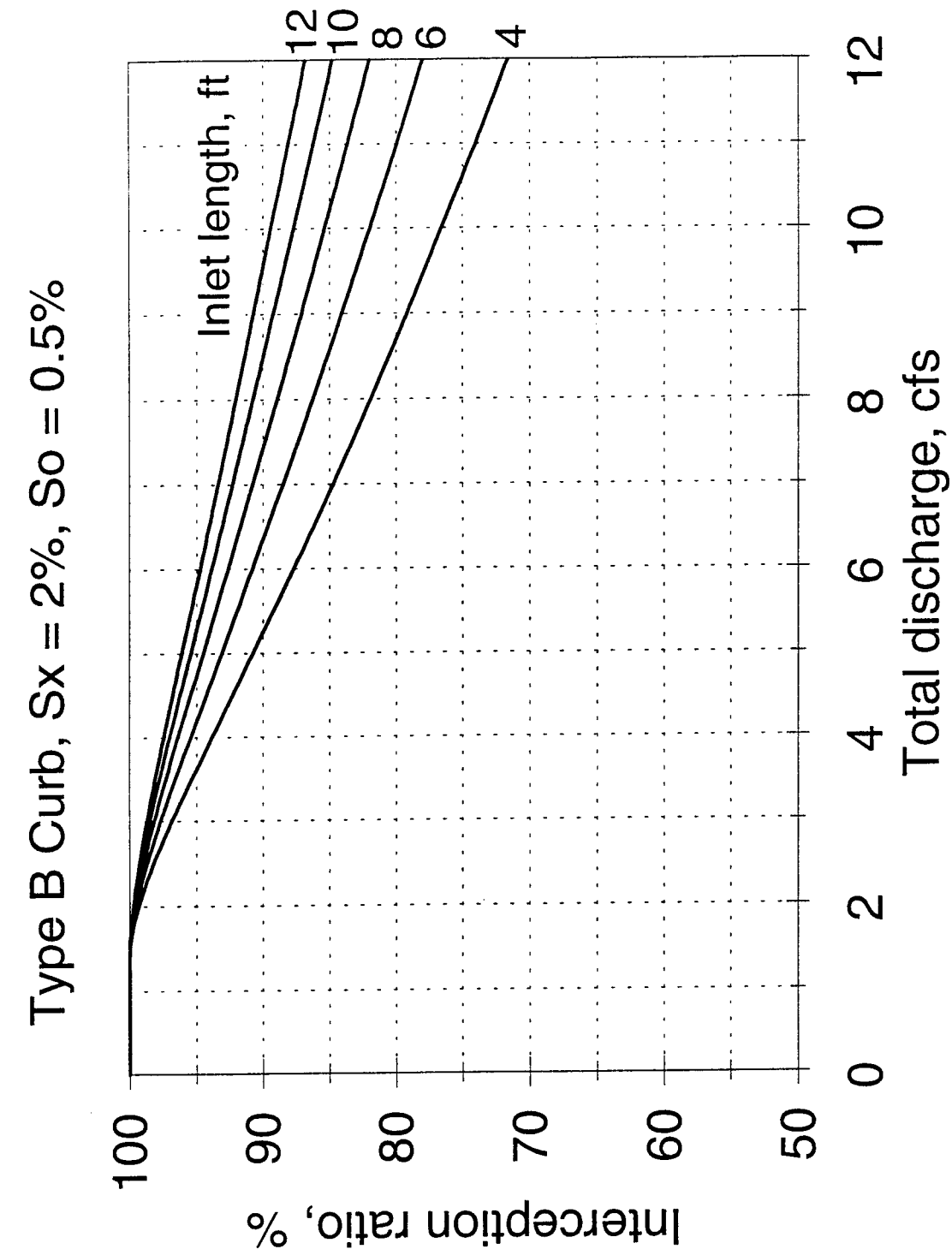

6-foot Inlet, Type A Curb, Sx = 4%
Captured discharge, cfs
Total discharge, cfs
0
1
2
3
4
5
6
7
8
1d
2d
4d
6d
8d
10d
12d
1c
2c
4c
6c
8c
10c
12c

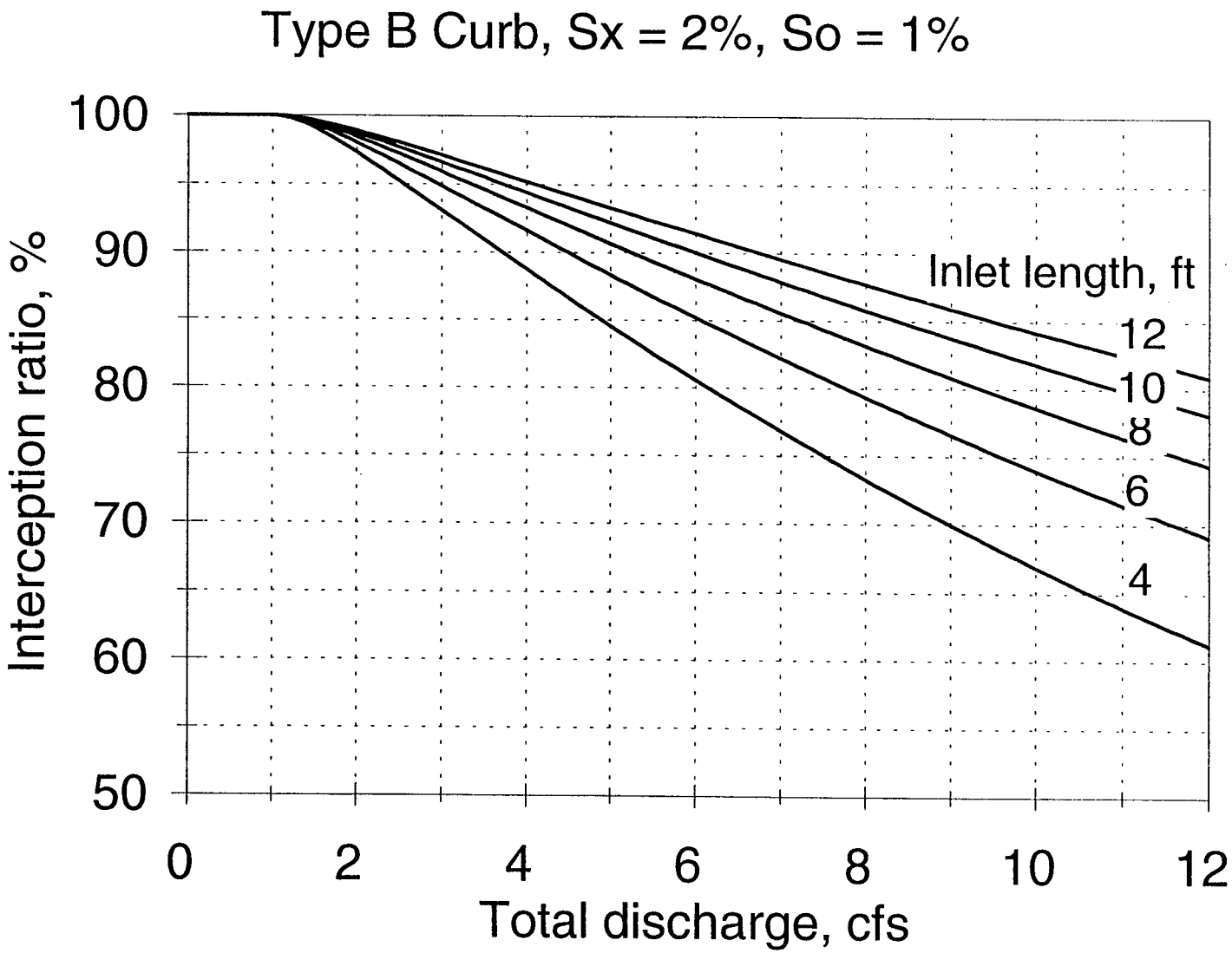

8-foot Inlet, Type A Curb, Sx = 4%
Captured discharge, cfs
Total discharge, cfs
0
1
2
3
4
5
6
7
8
1%
2%
4%
6%
8%
10%
12%
1%
2%
4%
6%
8%
10%
12%

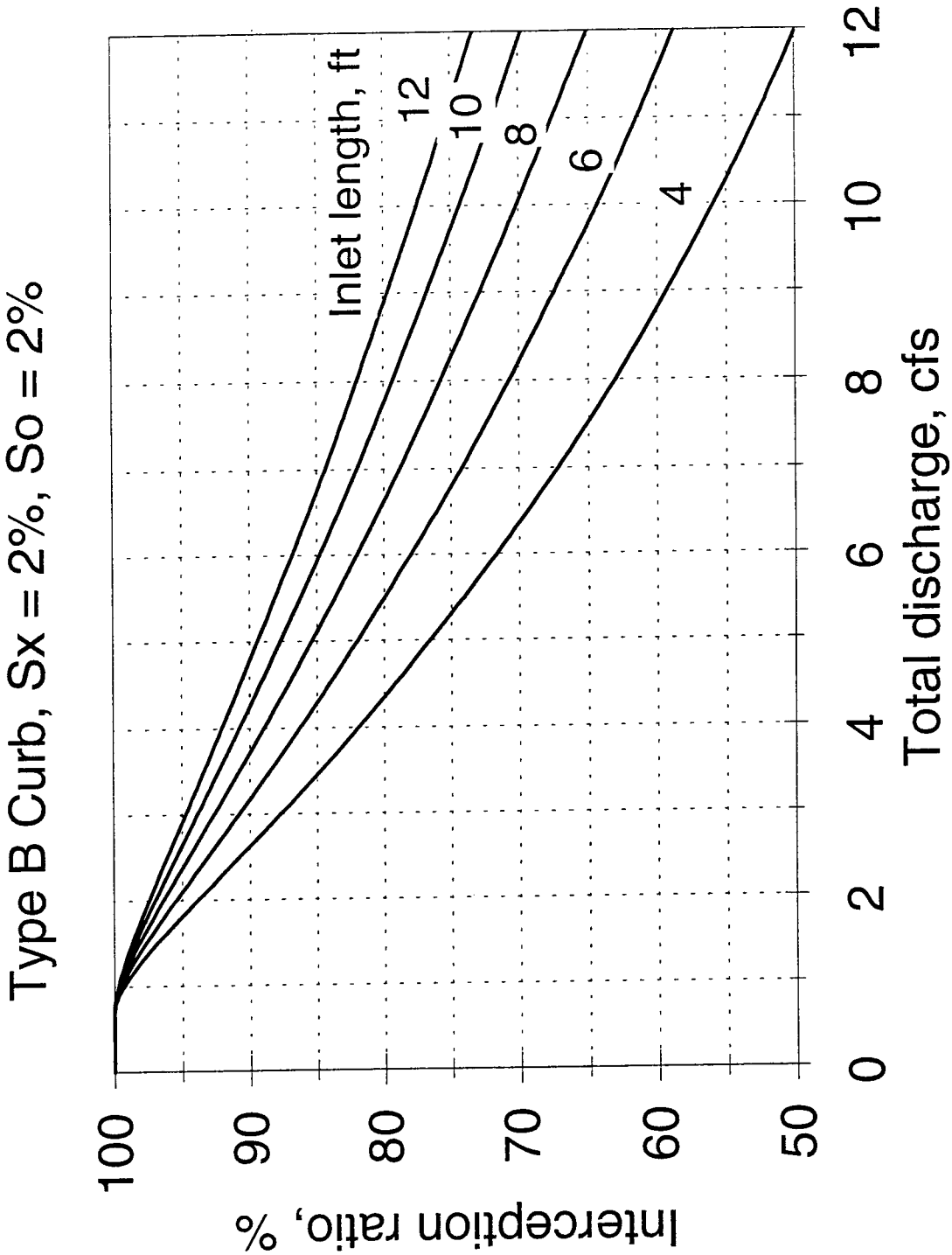

10-foot Inlet, Type A Curb, Sx = 4%
Captured discharge, cfs
Total discharge, cfs
0
1
2
3
4
5
6
0
2
4
6
8
10
2%
4%
6%
8%
10%
12%
2%
4%
6%
8%
10%
12%

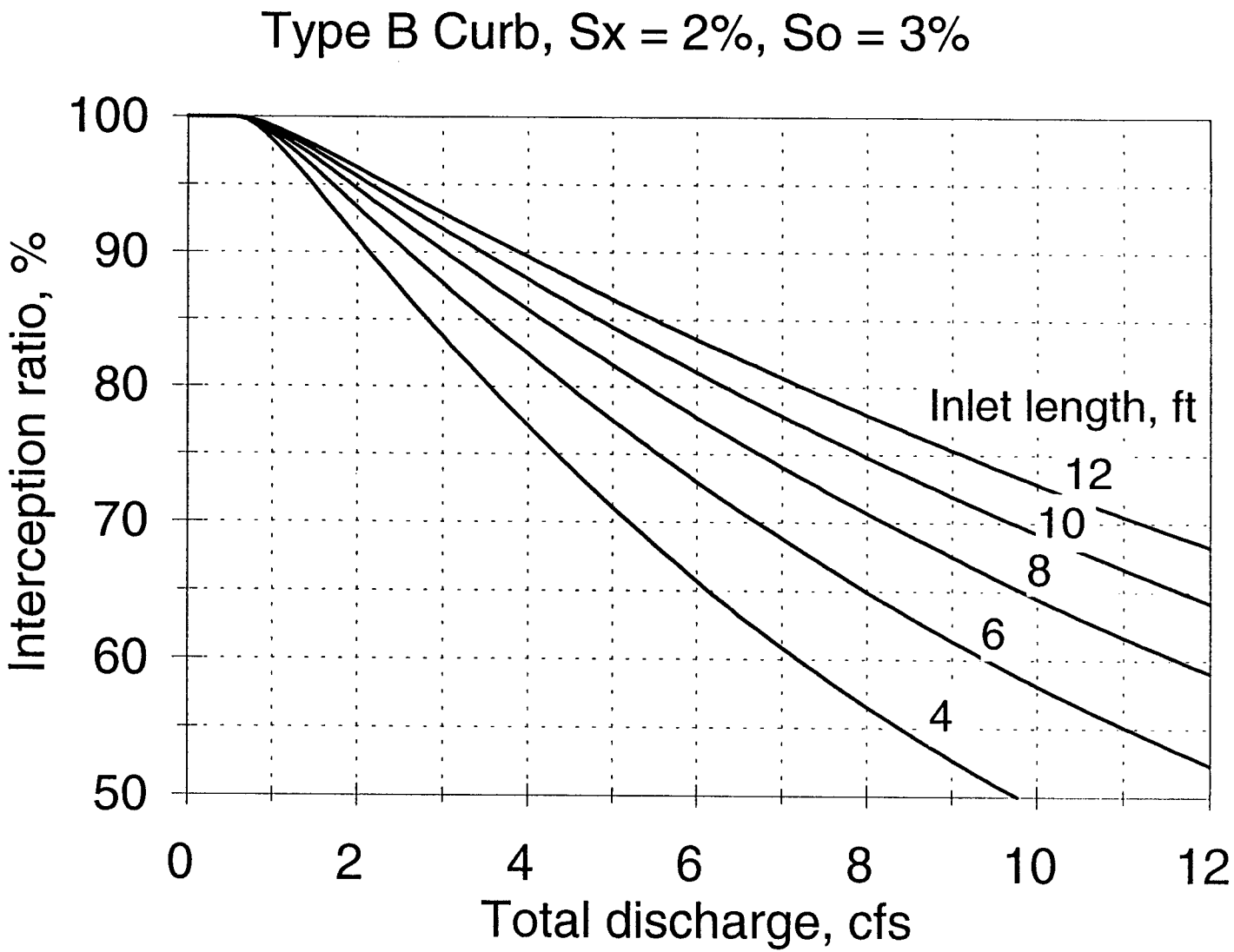
Appendix B

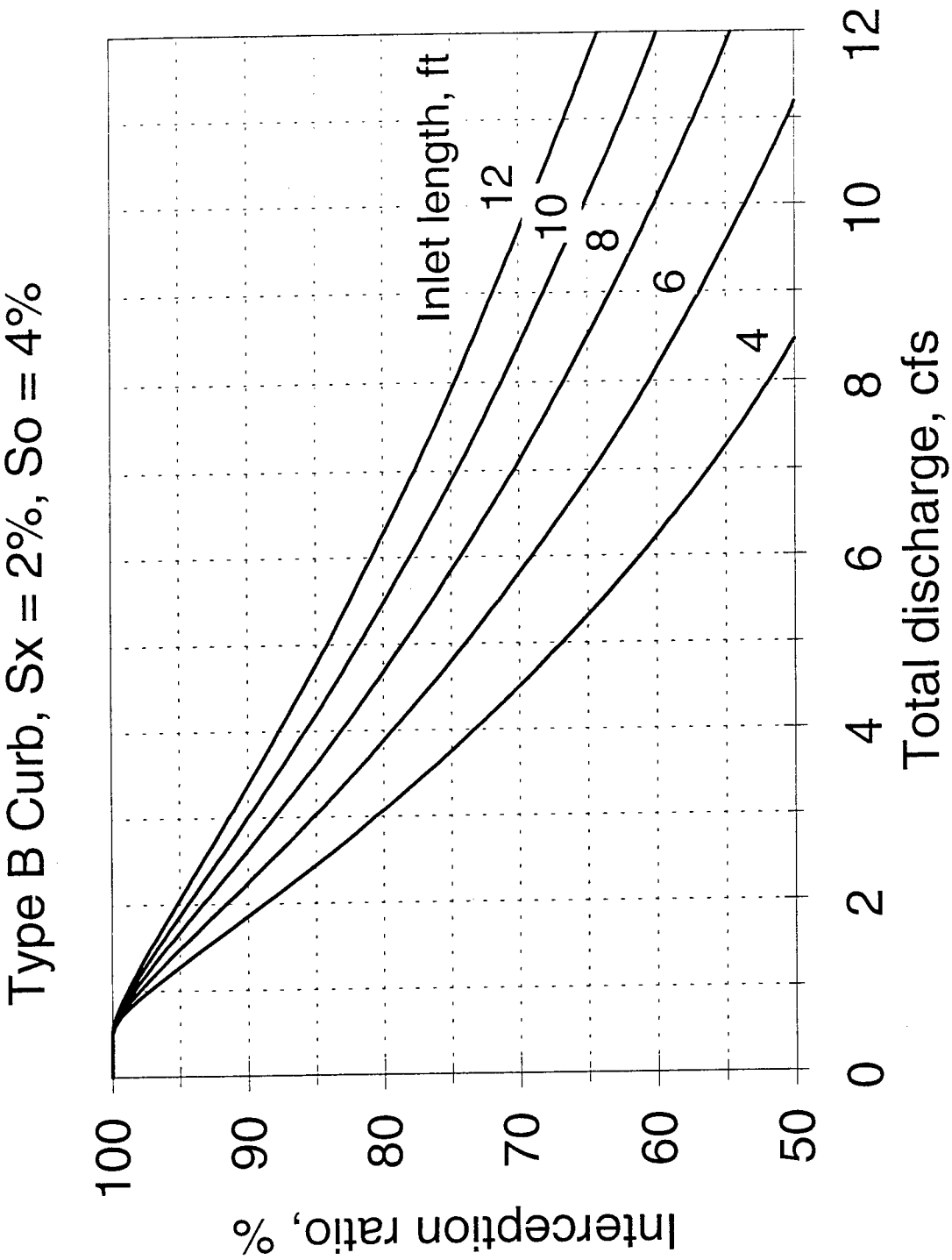
Hydraulic Design Charts
in U. S. Customary Units

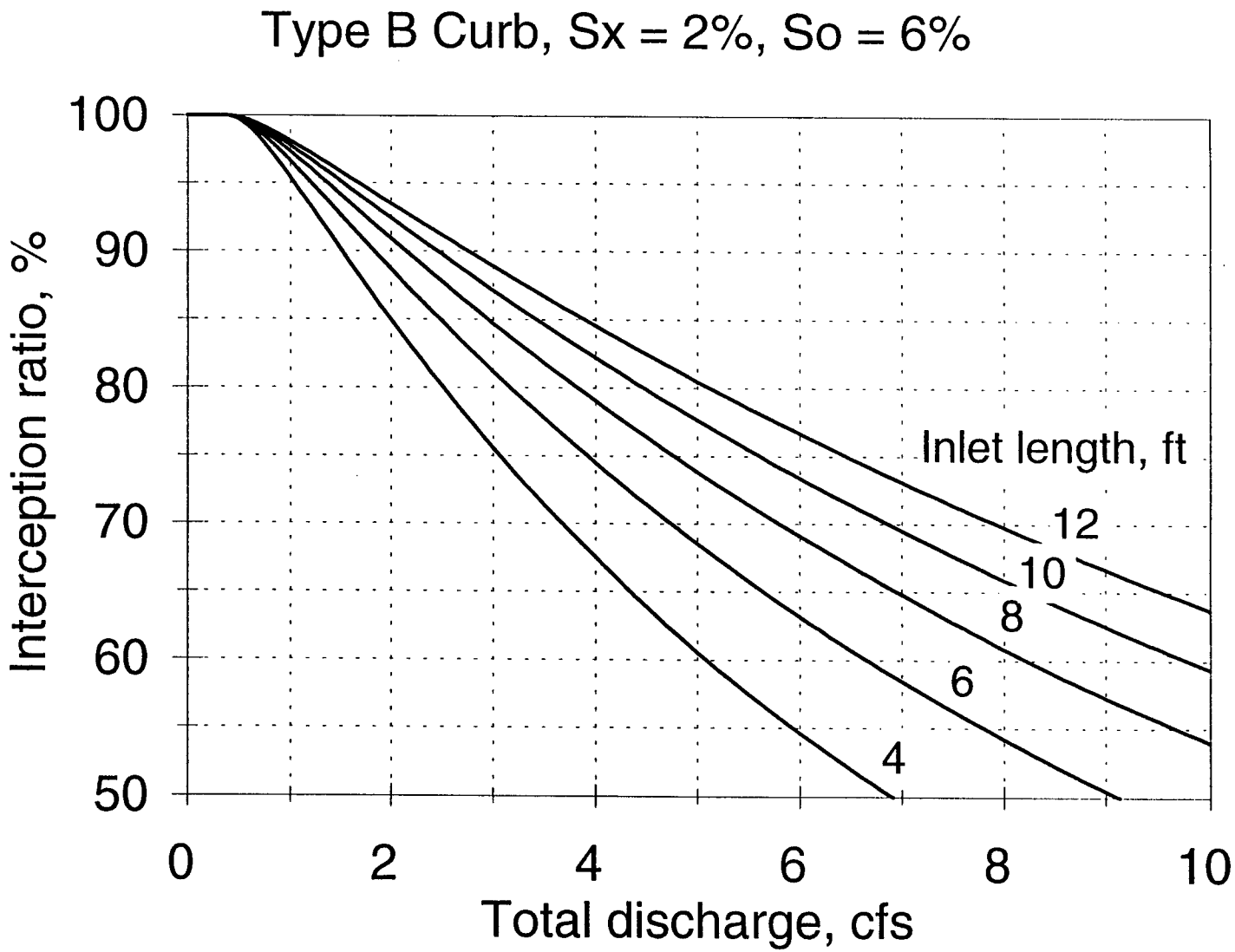

Type B Curb, Sx = 2%, So = 0.5%
Inlet length, ft
12
10
8
6
4
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs

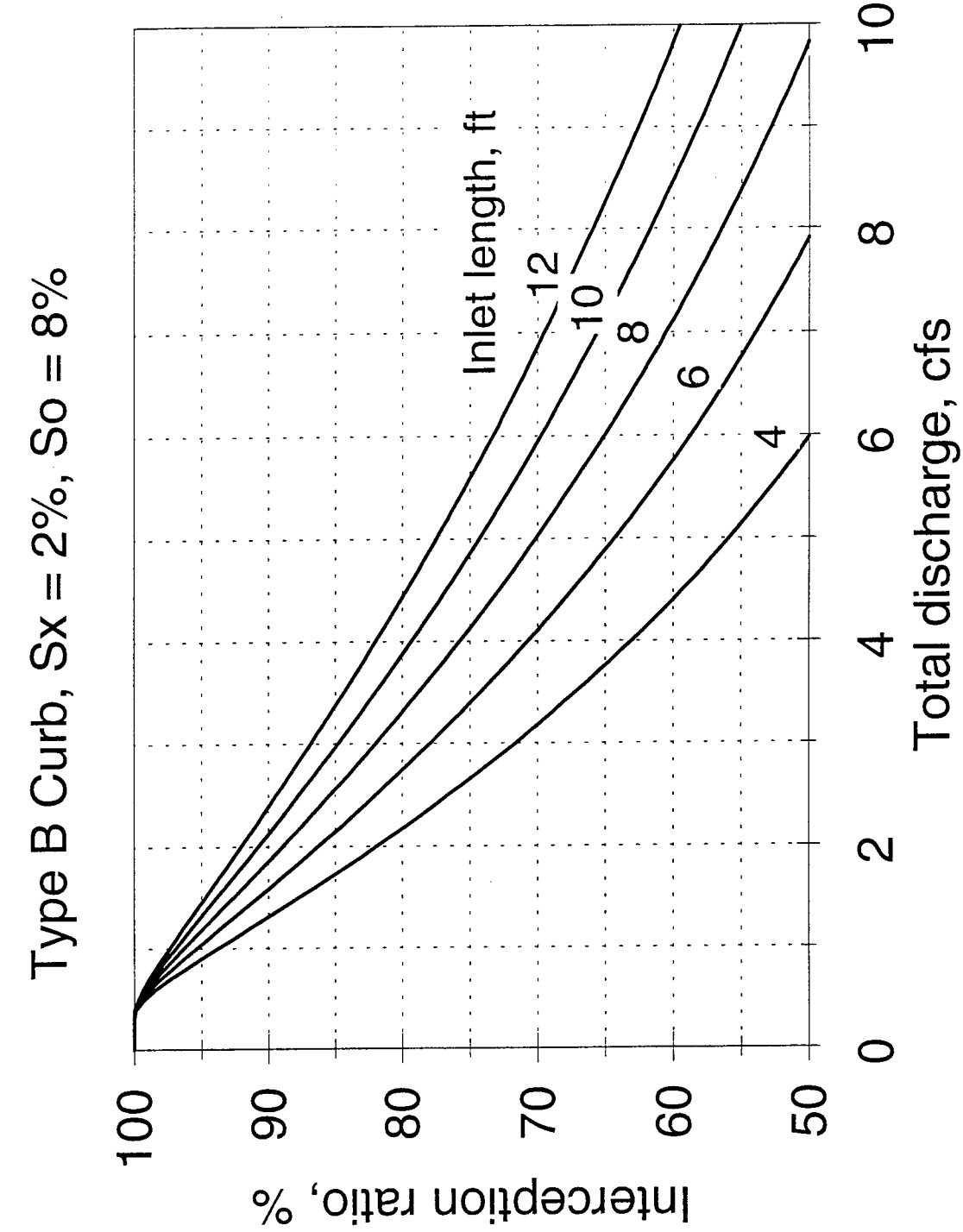

Type B Curb, Sx = 2%, So = 1%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

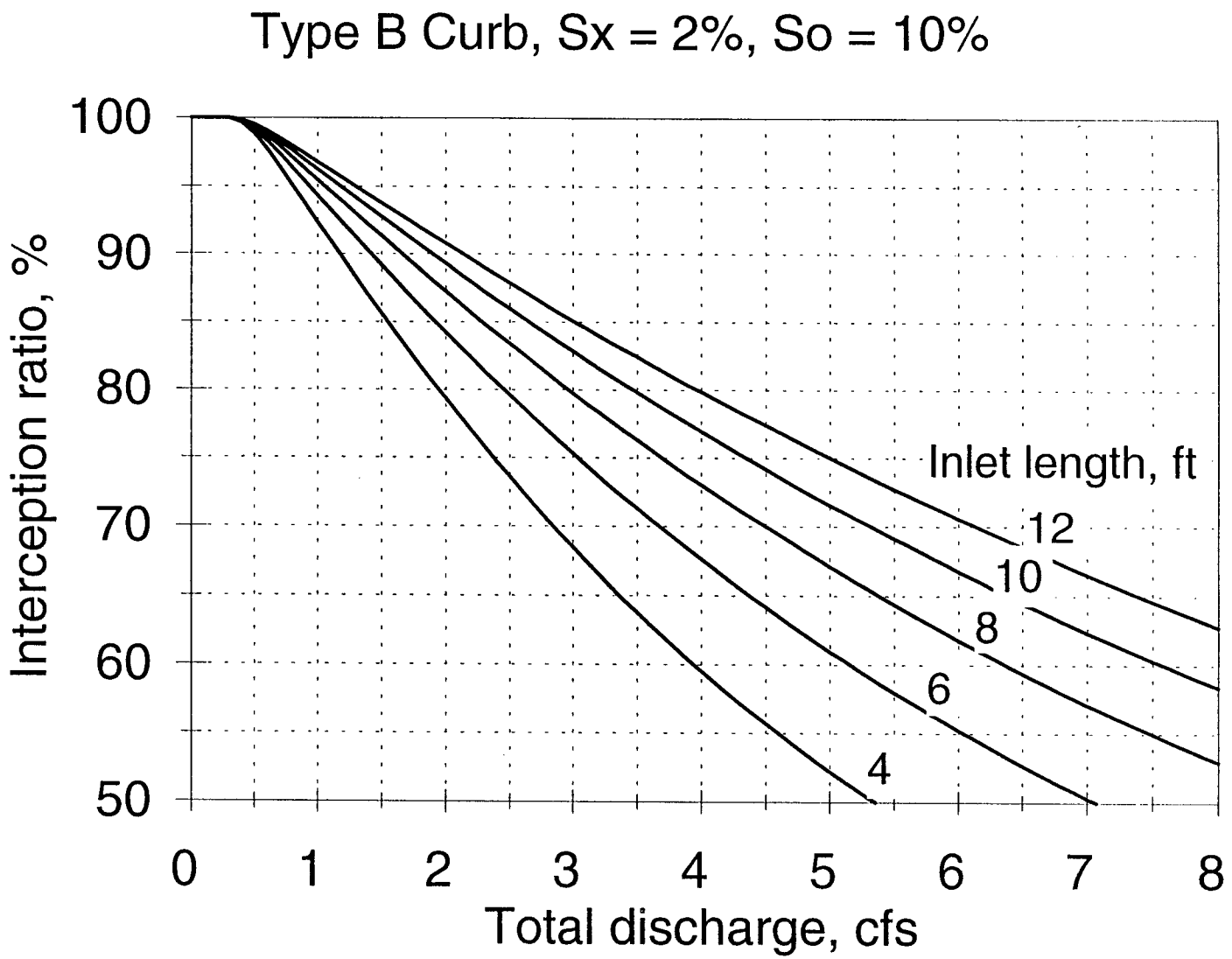

Type B Curb, Sx = 2%, So = 2%
Inlet length, ft
12
10
8
6
4
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs

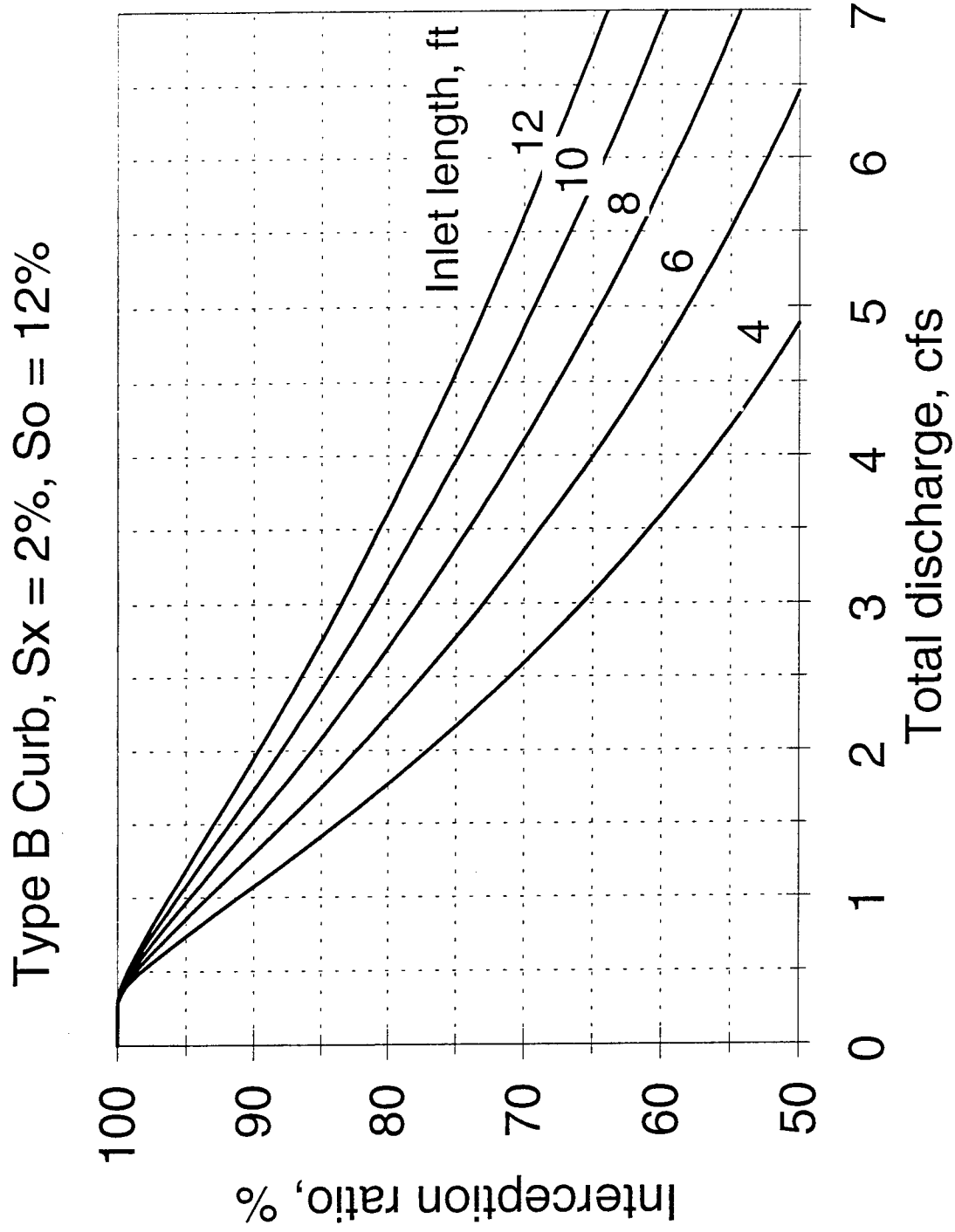

Type B Curb, Sx = 2%, So = 3%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

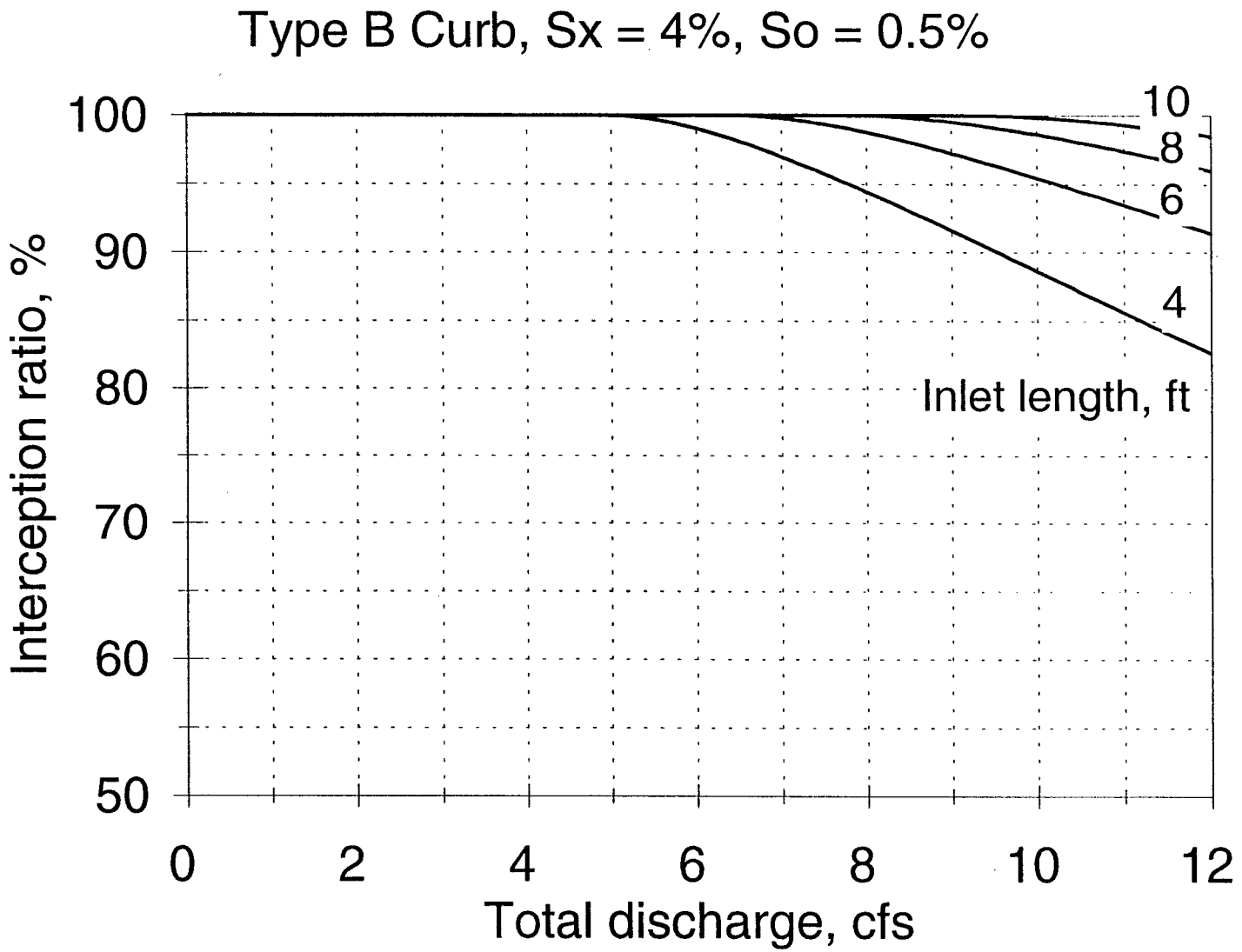

Type B Curb, Sx = 2%, So = 4%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

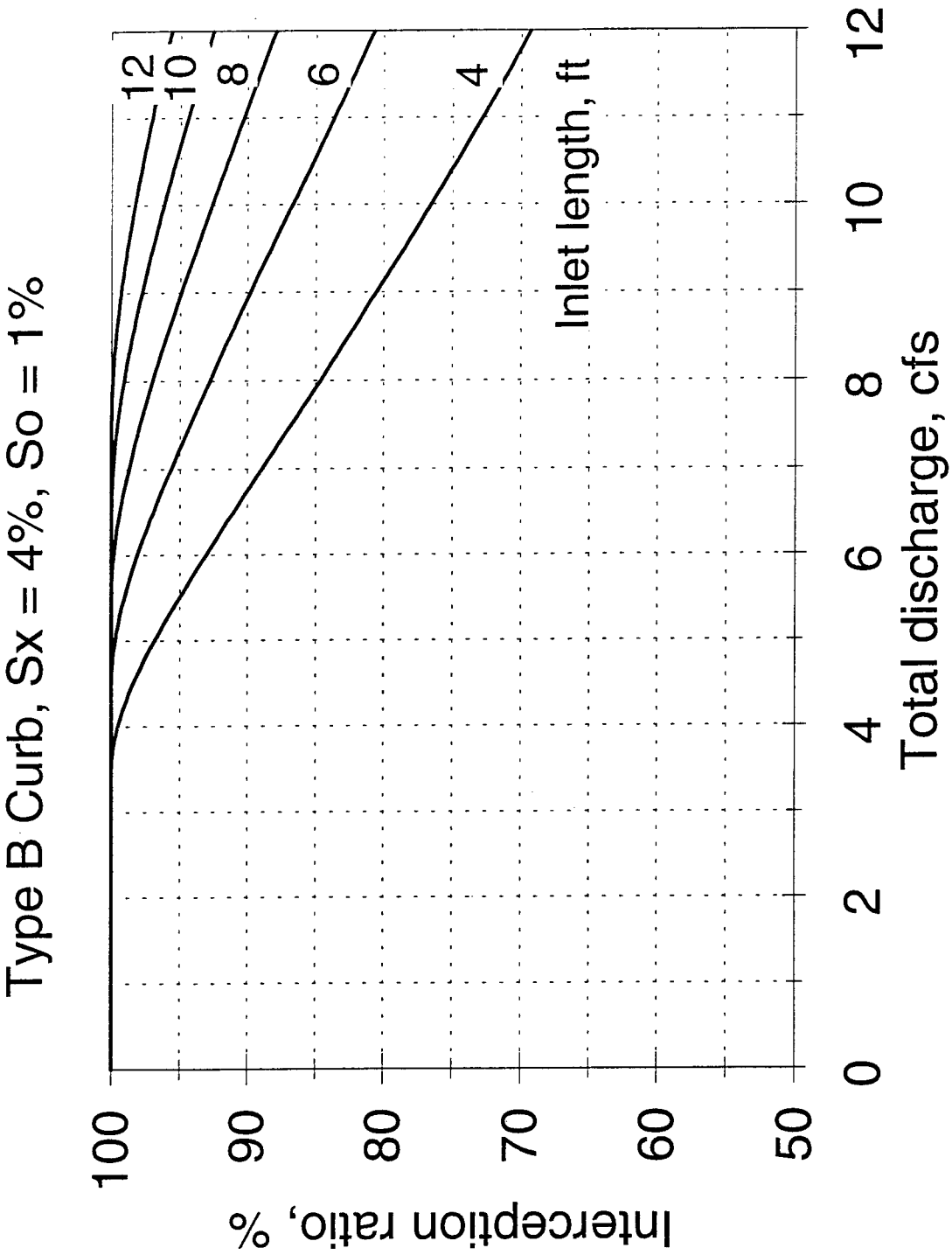

Type B Curb, Sx = 2%, So = 6%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

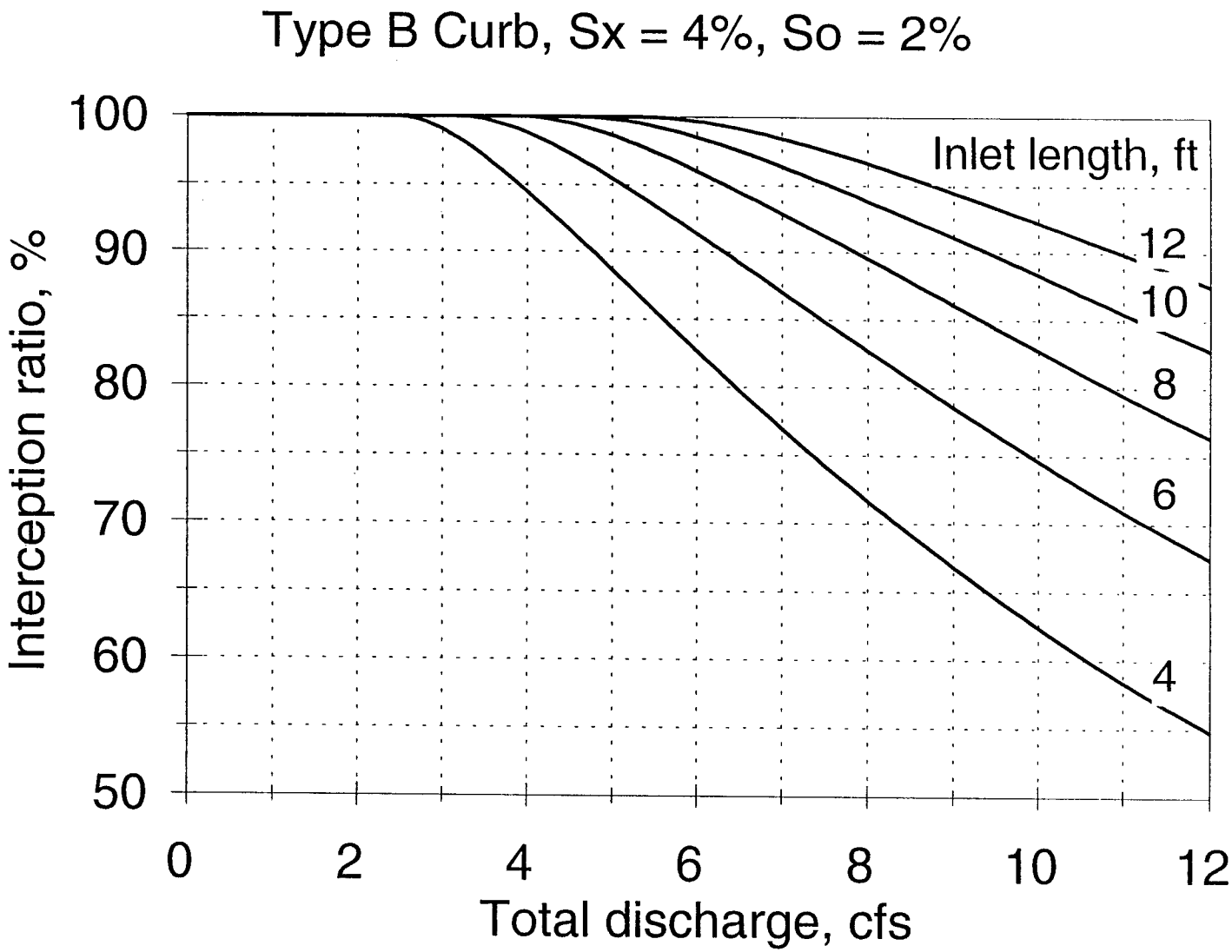

Type B Curb, Sx = 2%, So = 8%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

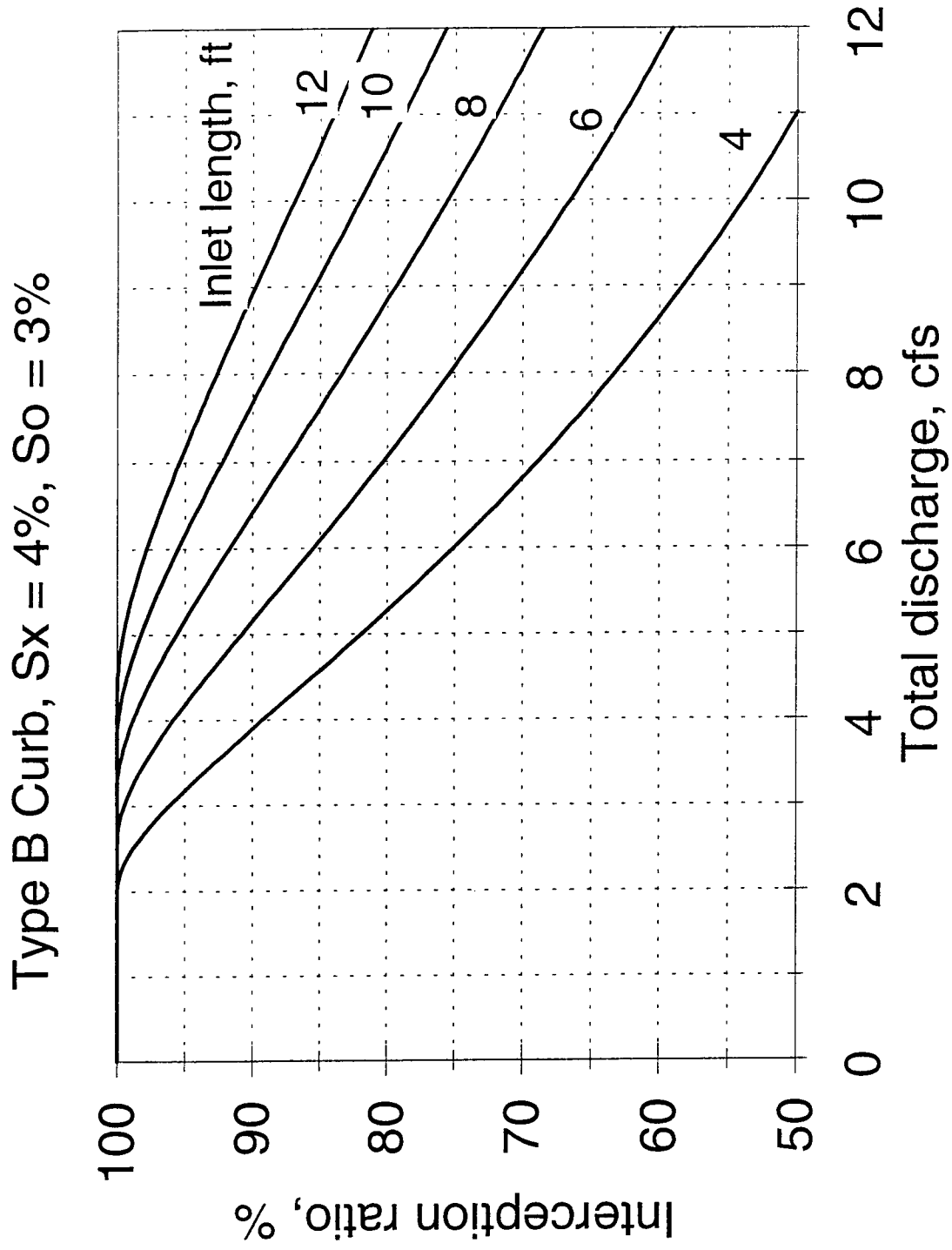

Type B Curb, Sx = 2%, So = 10%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
4
5
6
7
8
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

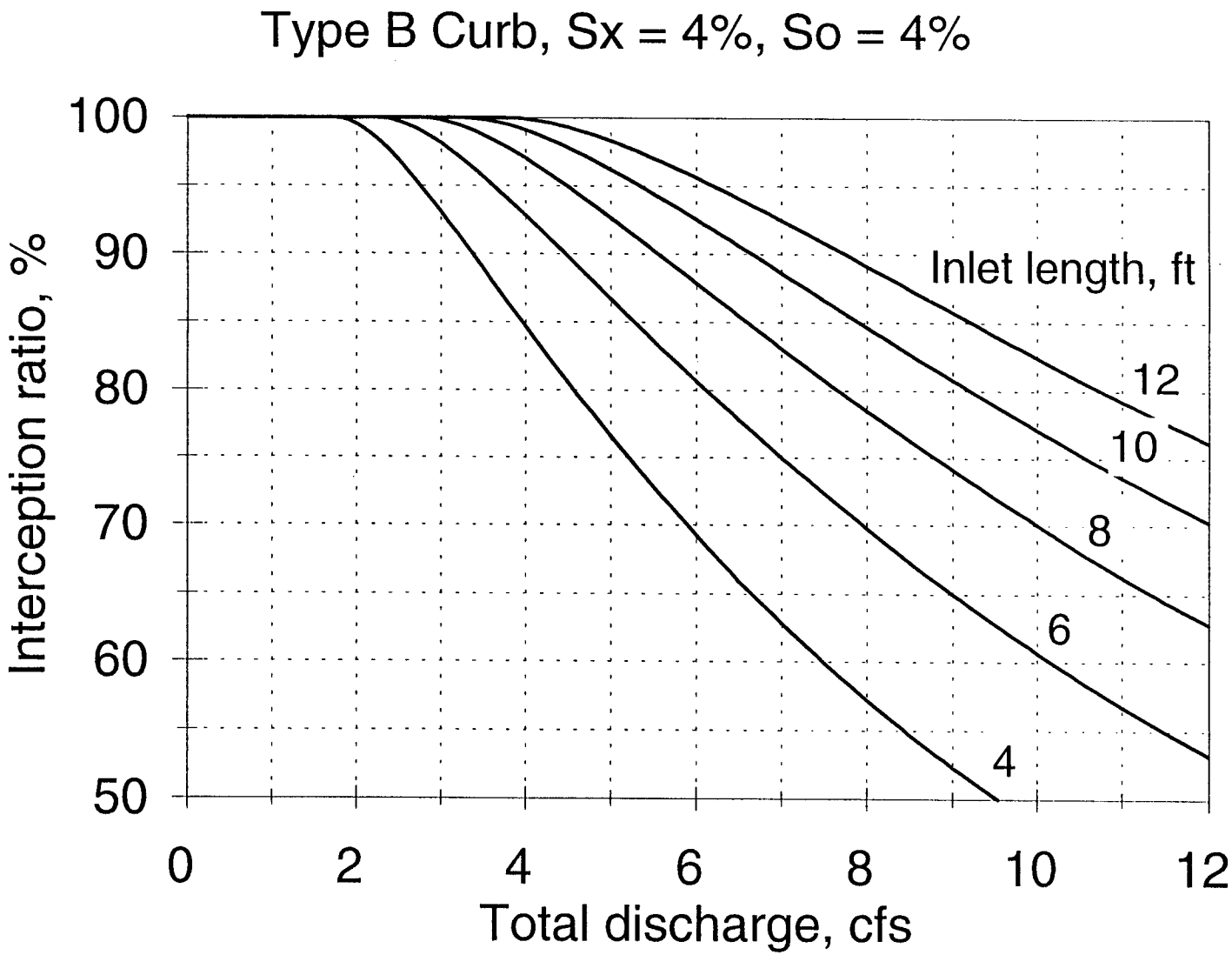

Type B Curb, Sx = 2%, So = 12%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
4
5
6
7
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

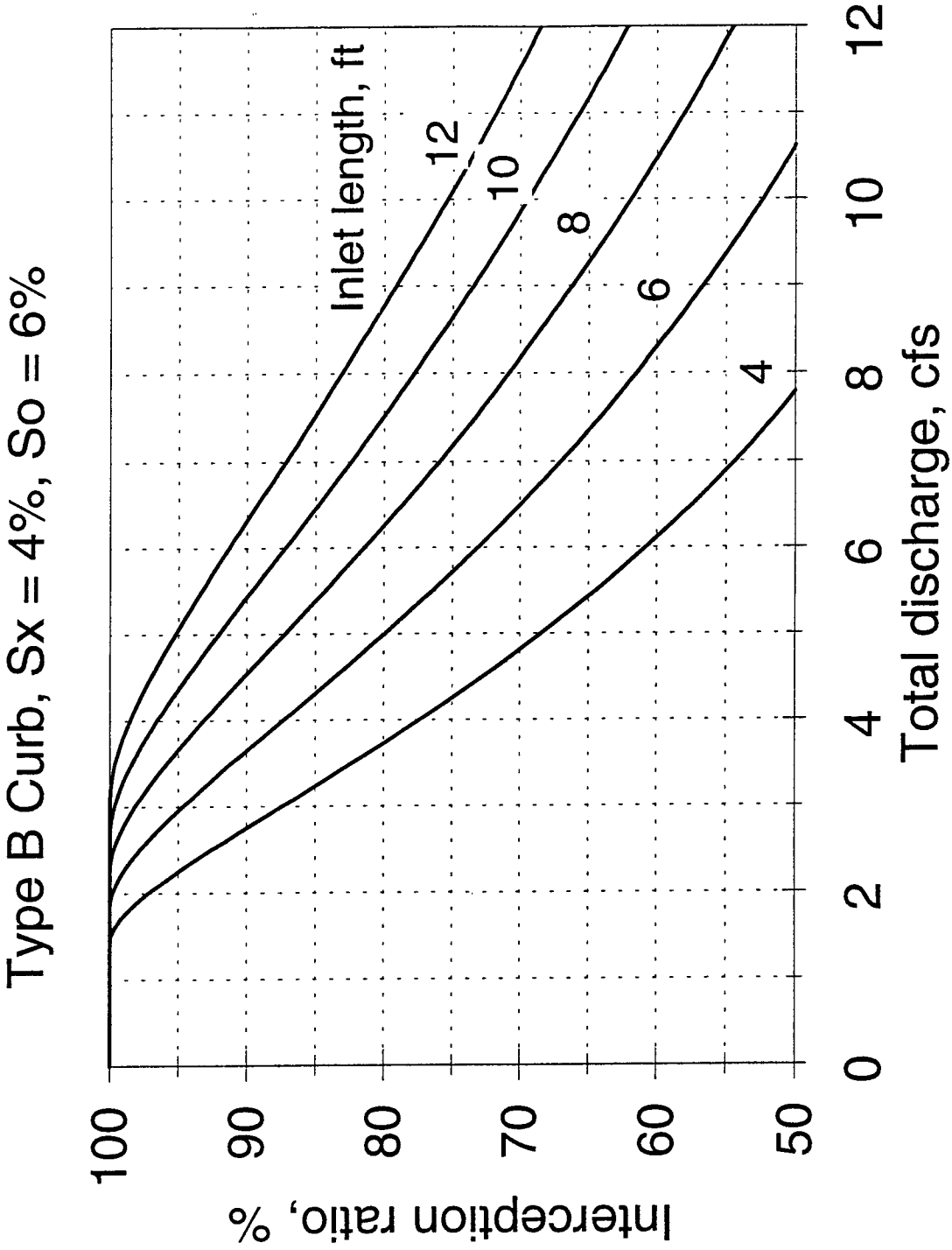

Type B Curb, Sx = 4%, So = 0.5%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
10
8
6
4
Inlet length, ft

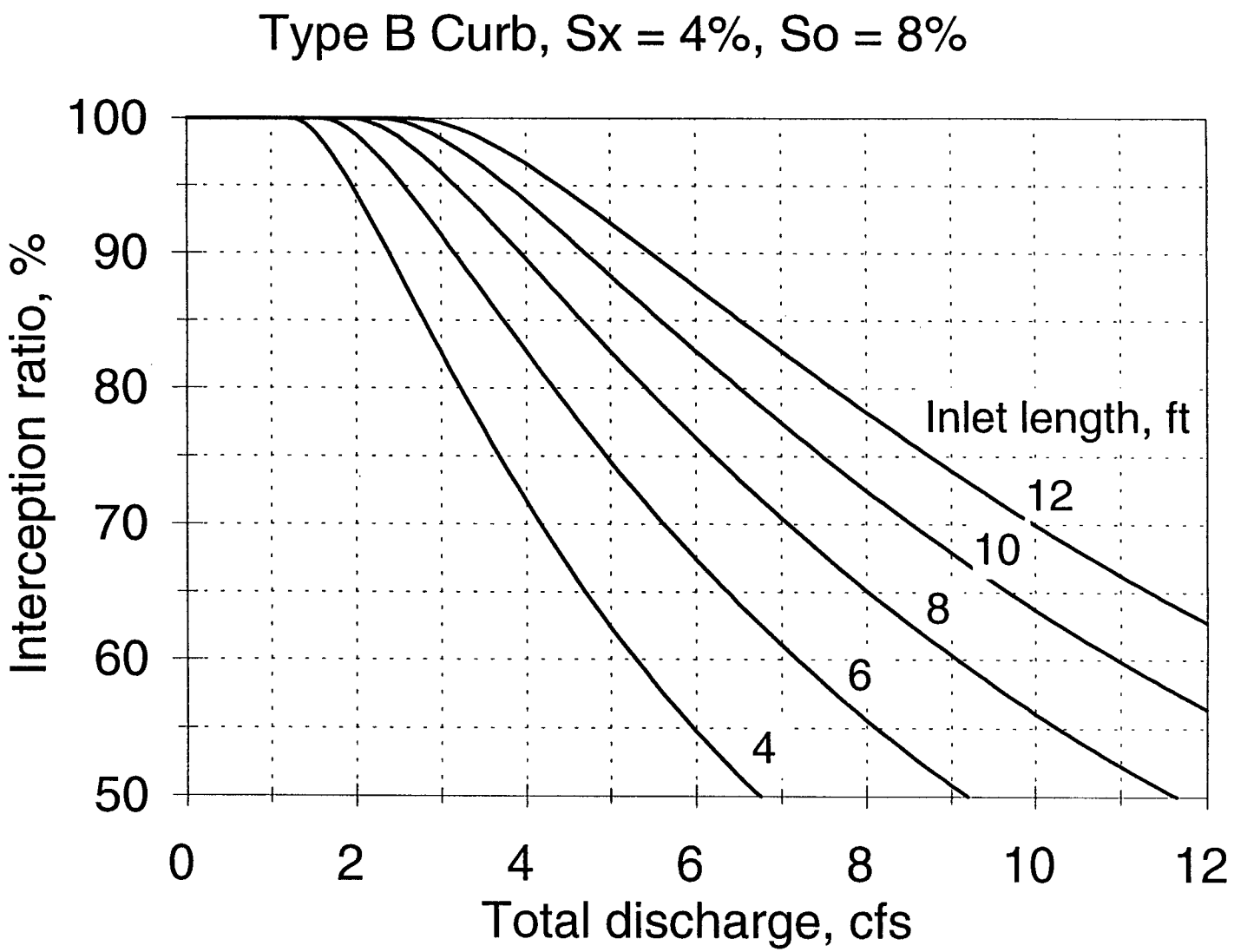

Type B Curb, Sx = 4%, So = 1%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

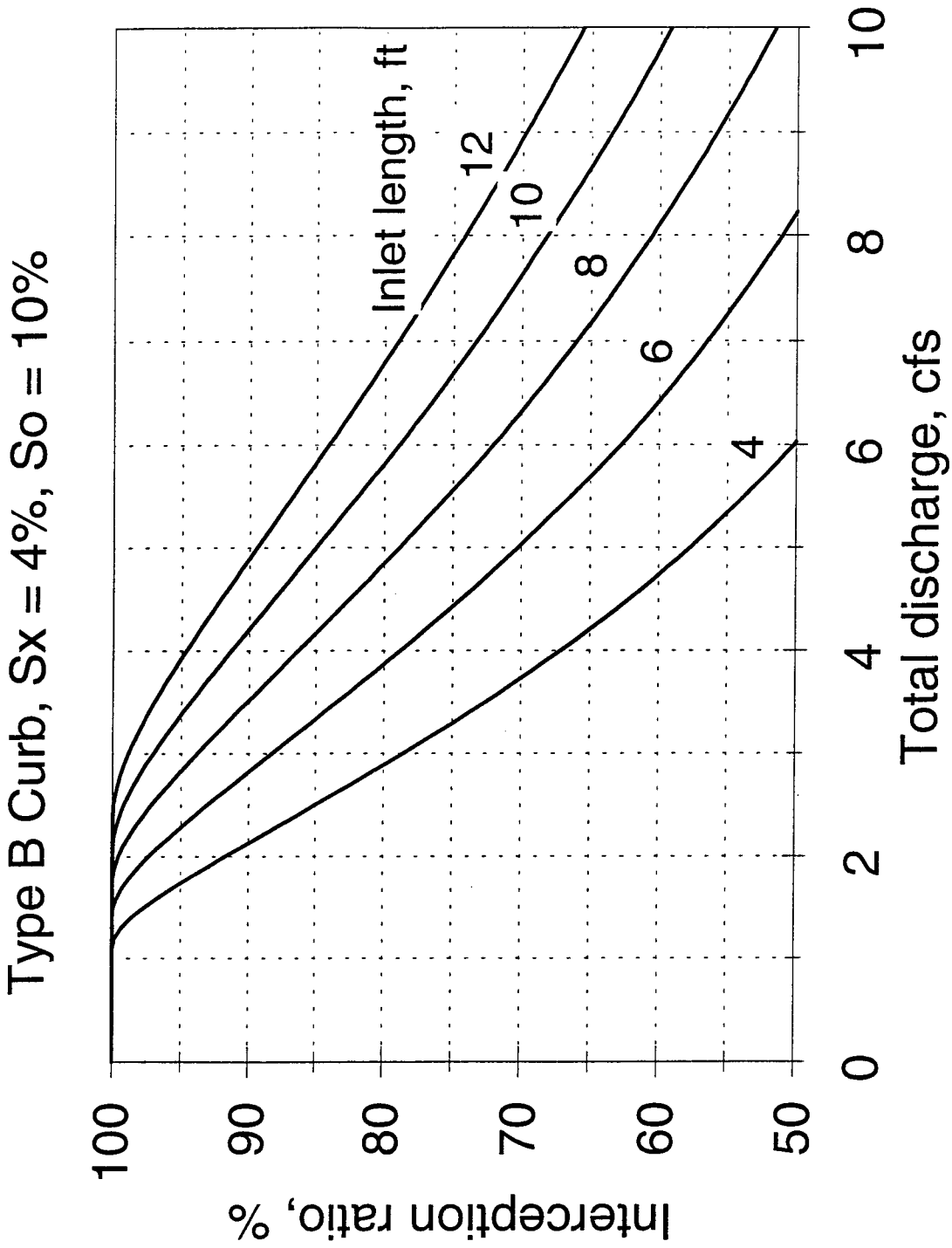

Type B Curb, Sx = 4%, So = 2%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

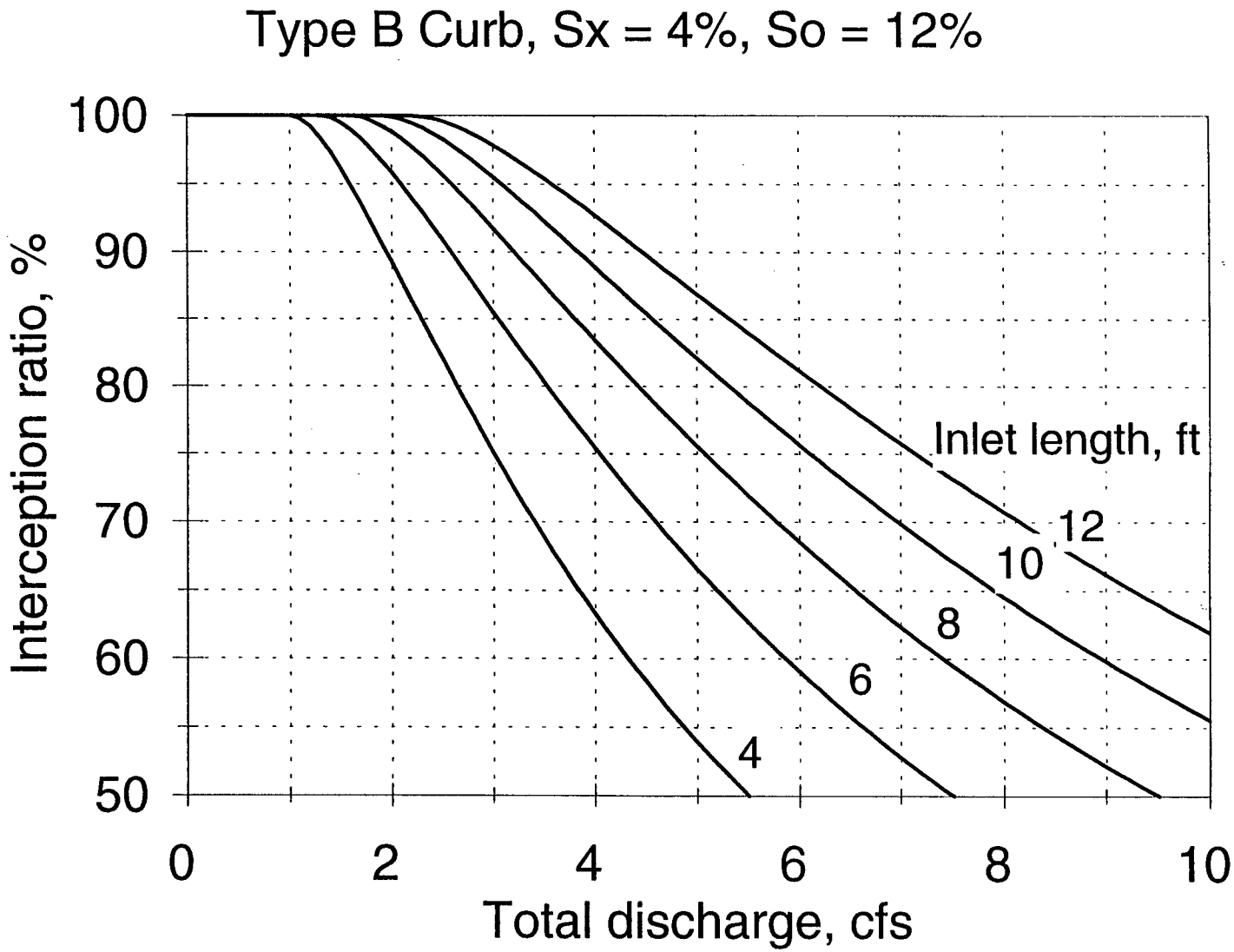

Type B Curb, Sx = 4%, So = 3%
Inlet length, ft
12
10
8
6
4
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs

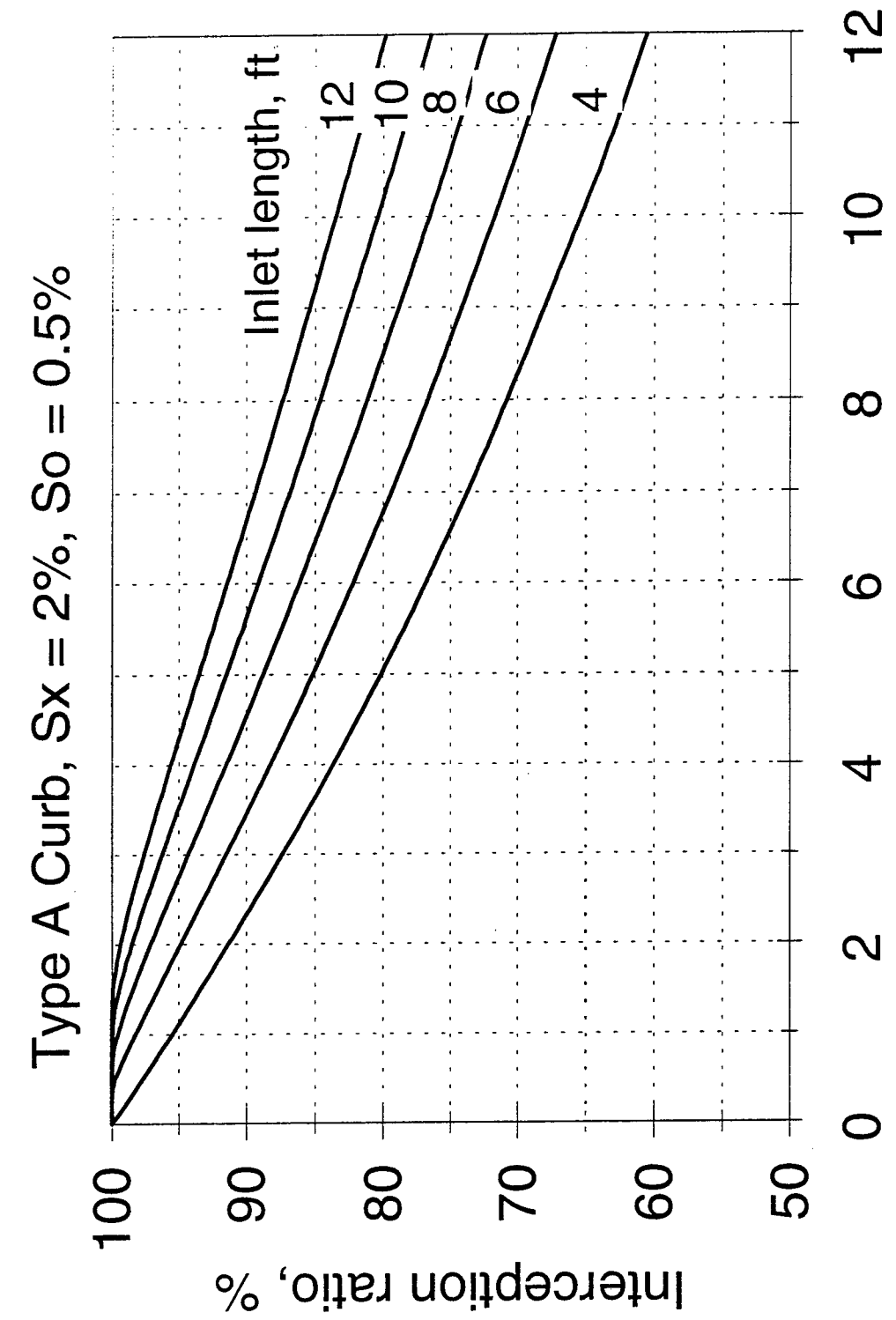

Type B Curb, Sx = 4%, So = 4%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

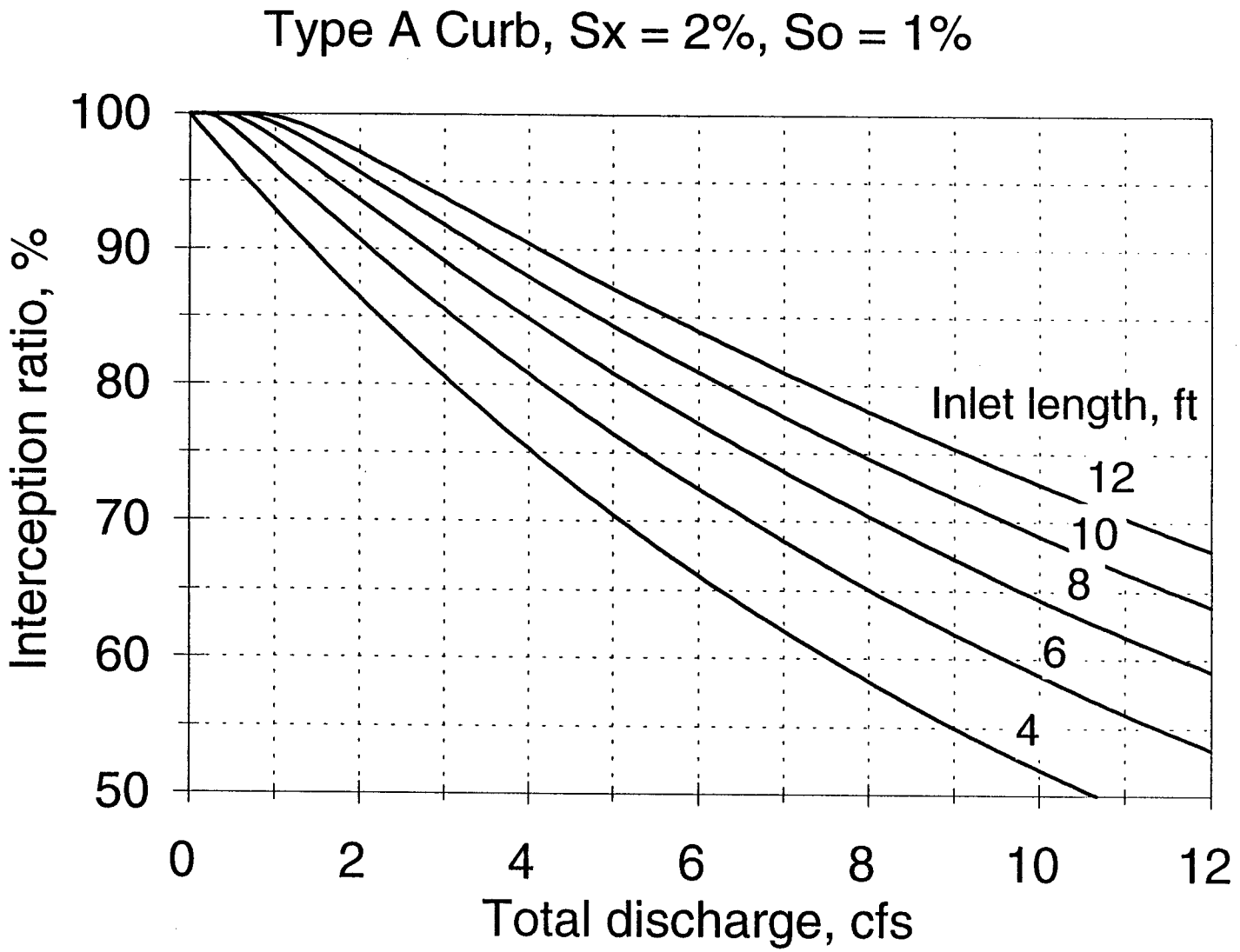

Type B Curb, Sx = 4%, So = 6%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

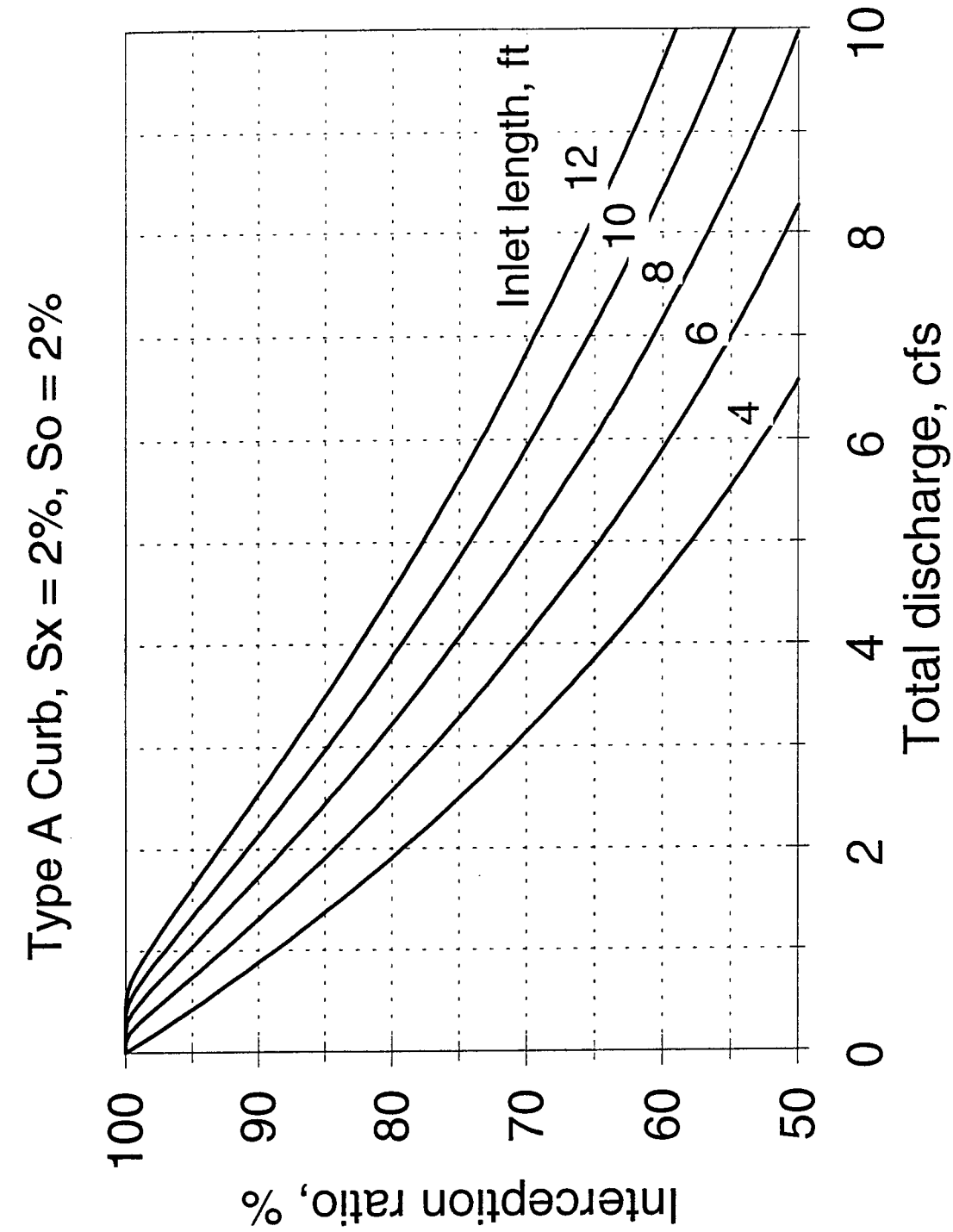

Type B Curb, Sx = 4%, So = 8%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

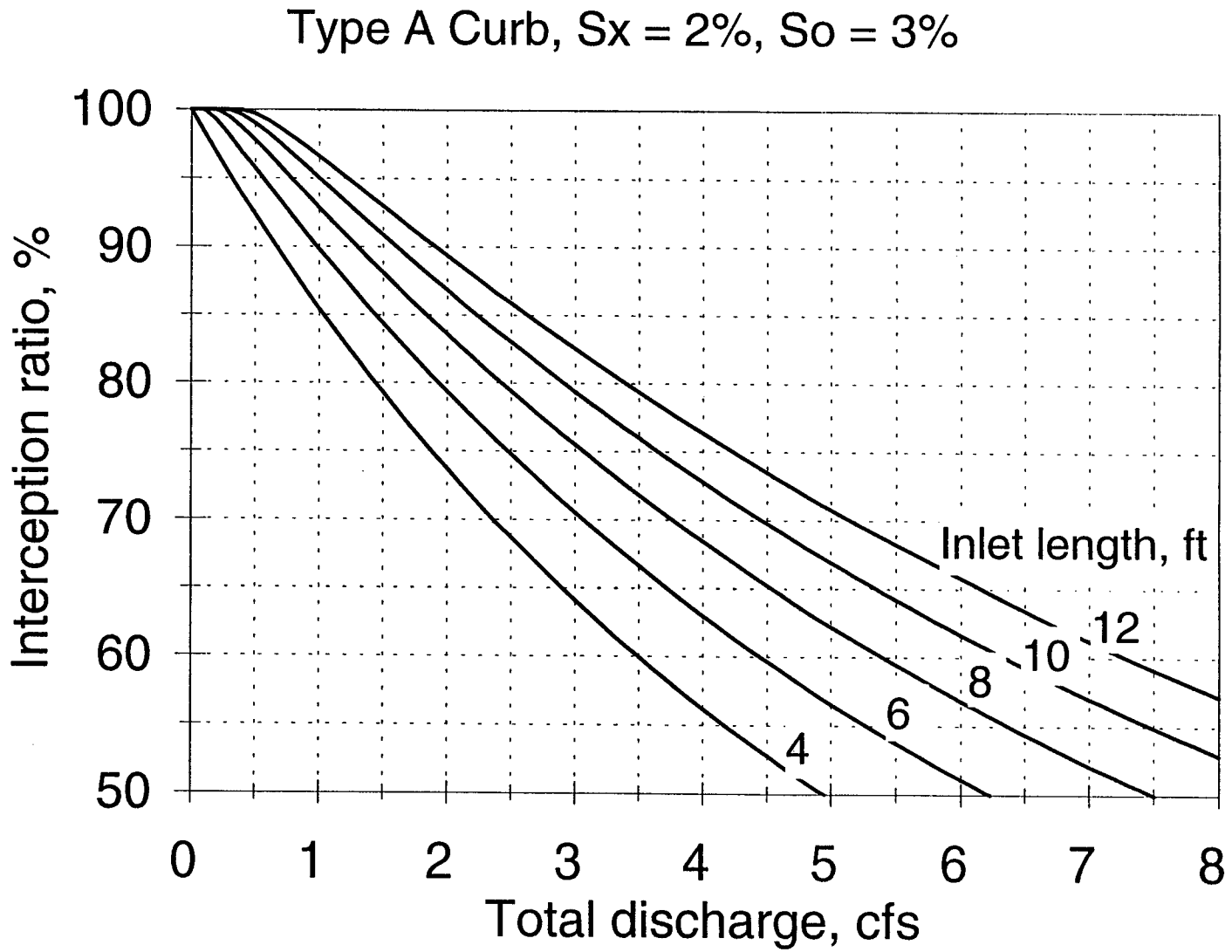

Type B Curb, Sx = 4%, So = 10%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

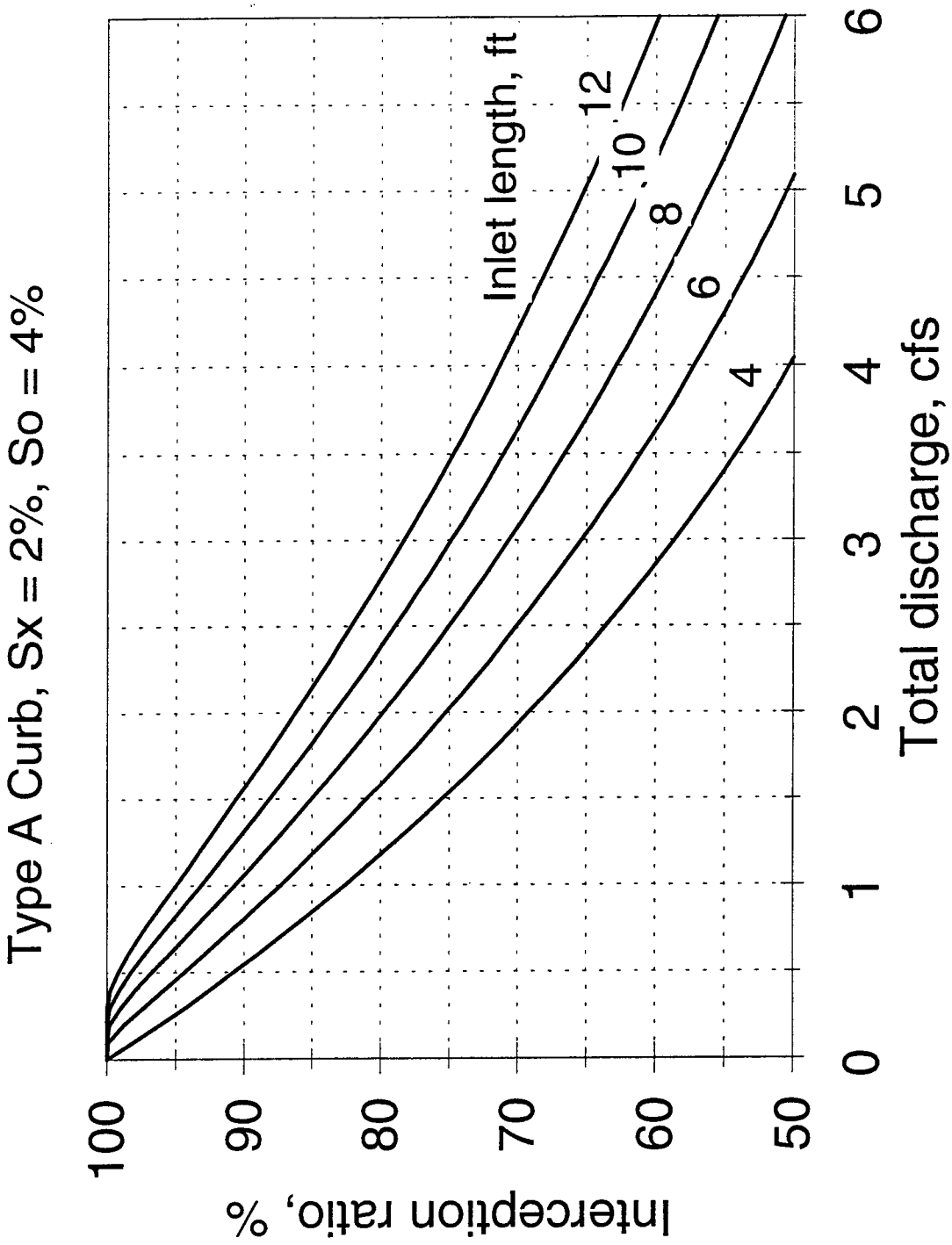

Type B Curb, Sx = 4%, So = 12%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

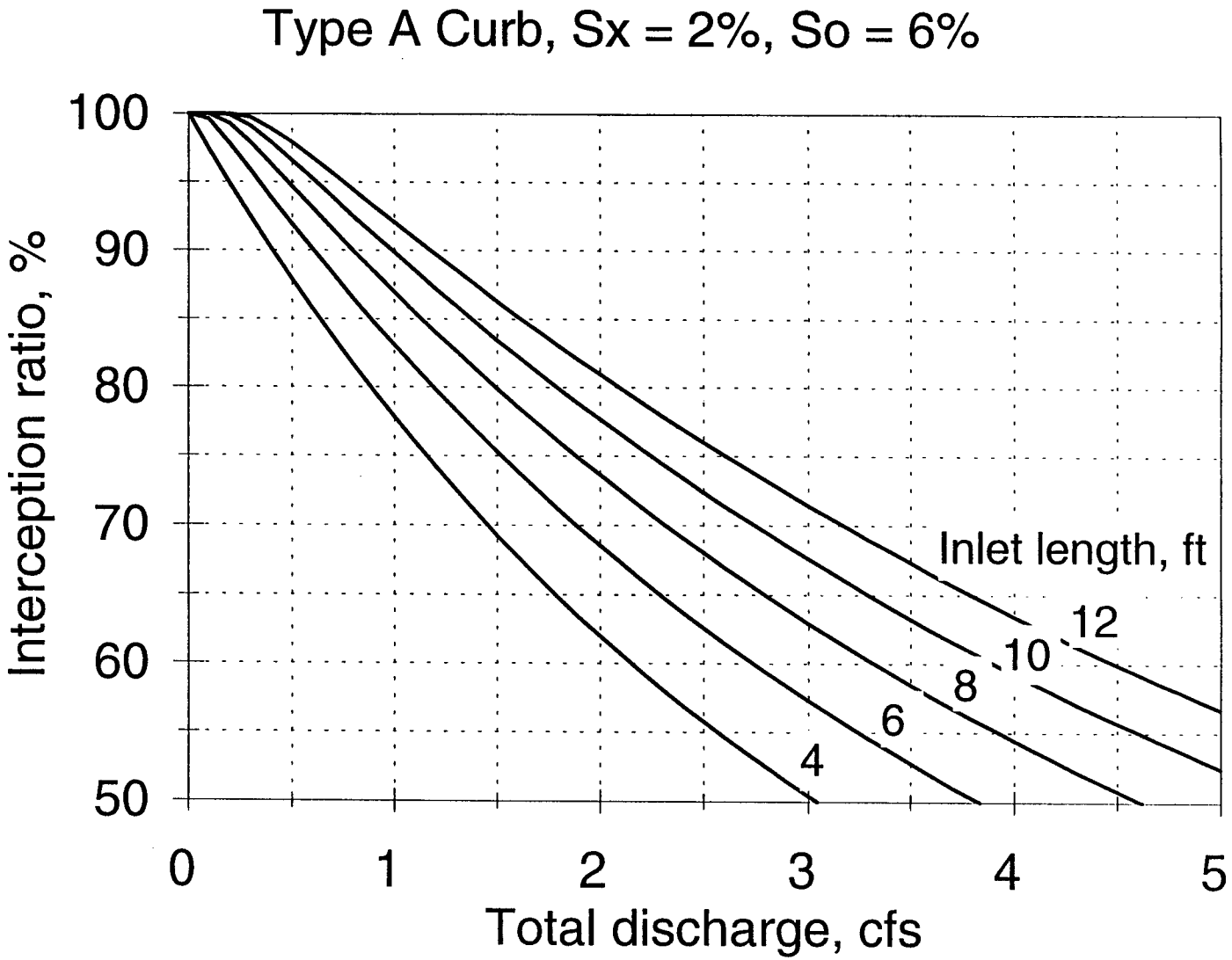

Type A Curb, Sx = 2%, So = 0.5%
Inlet length, ft
12
10
8
6
4
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs

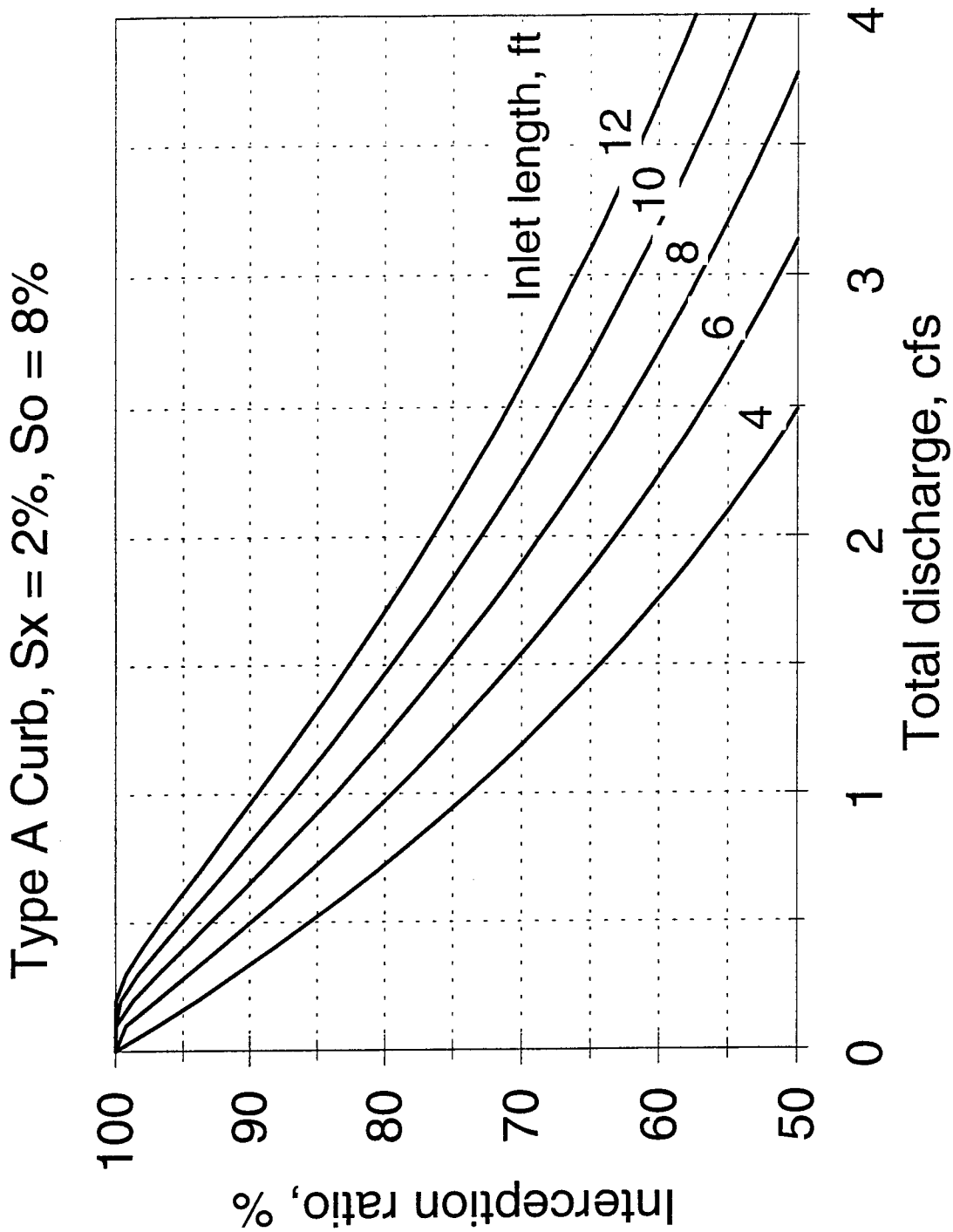

Type A Curb, Sx = 2%, So = 1%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

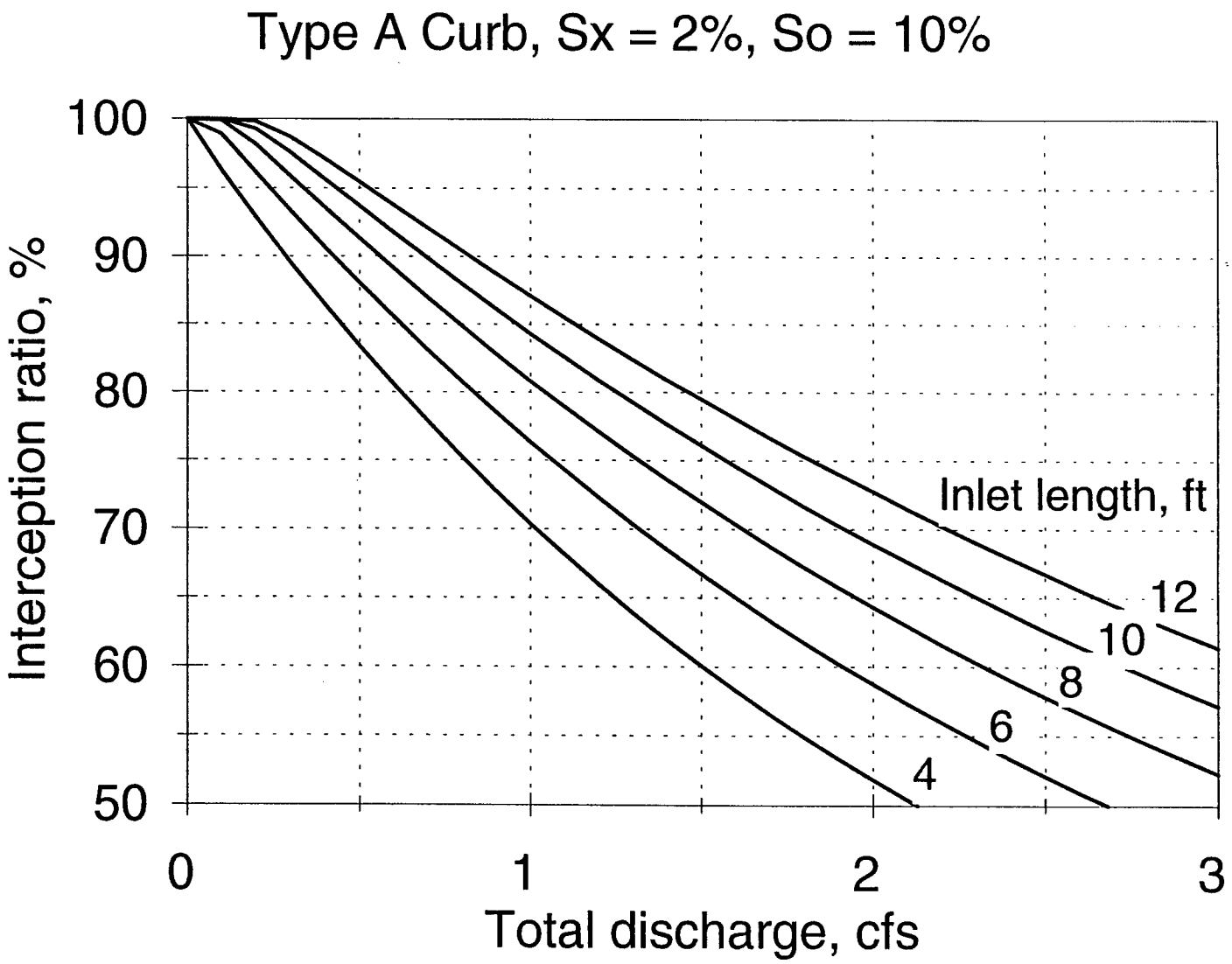

Type A Curb, Sx = 2%, So = 2%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

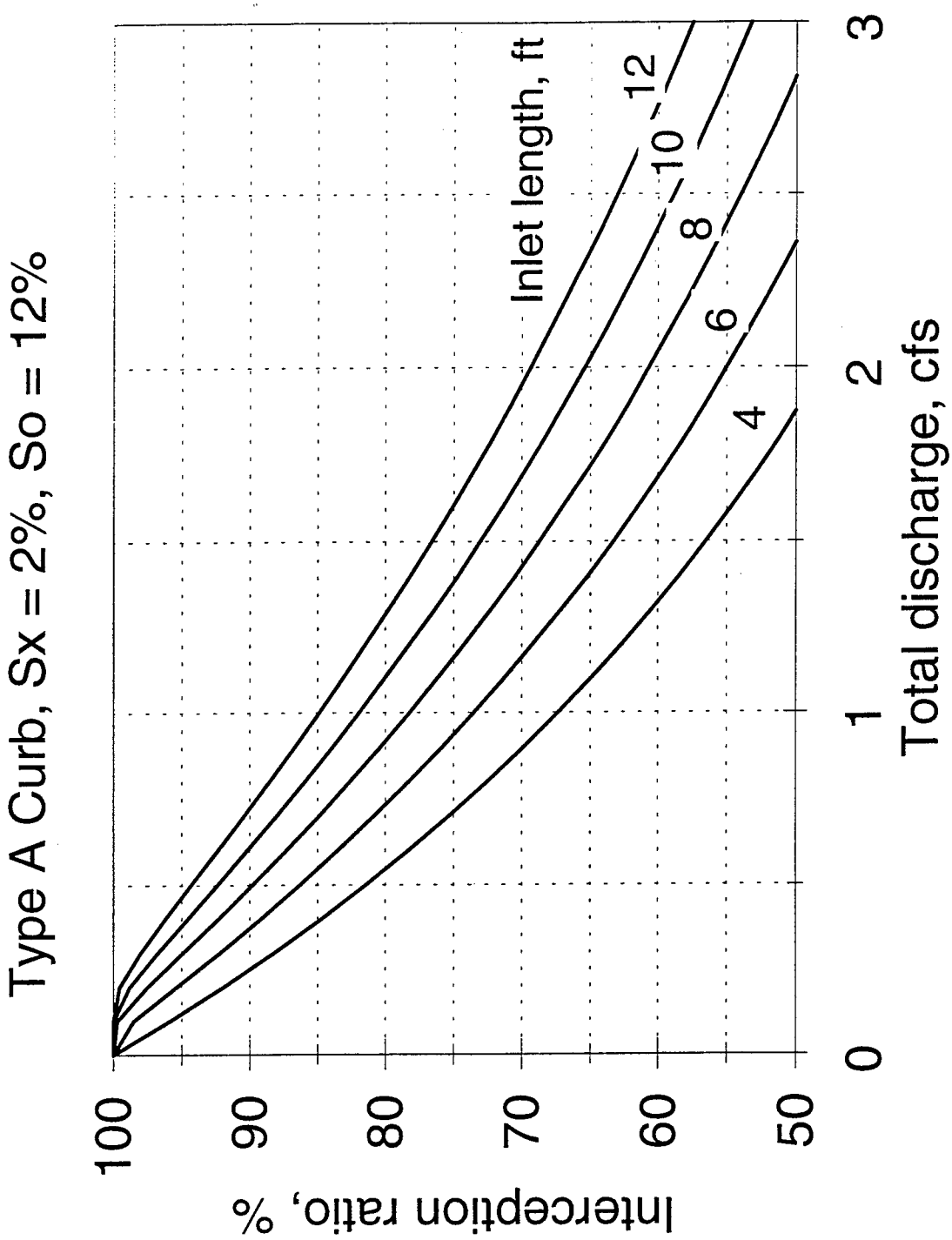

Type A Curb, Sx = 2%, So = 3%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
4
5
6
7
8
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

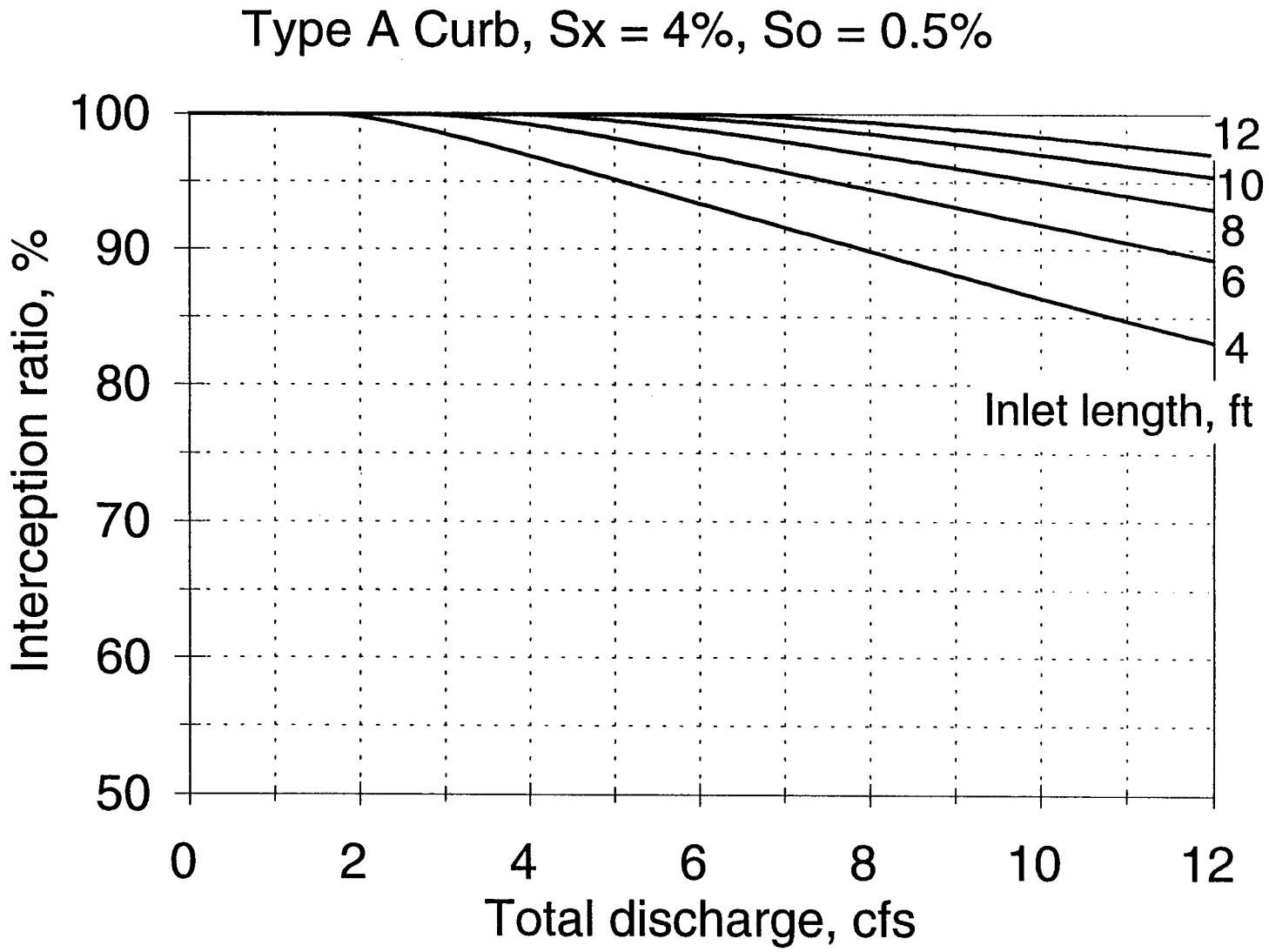

Type A Curb, Sx = 2%, So = 4%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
4
5
6
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

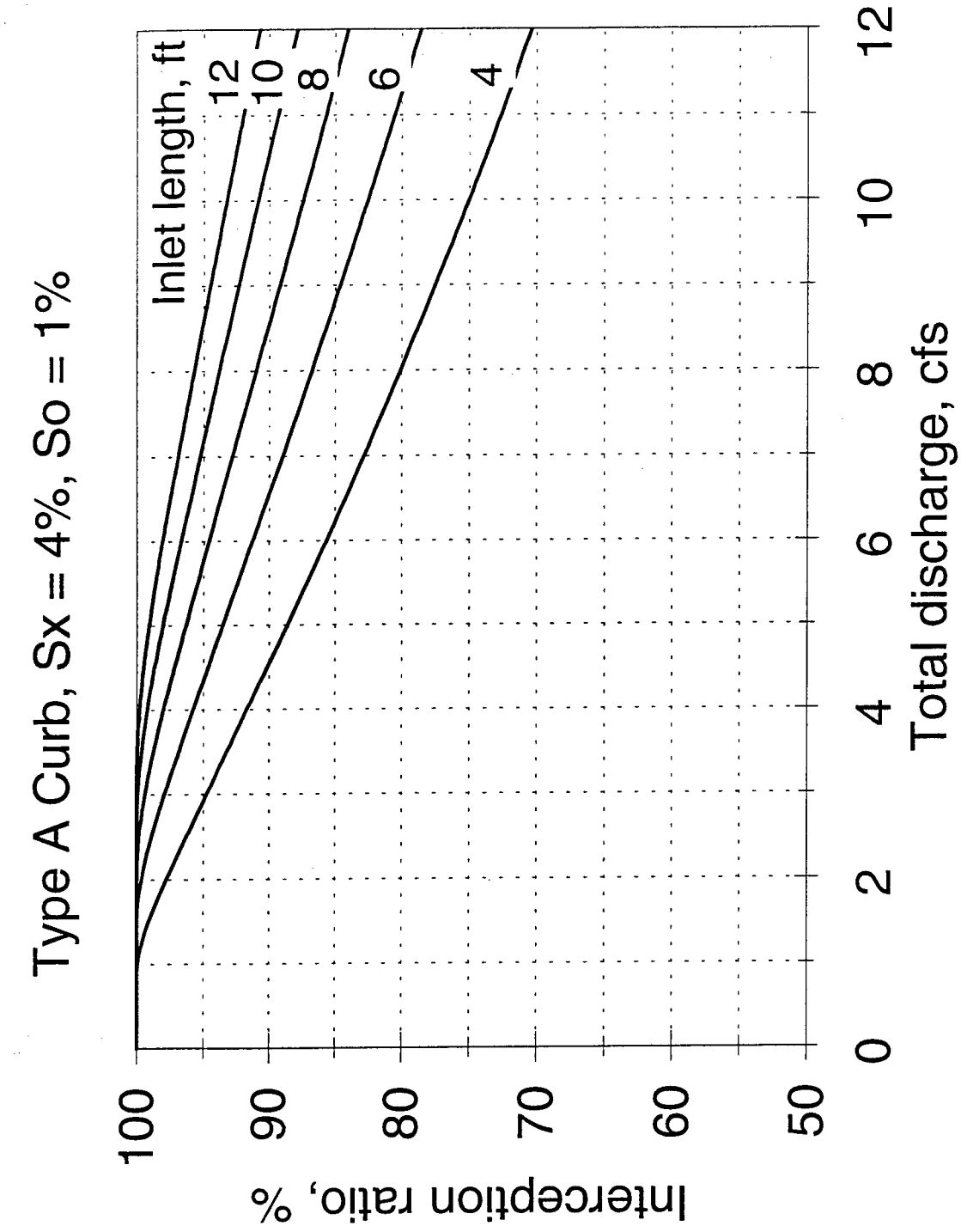

Type A Curb, Sx = 2%, So = 6%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
4
5
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

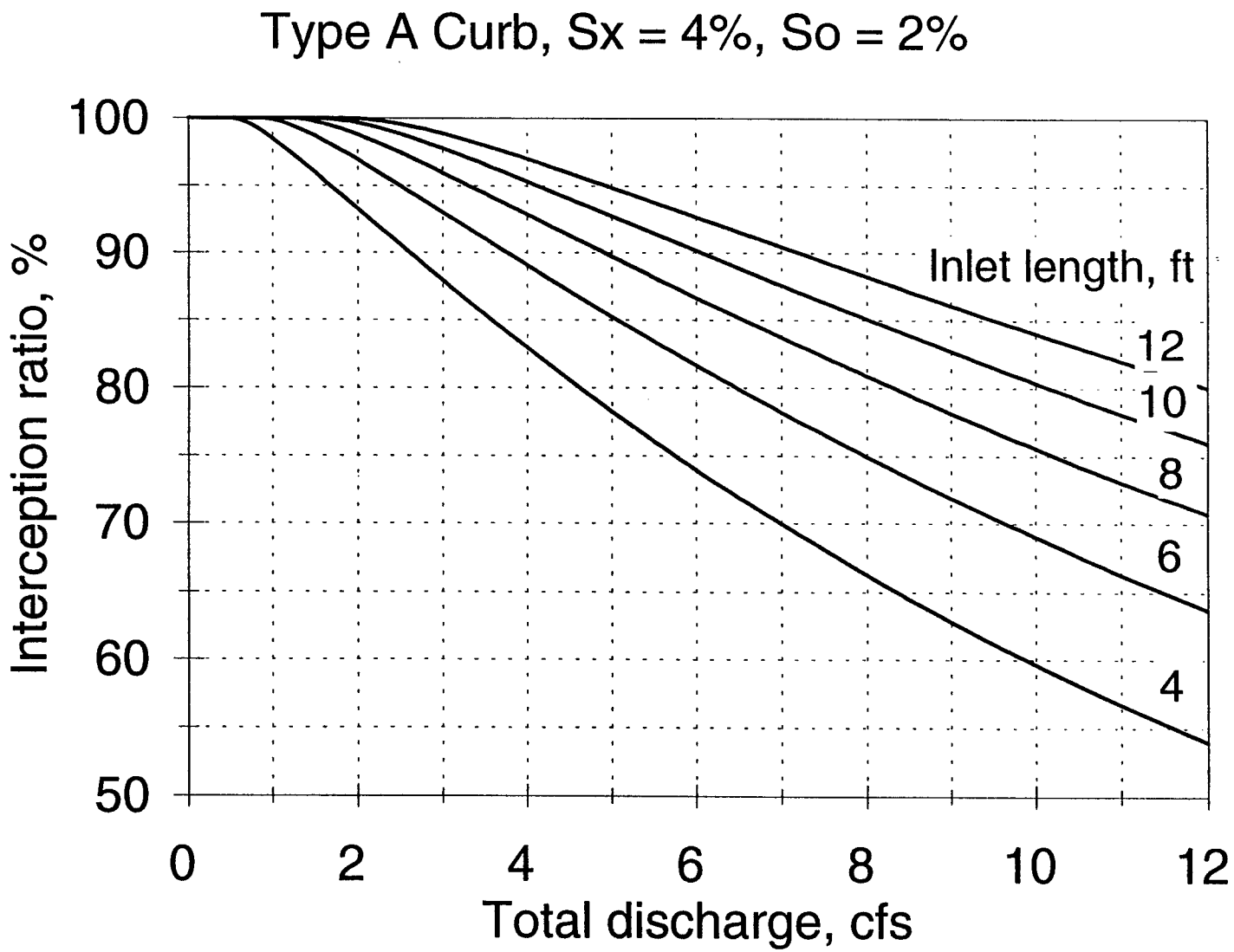

Type A Curb, Sx = 2%, So = 8%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
4
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

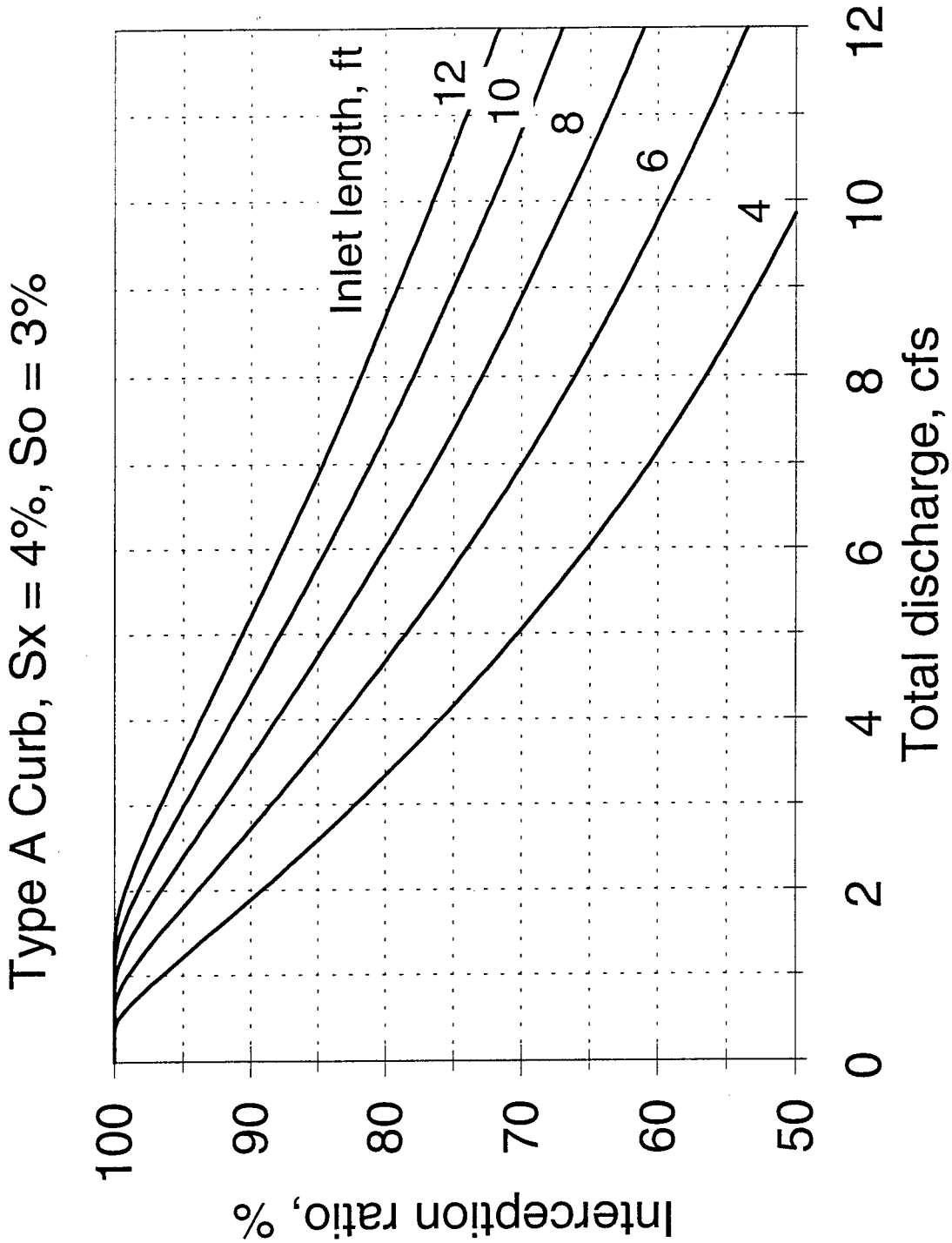

Type A Curb, Sx = 2%, So = 10%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

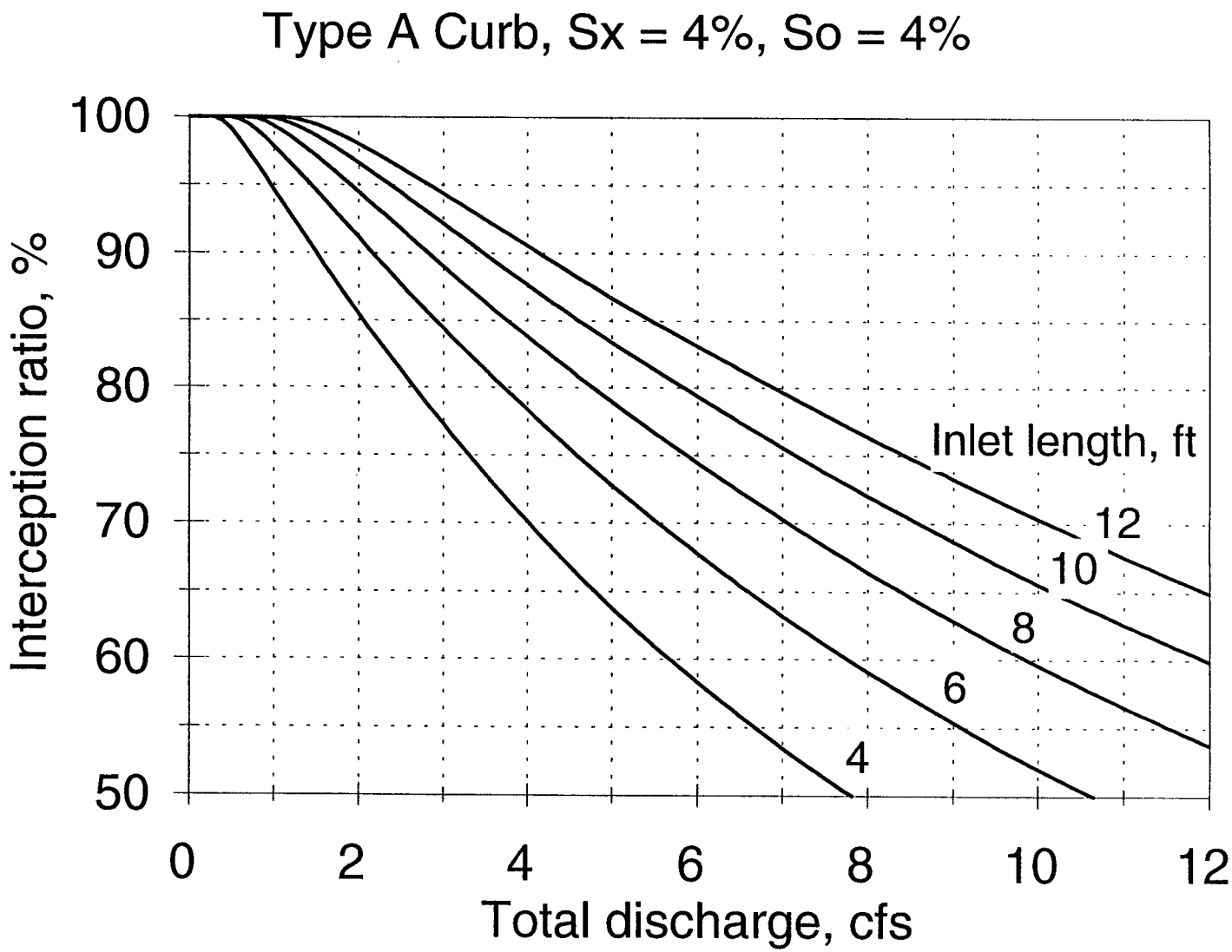

Type A Curb, Sx = 2%, So = 12%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
Total discharge, cfs
Inlet length, ft
4
6
8
10
12

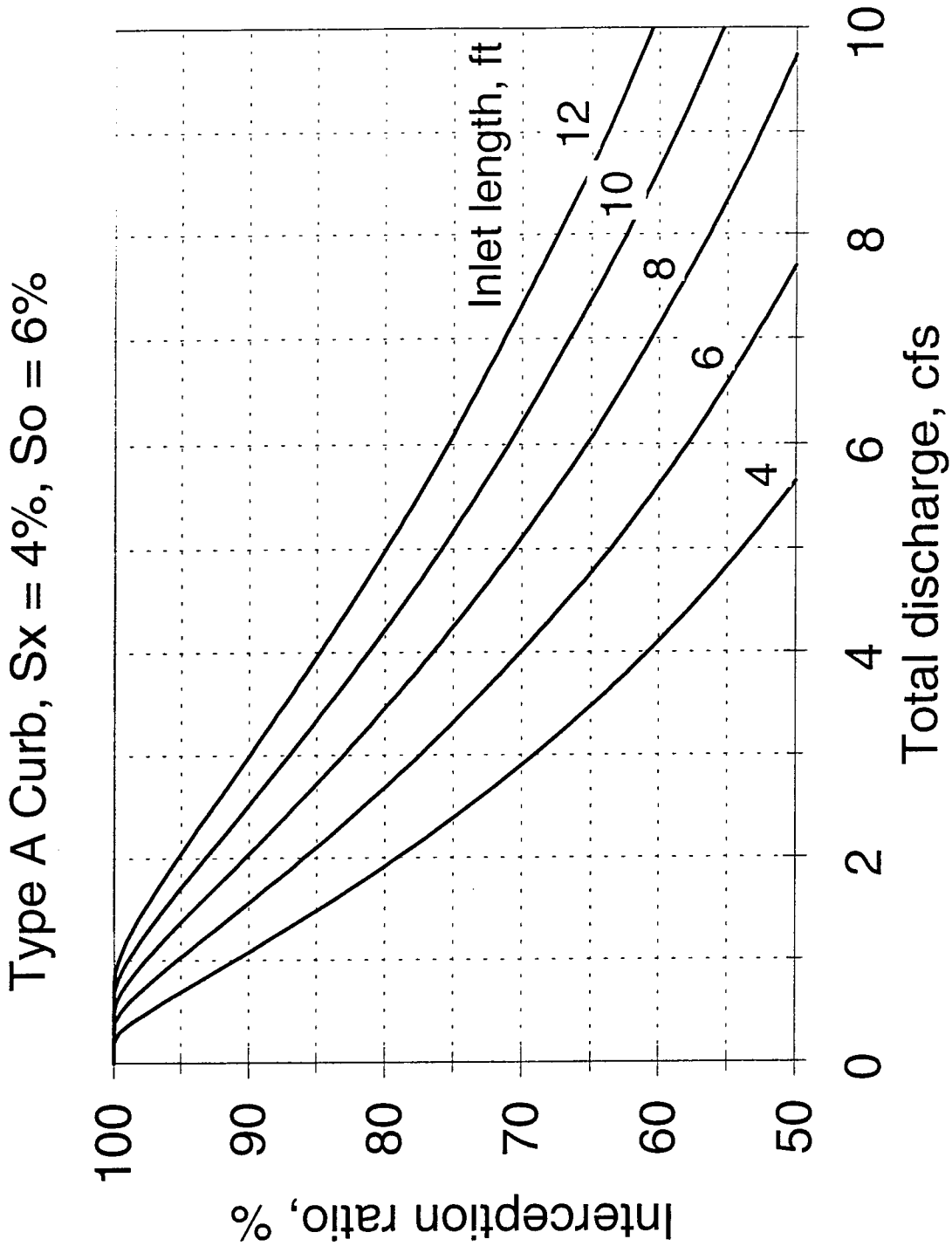

Type A Curb, Sx = 4%, So = 0.5%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
12
10
8
6
4
Inlet length, ft

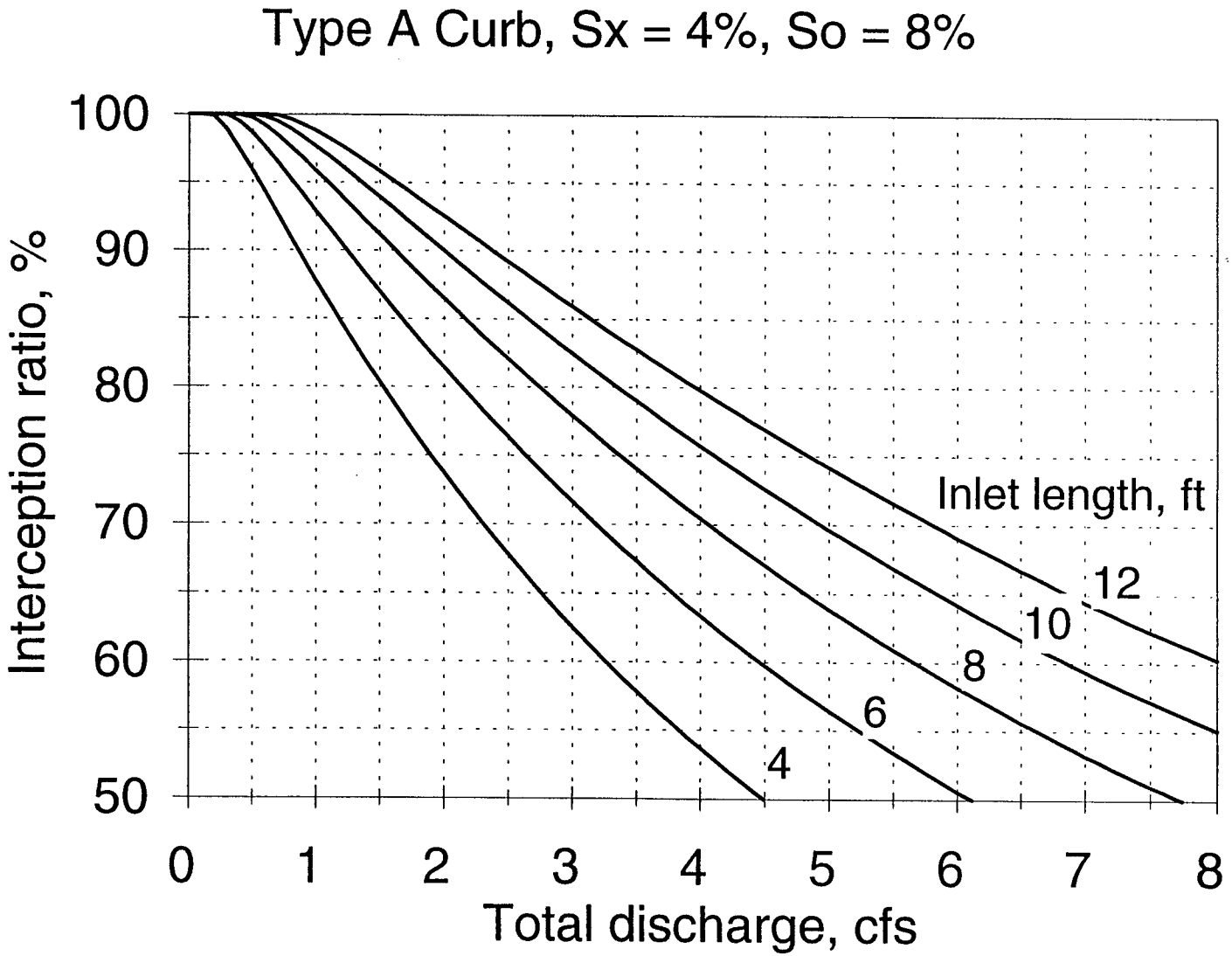

Type A Curb, Sx = 4%, So = 1%
Inlet length, ft
12
10
8
6
4
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs

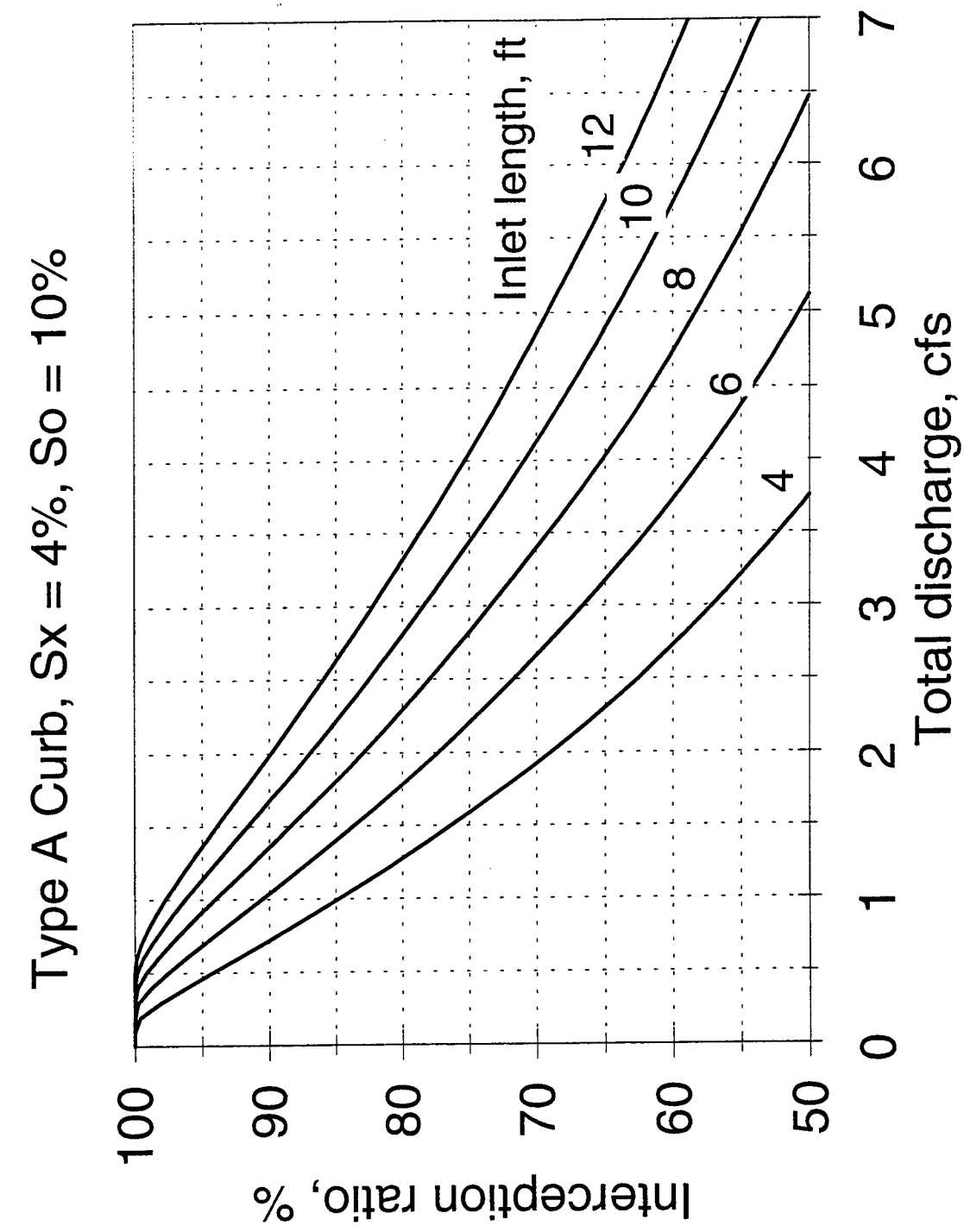

Type A Curb, Sx = 4%, So = 2%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

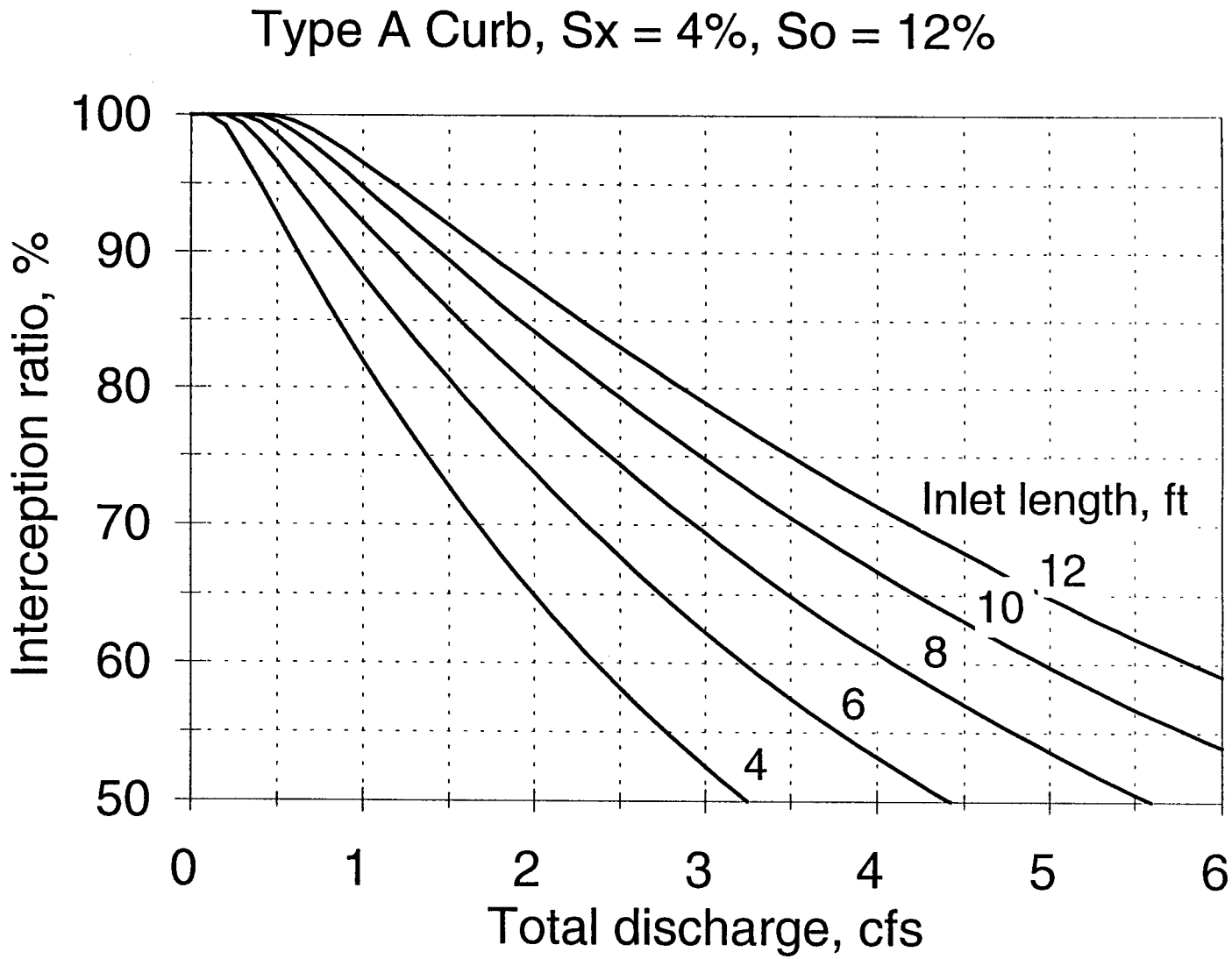

Type A Curb, Sx = 4%, So = 3%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4


Type A Curb, Sx = 4%, So = 4%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
12
Total discharge, cfs
Inlet length, ft
12
10
8
6
4


Type A Curb, Sx = 4%, So = 6%
Interception ratio, %
100
90
80
70
60
50
0
2
4
6
8
10
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

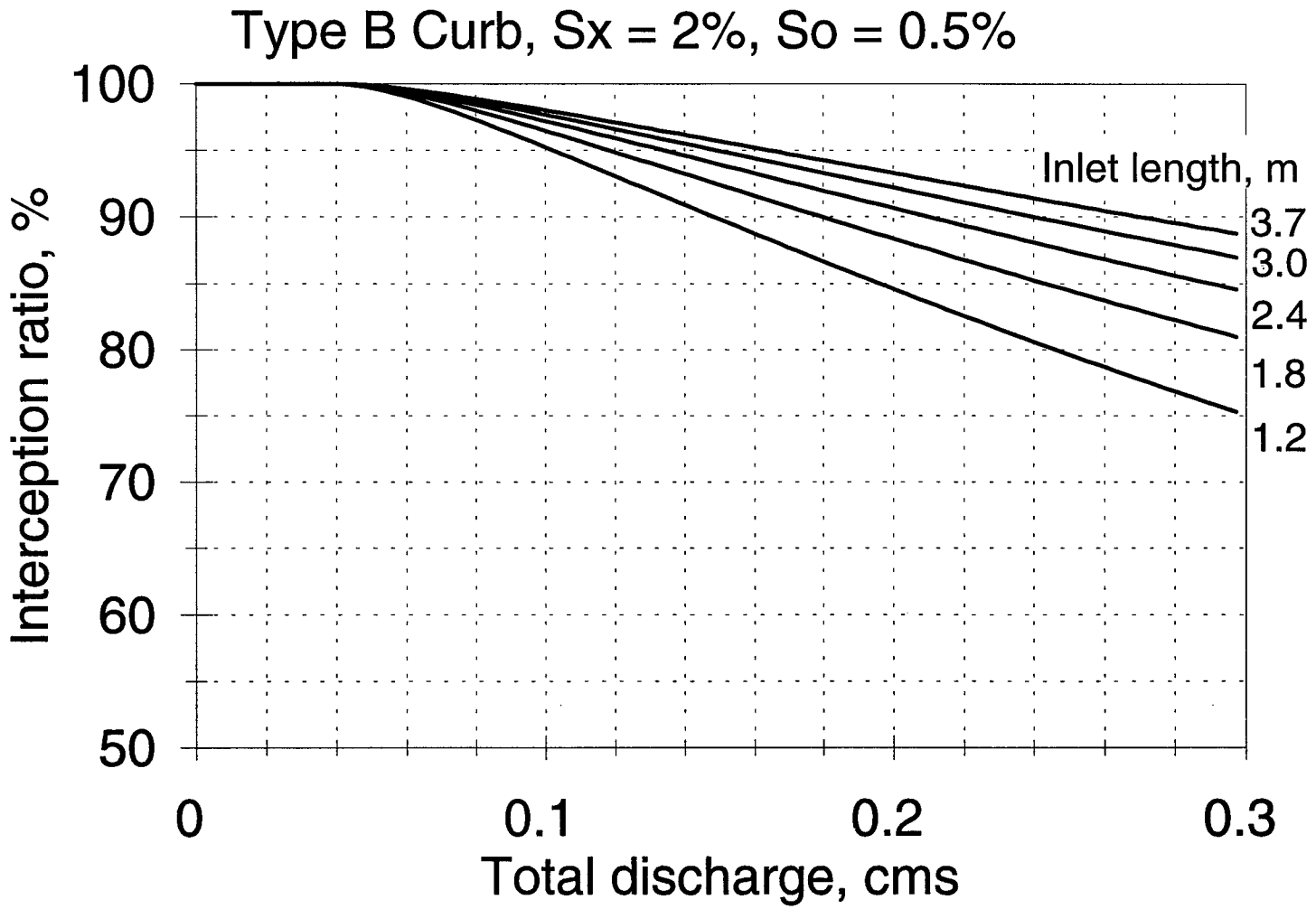

Type A Curb, Sx = 4%, So = 8%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
4
5
6
7
8
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

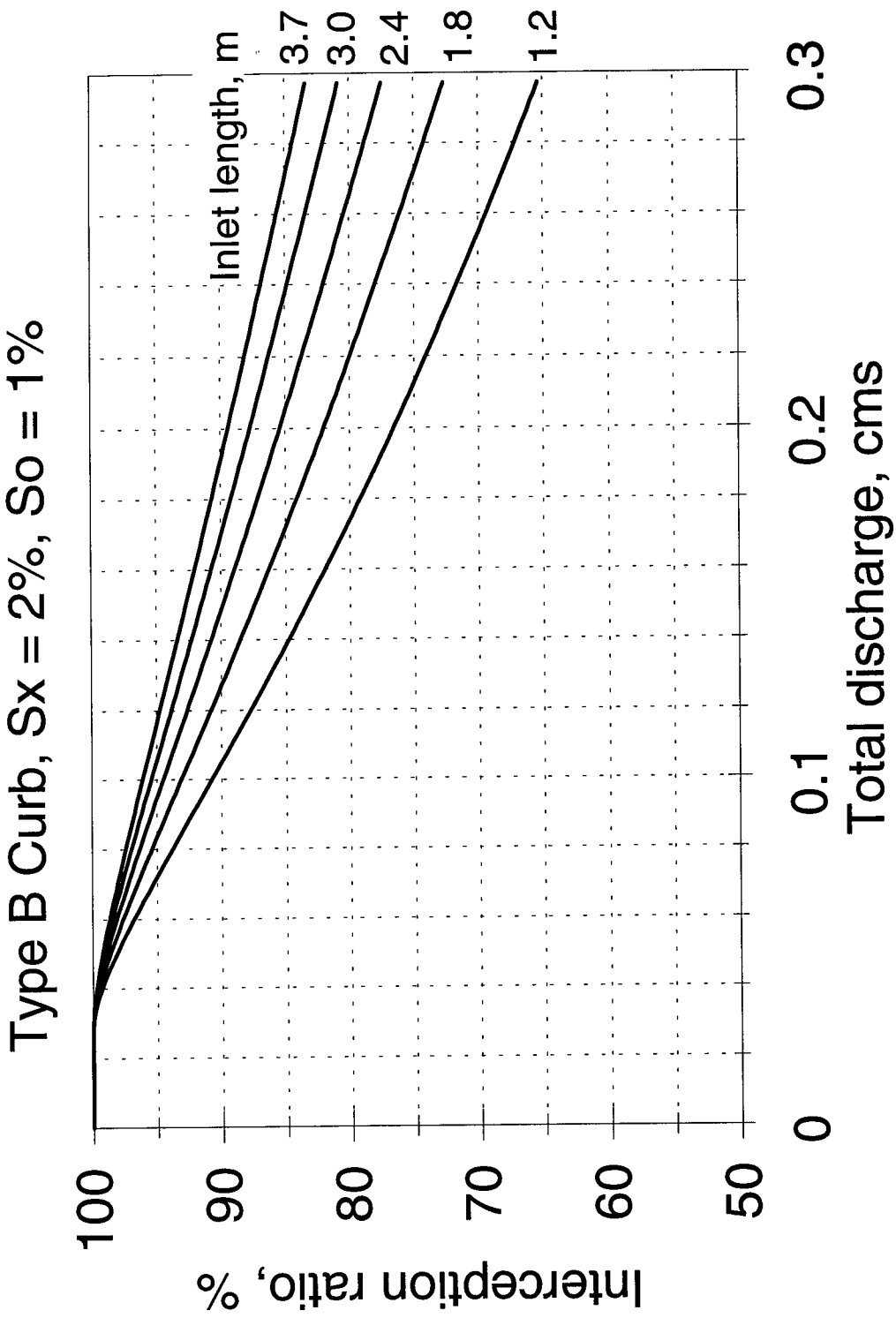

Type A Curb, Sx = 4%, So = 10%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
4
5
6
7
Total discharge, cfs
Inlet length, ft
4
6
8
10
12

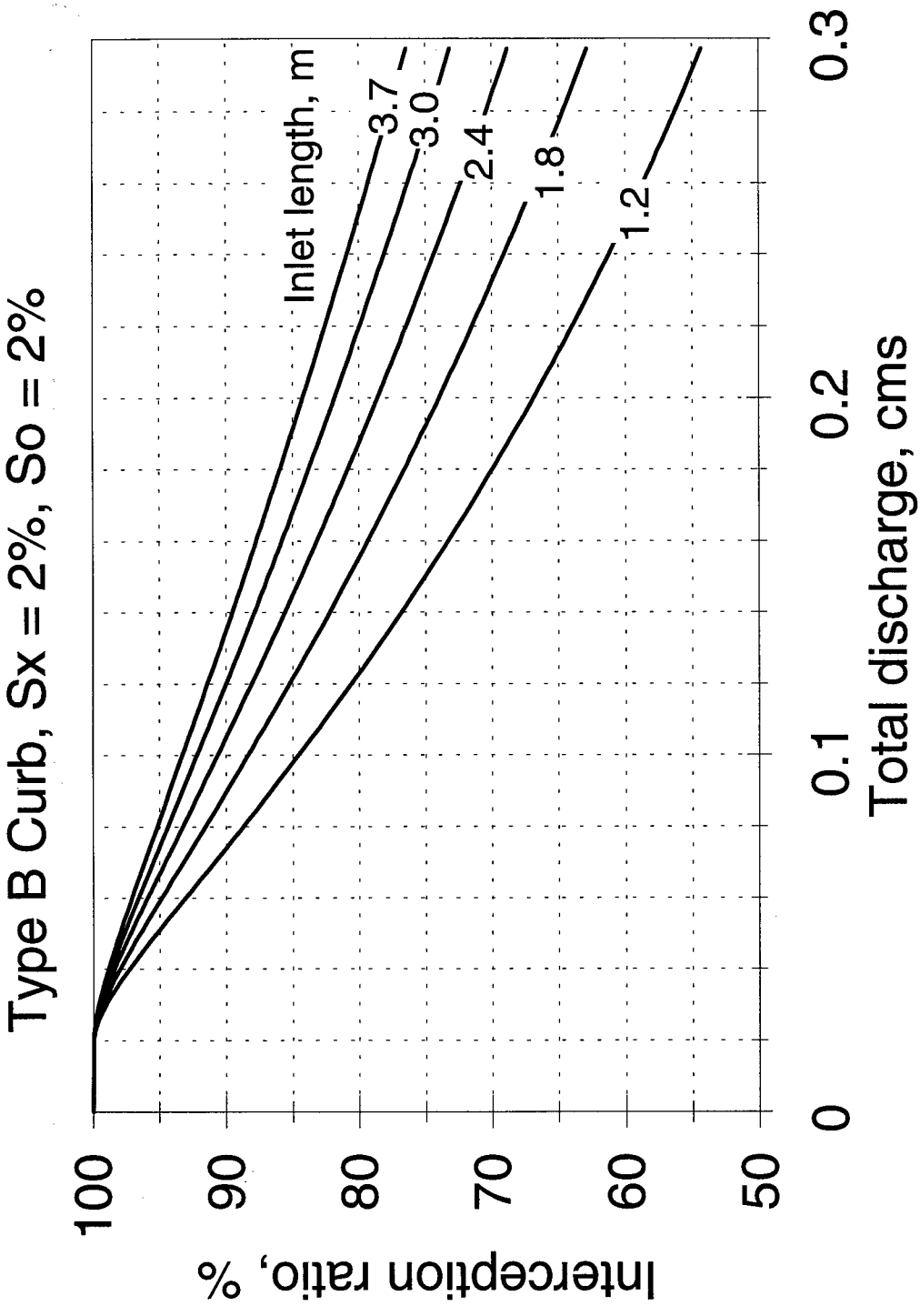

Type A Curb, Sx = 4%, So = 12%
Interception ratio, %
100
90
80
70
60
50
0
1
2
3
4
5
6
Total discharge, cfs
Inlet length, ft
12
10
8
6
4

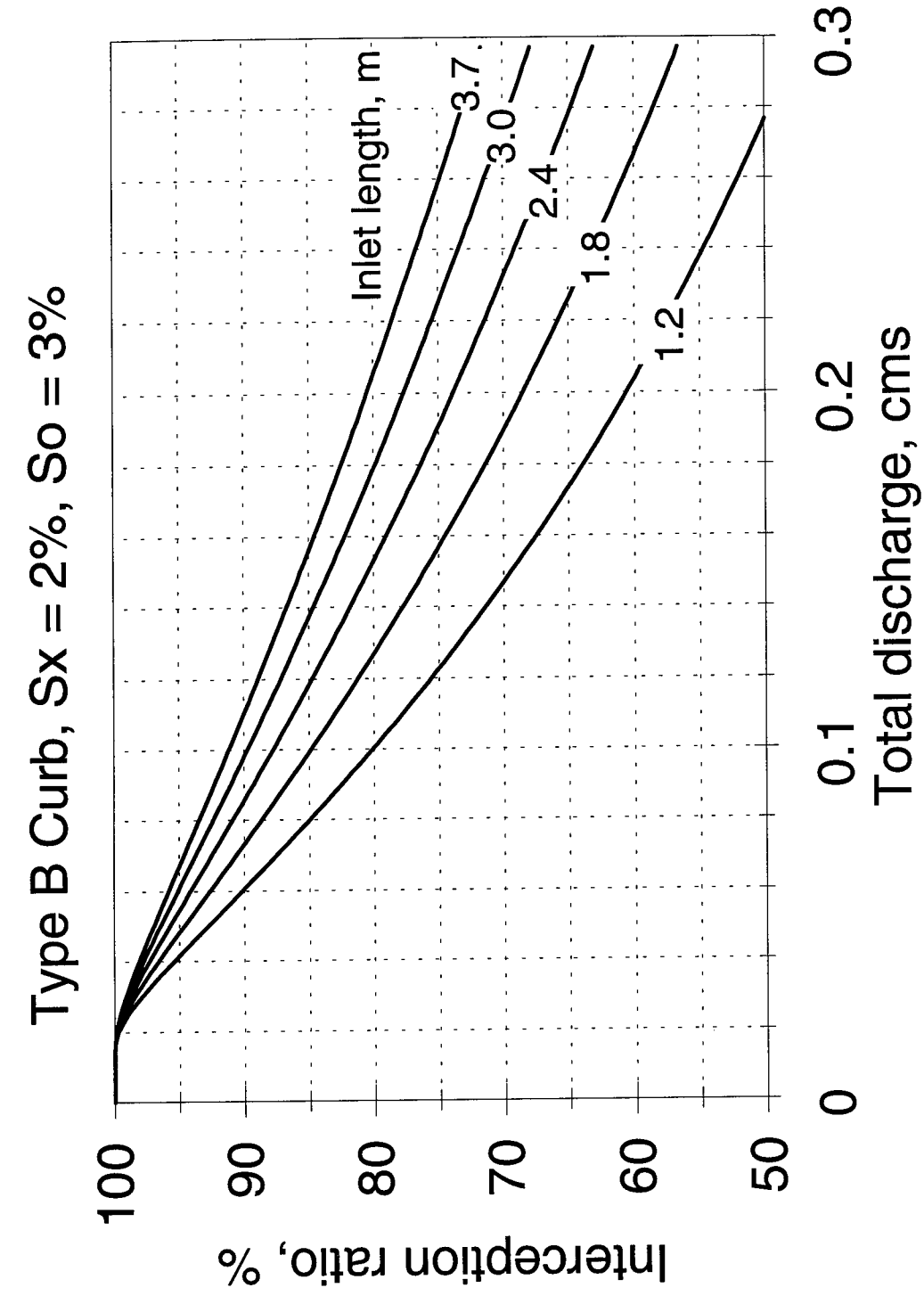
Appendix C

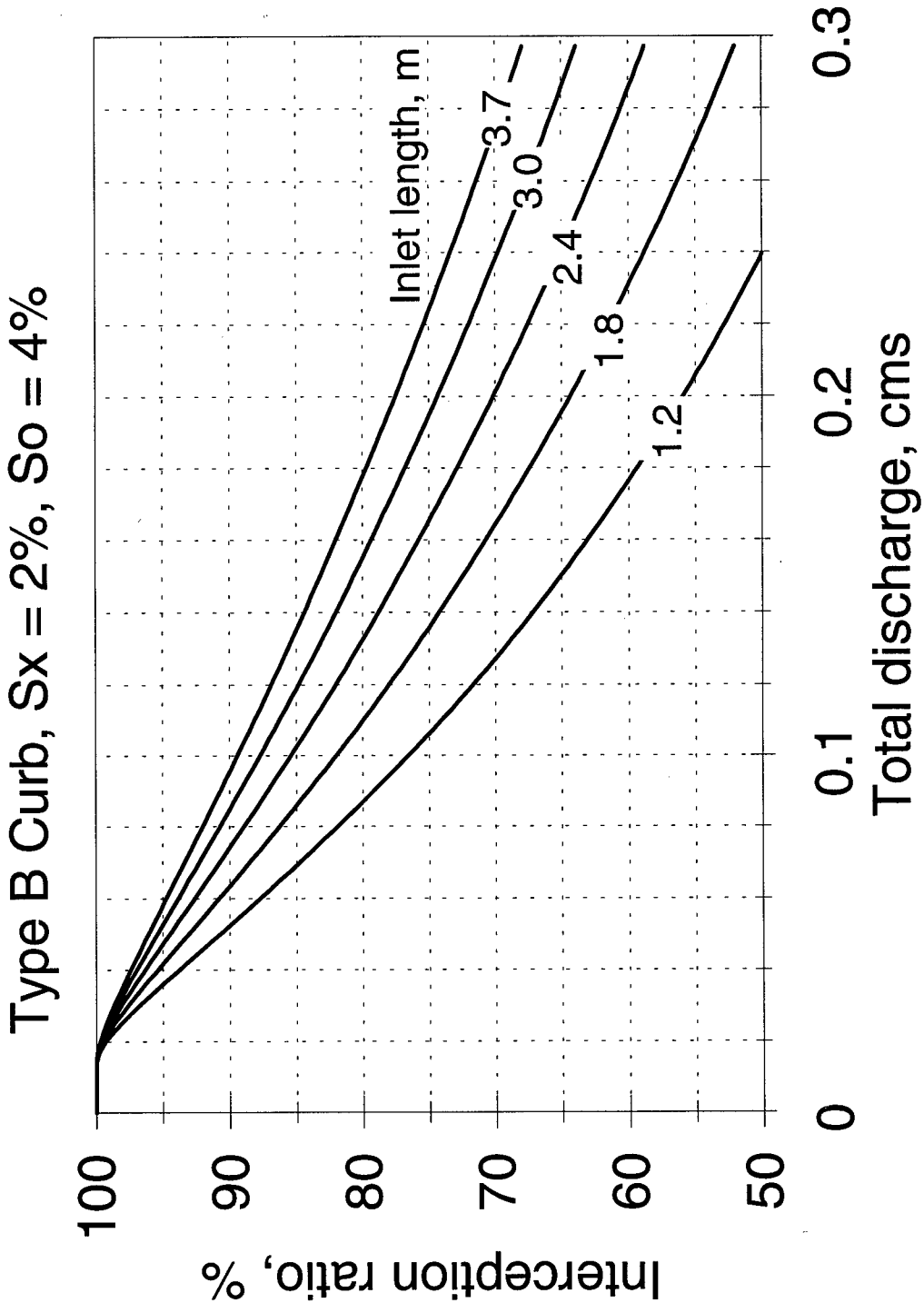
Hydraulic Design Charts in Metric Units

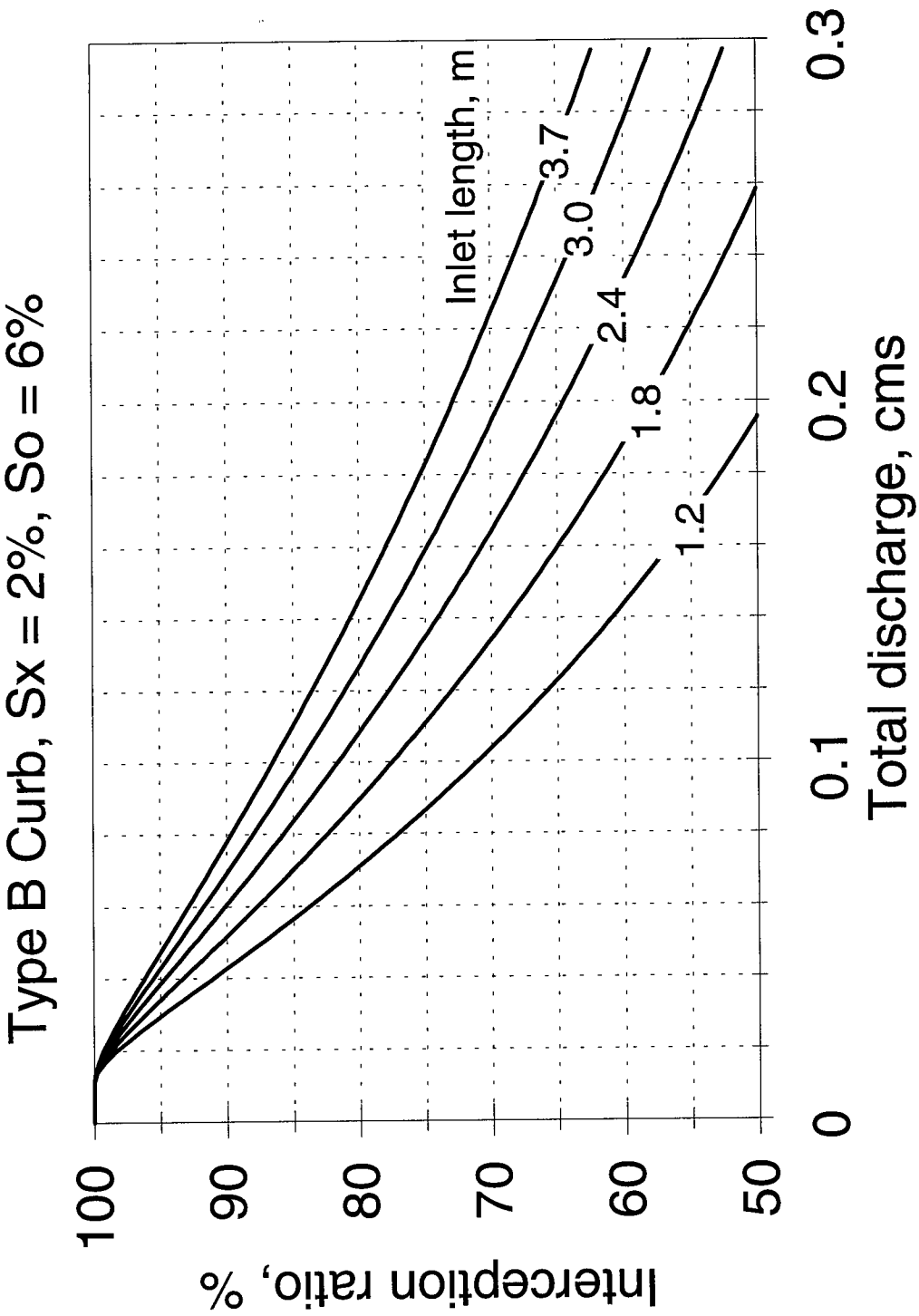

Type B Curb, Sx = 2%, So = 0.5%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

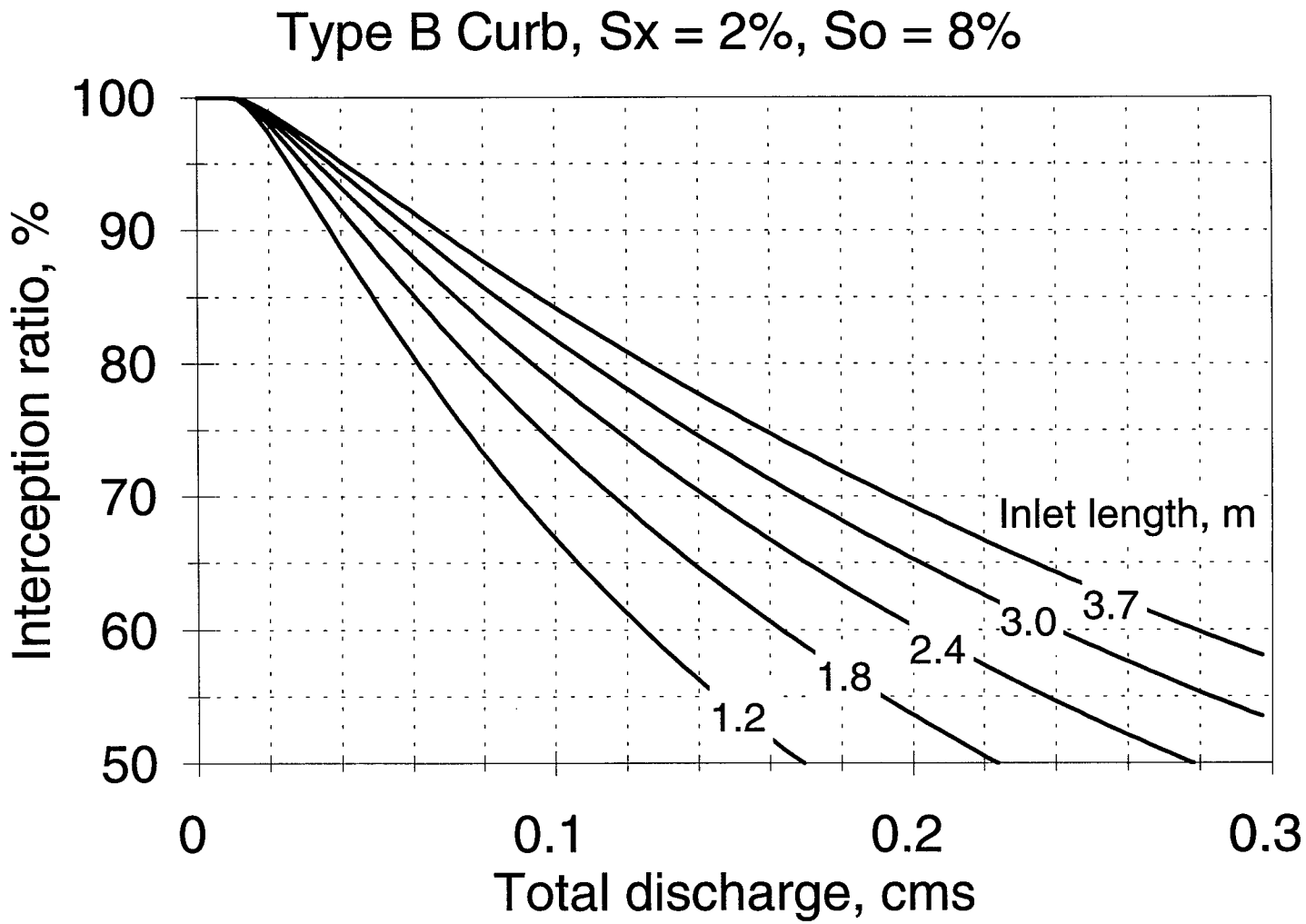

Type B Curb, Sx = 2%, So = 1%
Inlet length, m
3.7
3.0
2.4
1.8
1.2
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms

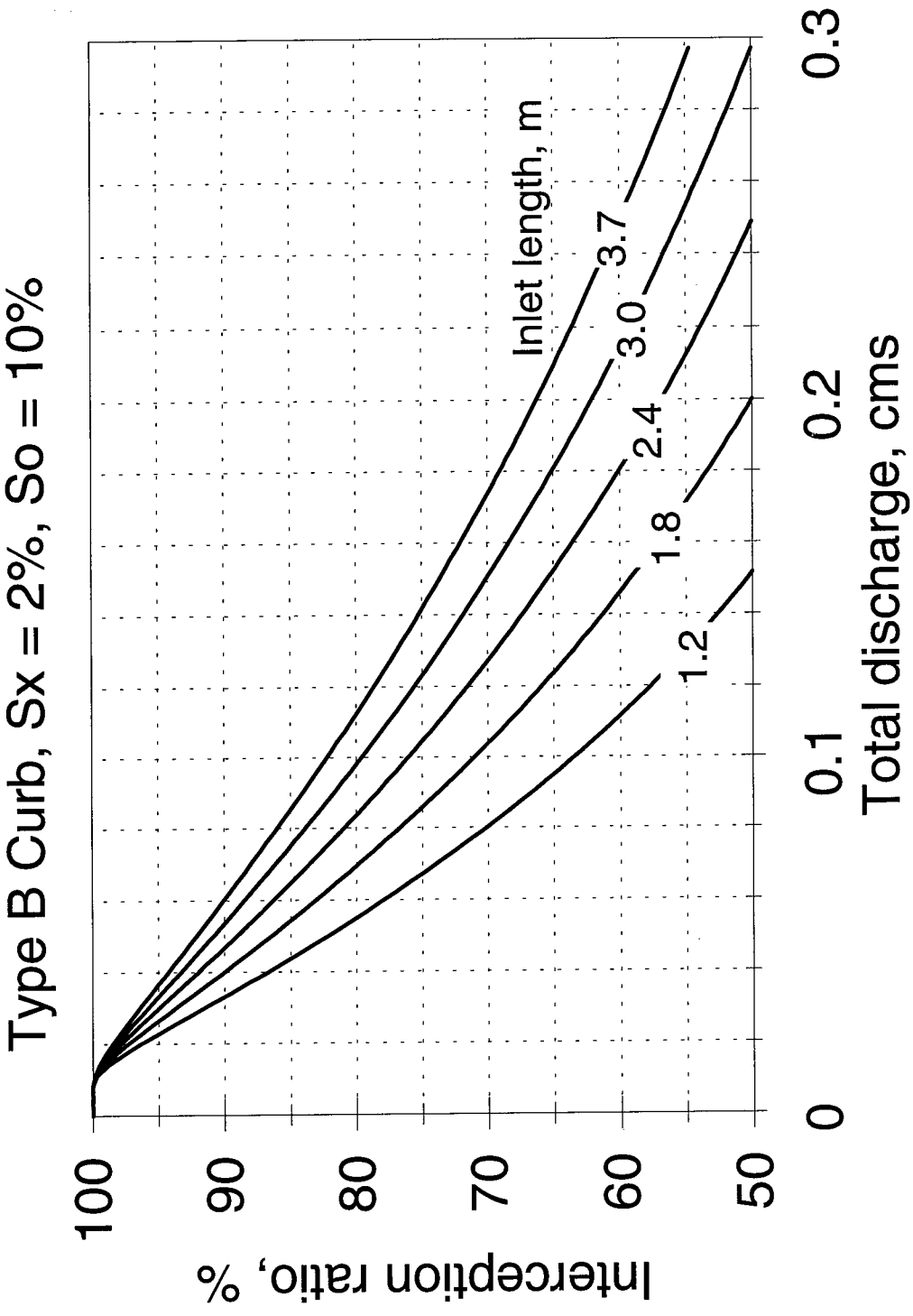

Type B Curb, Sx = 2%, So = 2%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

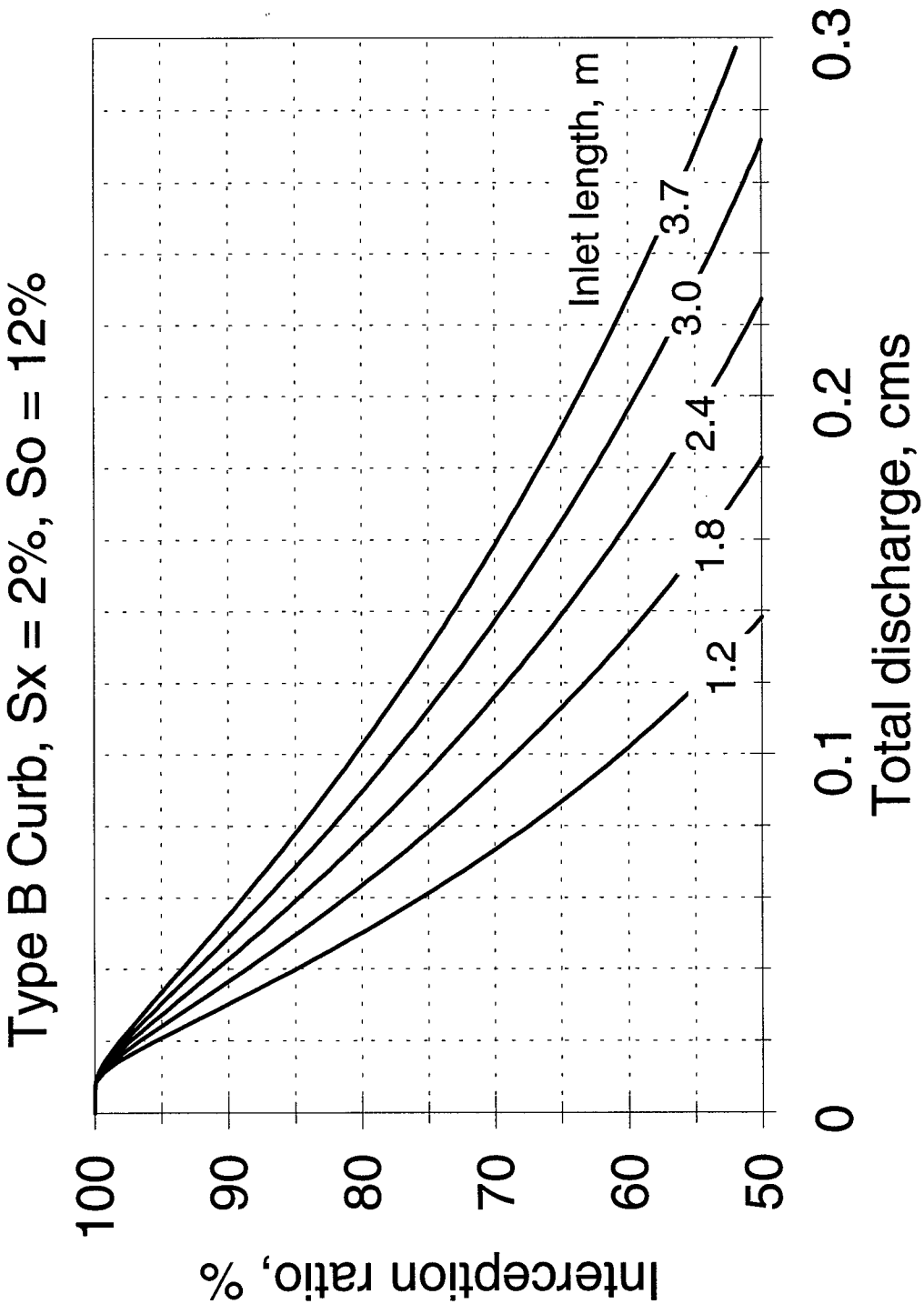

Type B Curb, Sx = 2%, So = 3%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

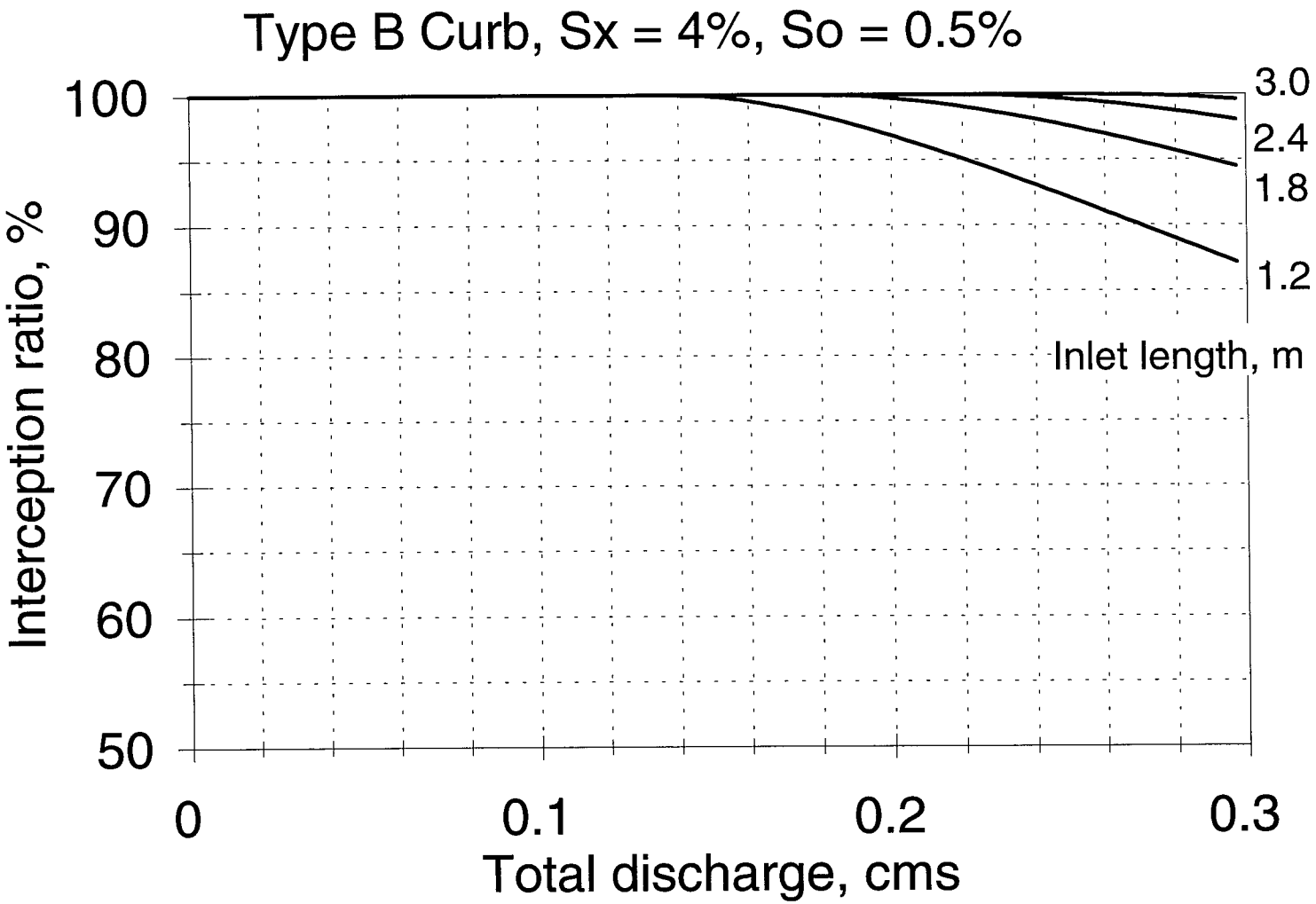

Type B Curb, Sx = 2%, So = 4%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

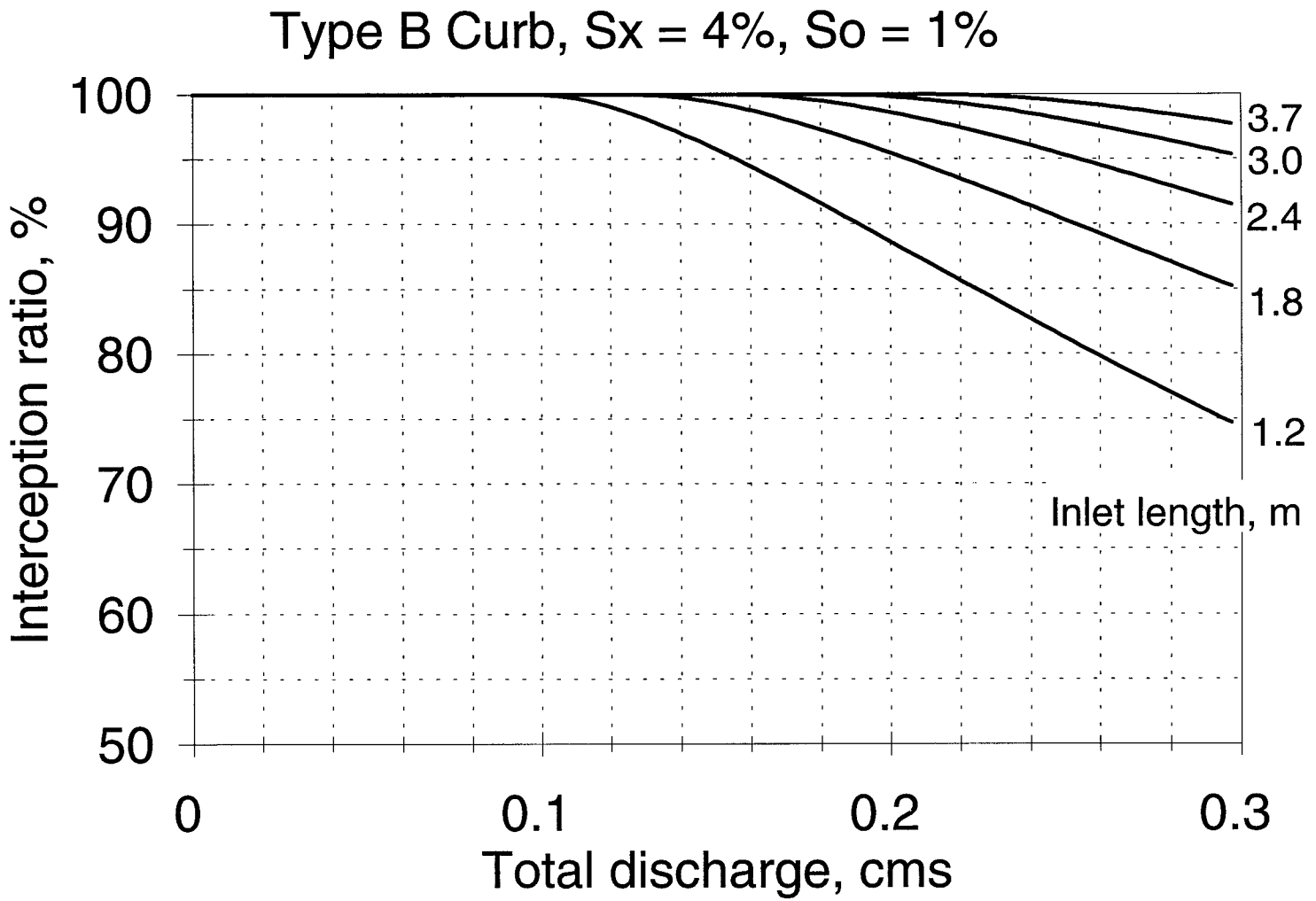

Type B Curb, Sx = 2%, So = 6%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

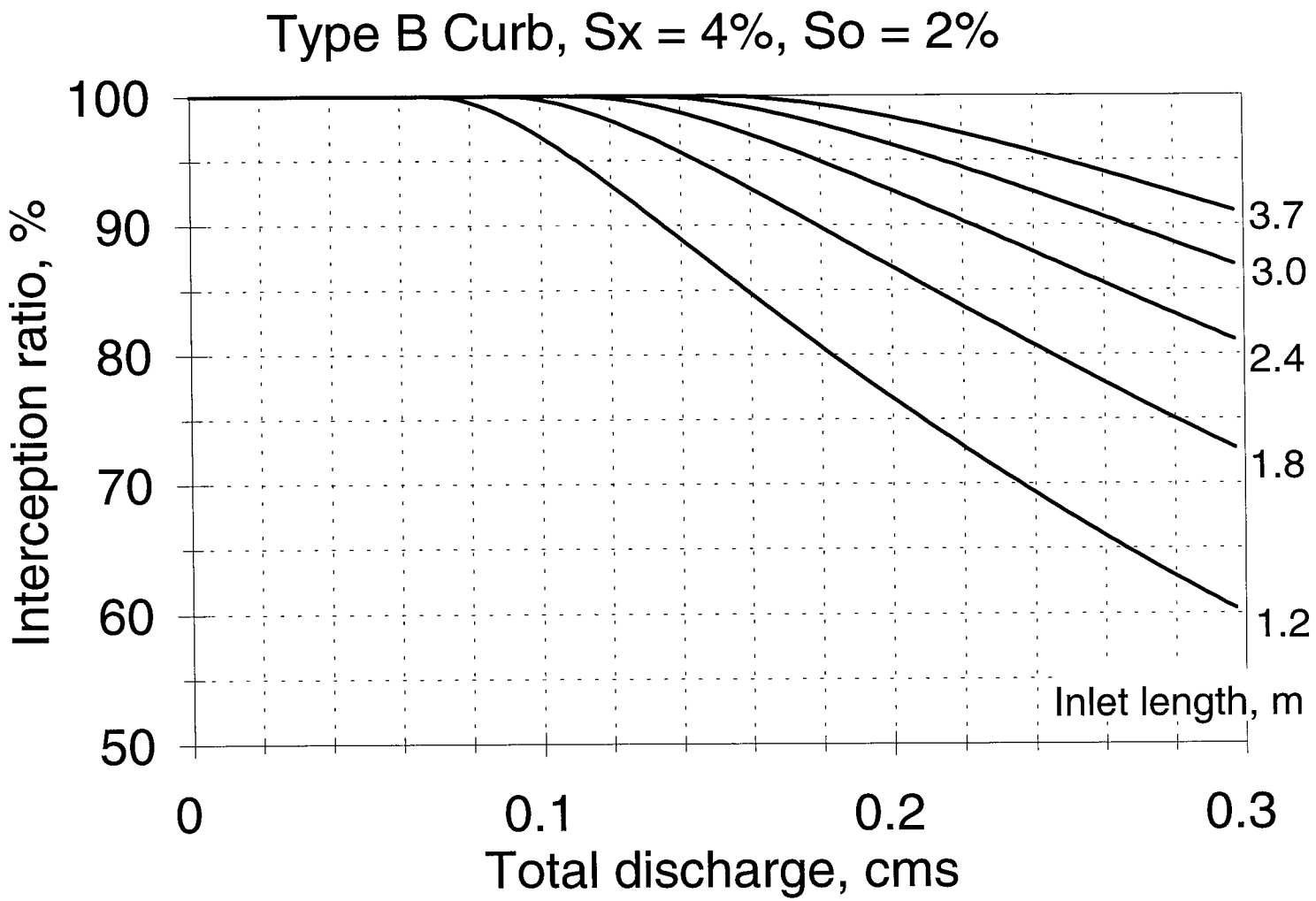

Type B Curb, Sx = 2%, So = 8%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

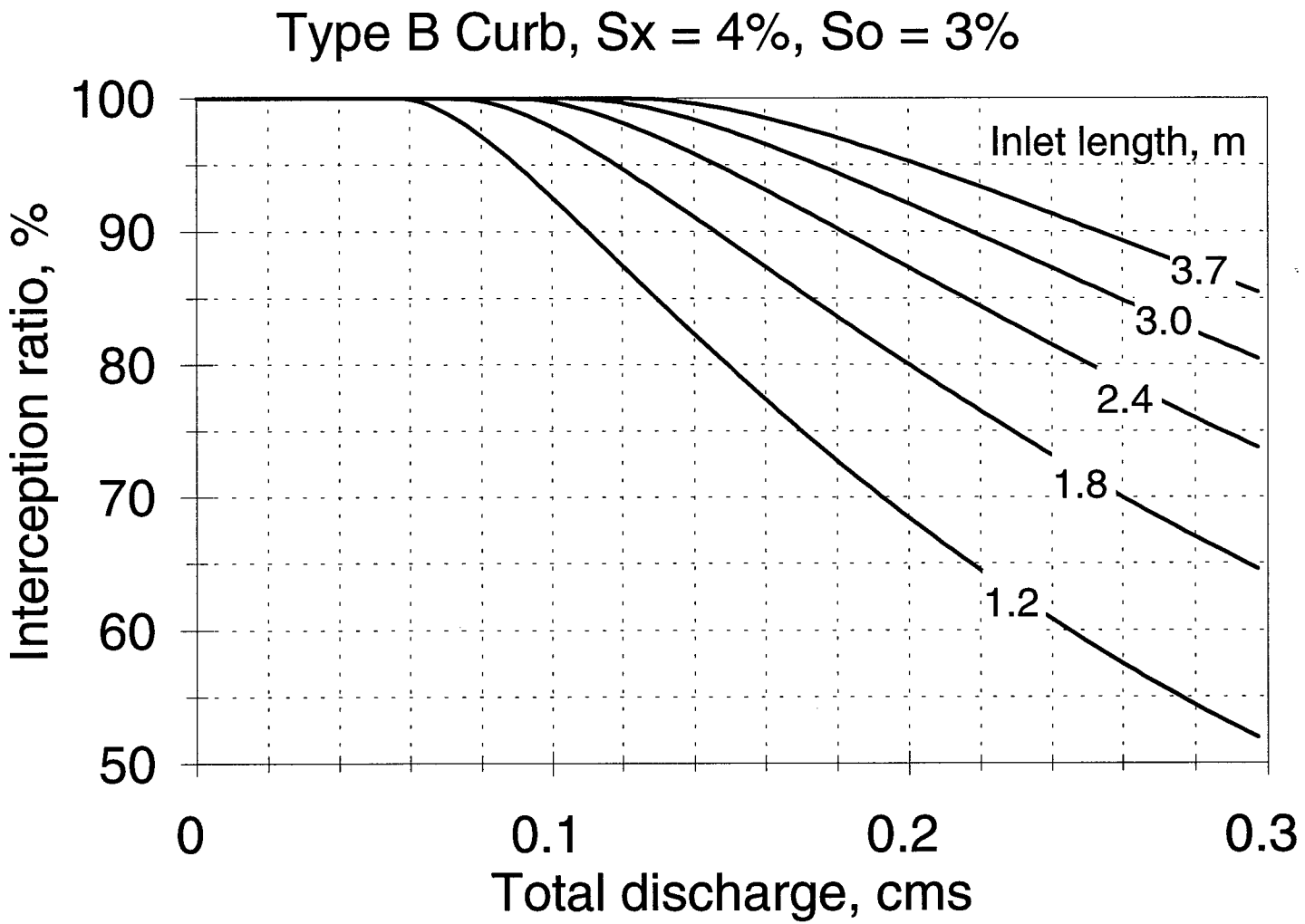

Type B Curb, Sx = 2%, So = 10%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
1.2
1.8
2.4
3.0
3.7

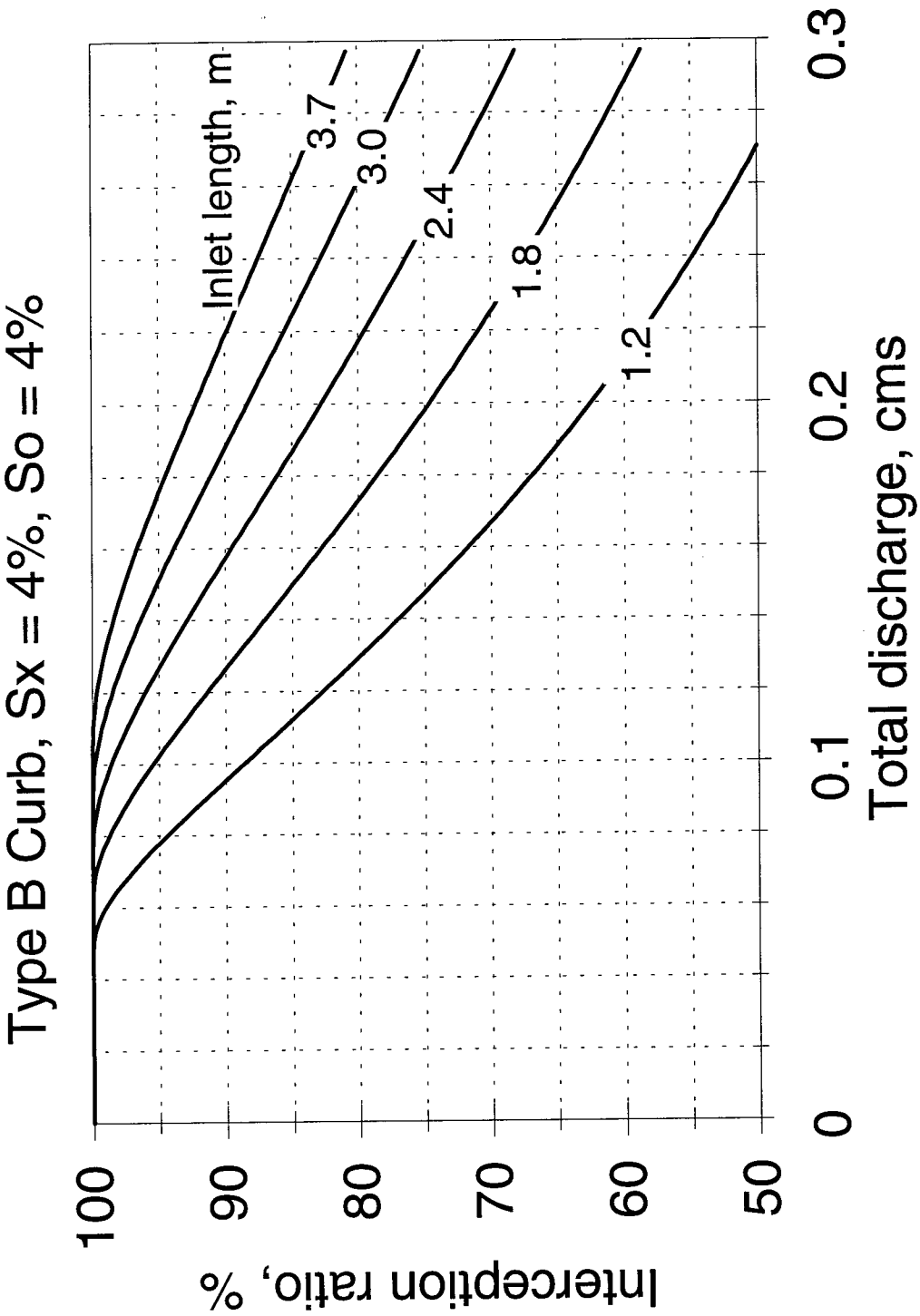

Type B Curb, Sx = 2%, So = 12%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
1.2
1.8
2.4
3.0
3.7

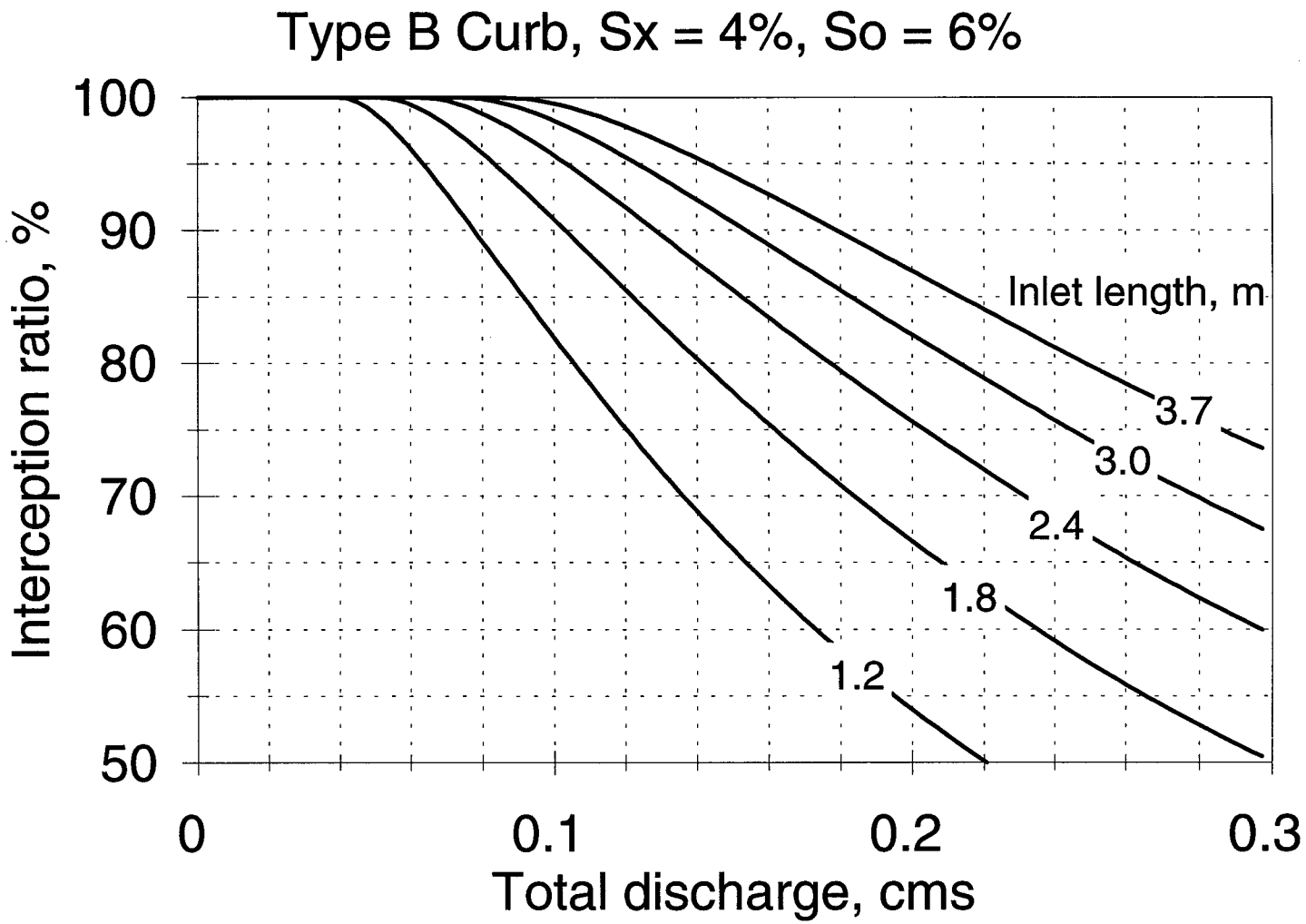

Type B Curb, Sx = 4%, So = 0.5%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
3.0
2.4
1.8
1.2
Inlet length, m

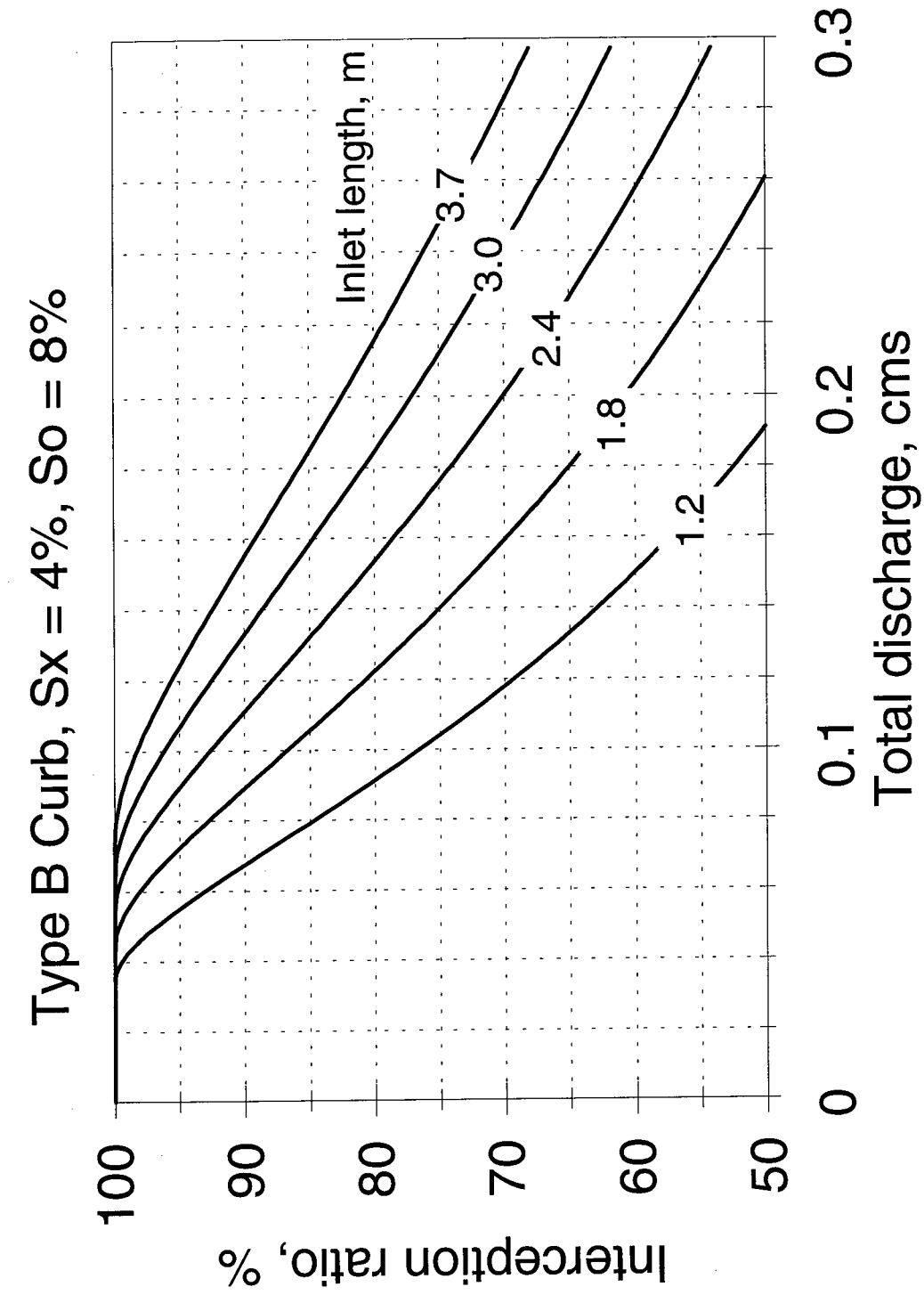

Type B Curb, Sx = 4%, So = 1%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
3.7
3.0
2.4
1.8
1.2
Inlet length, m

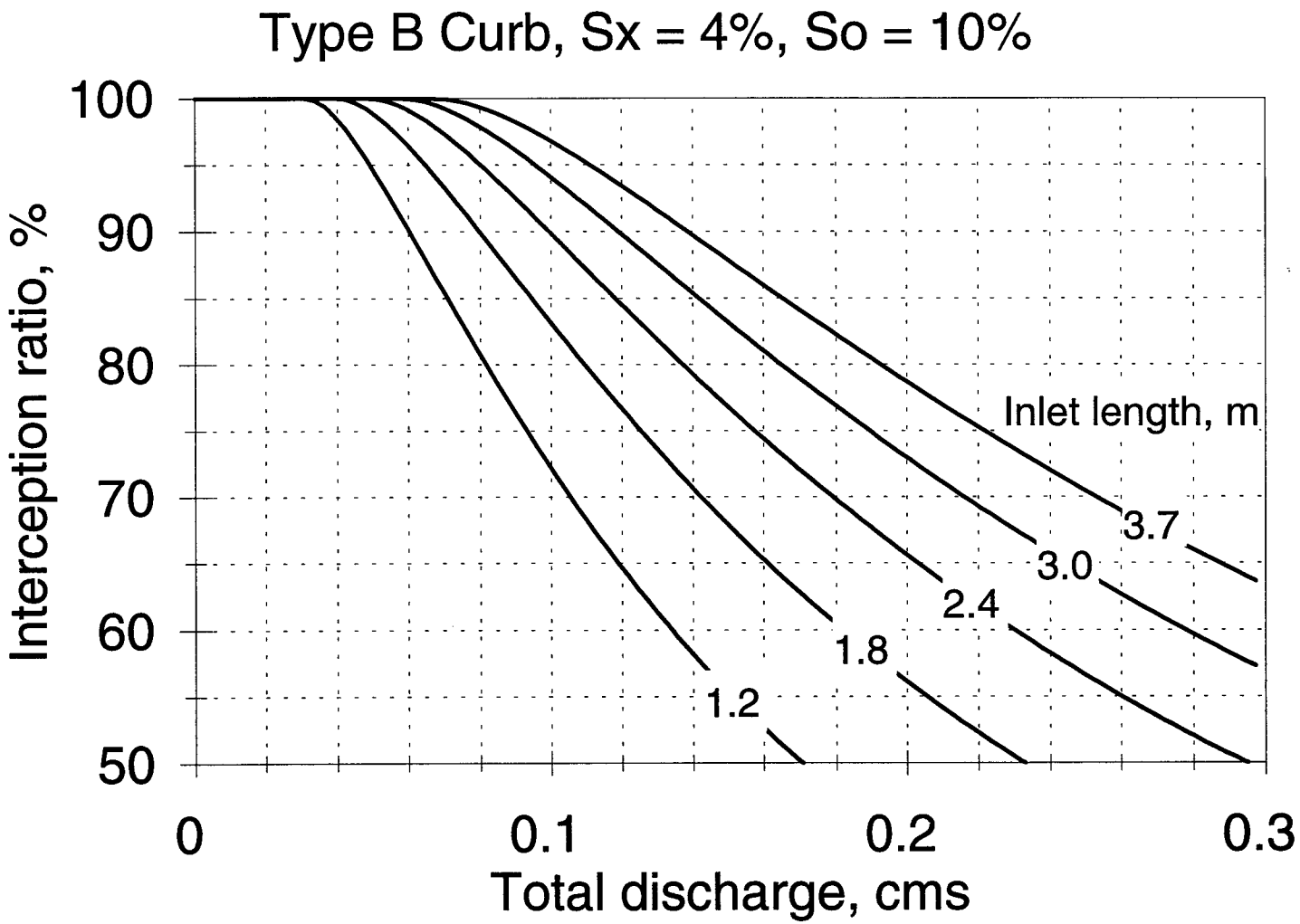

Type B Curb, Sx = 4%, So = 2%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
3.7
3.0
2.4
1.8
1.2
Inlet length, m

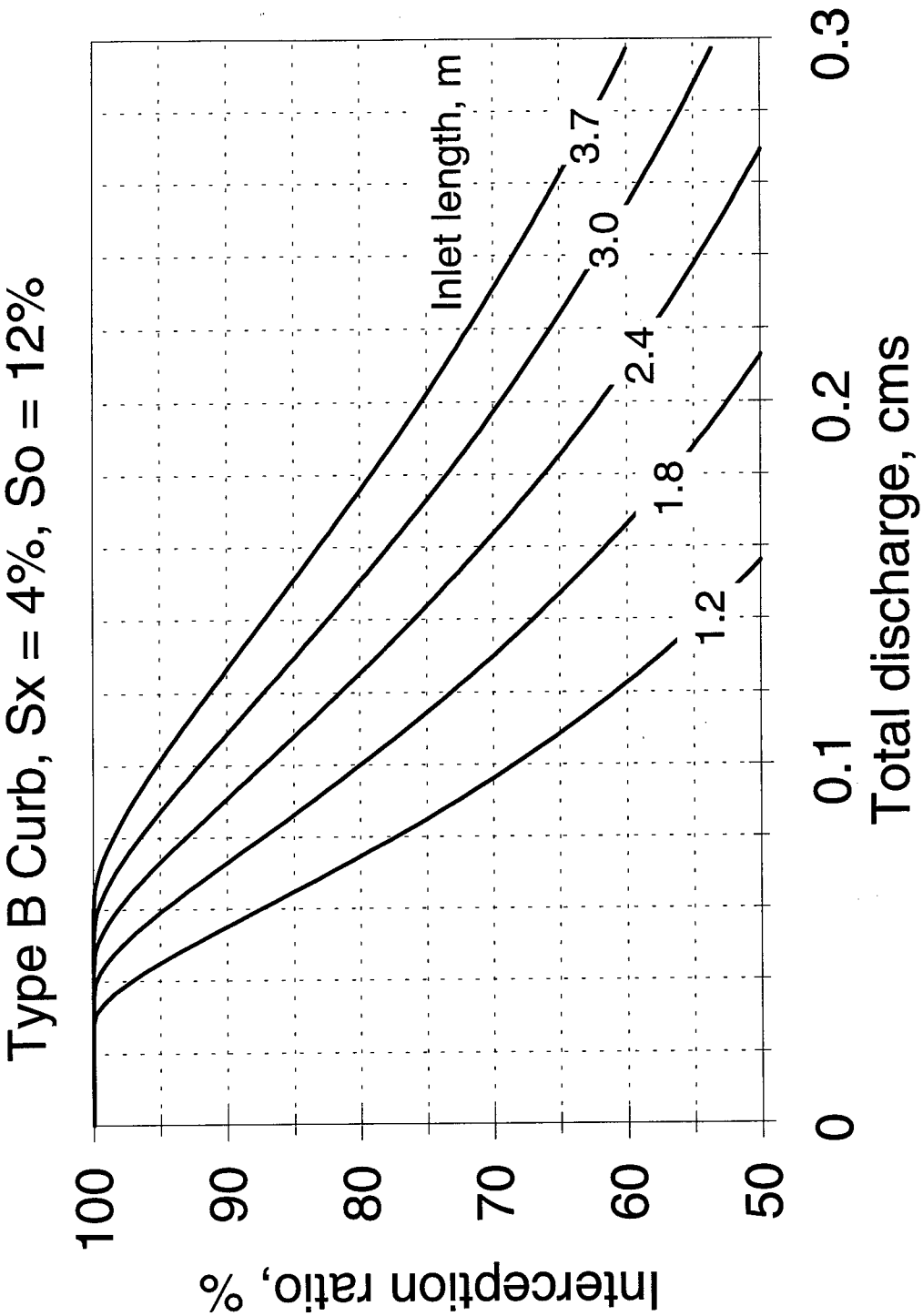

Type B Curb, Sx = 4%, So = 3%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2


Type B Curb, Sx = 4%, So = 4%
Inlet length, m
3.7
3.0
2.4
1.8
1.2
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms

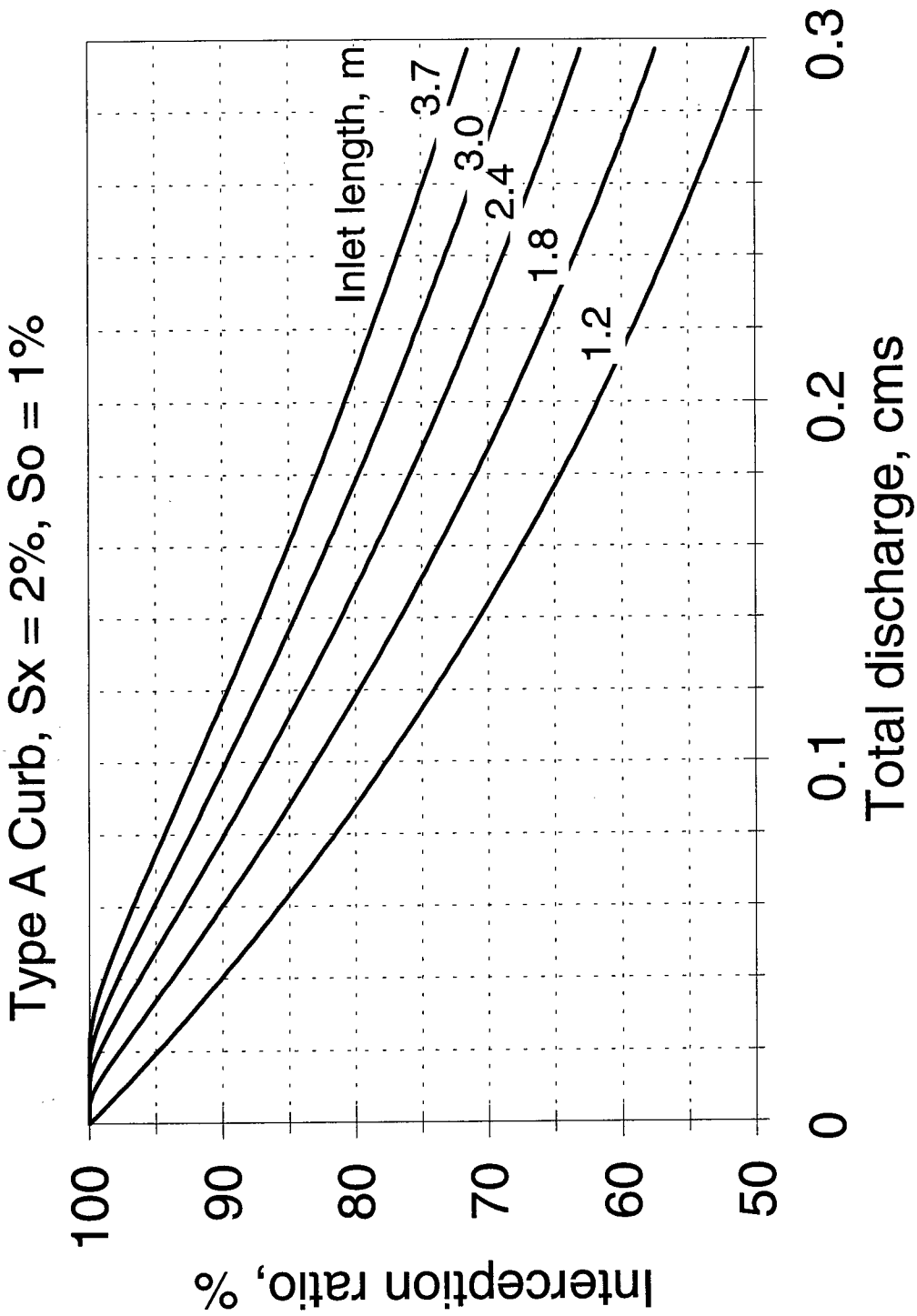

Type B Curb, Sx = 4%, So = 6%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

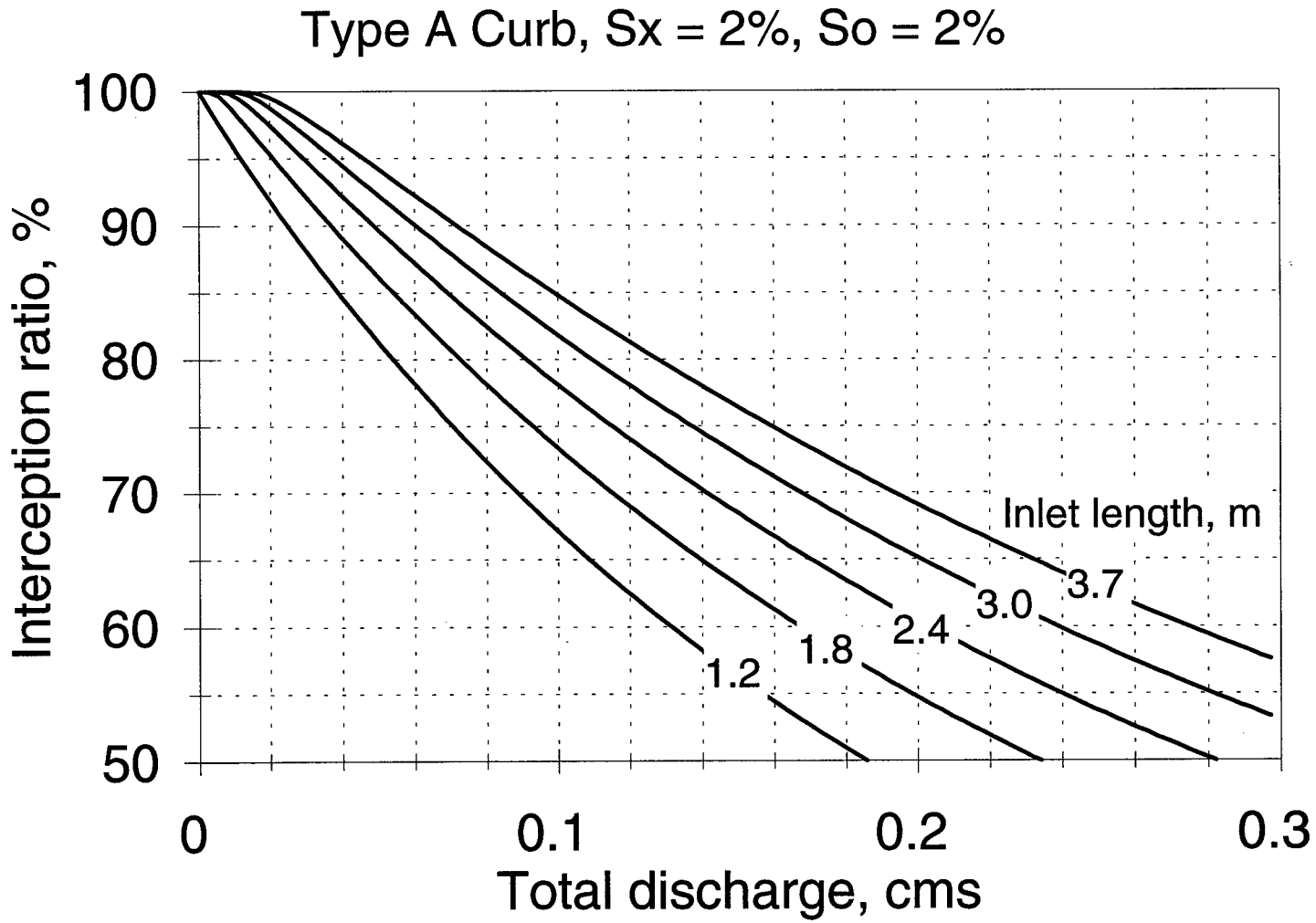

Type B Curb, Sx = 4%, So = 8%
Inlet length, m
3.7
3.0
2.4
1.8
1.2
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms

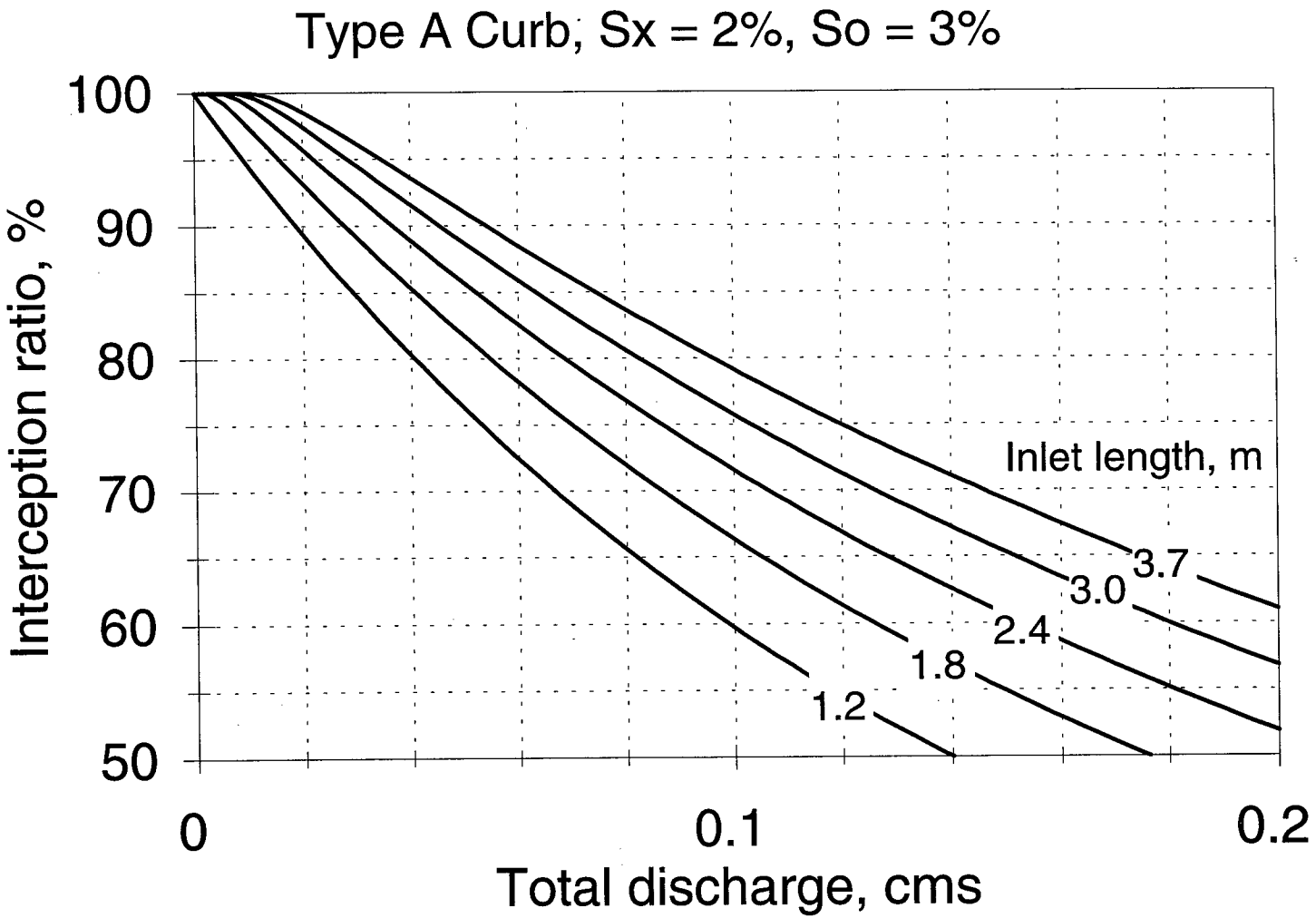

Type B Curb, Sx = 4%, So = 10%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

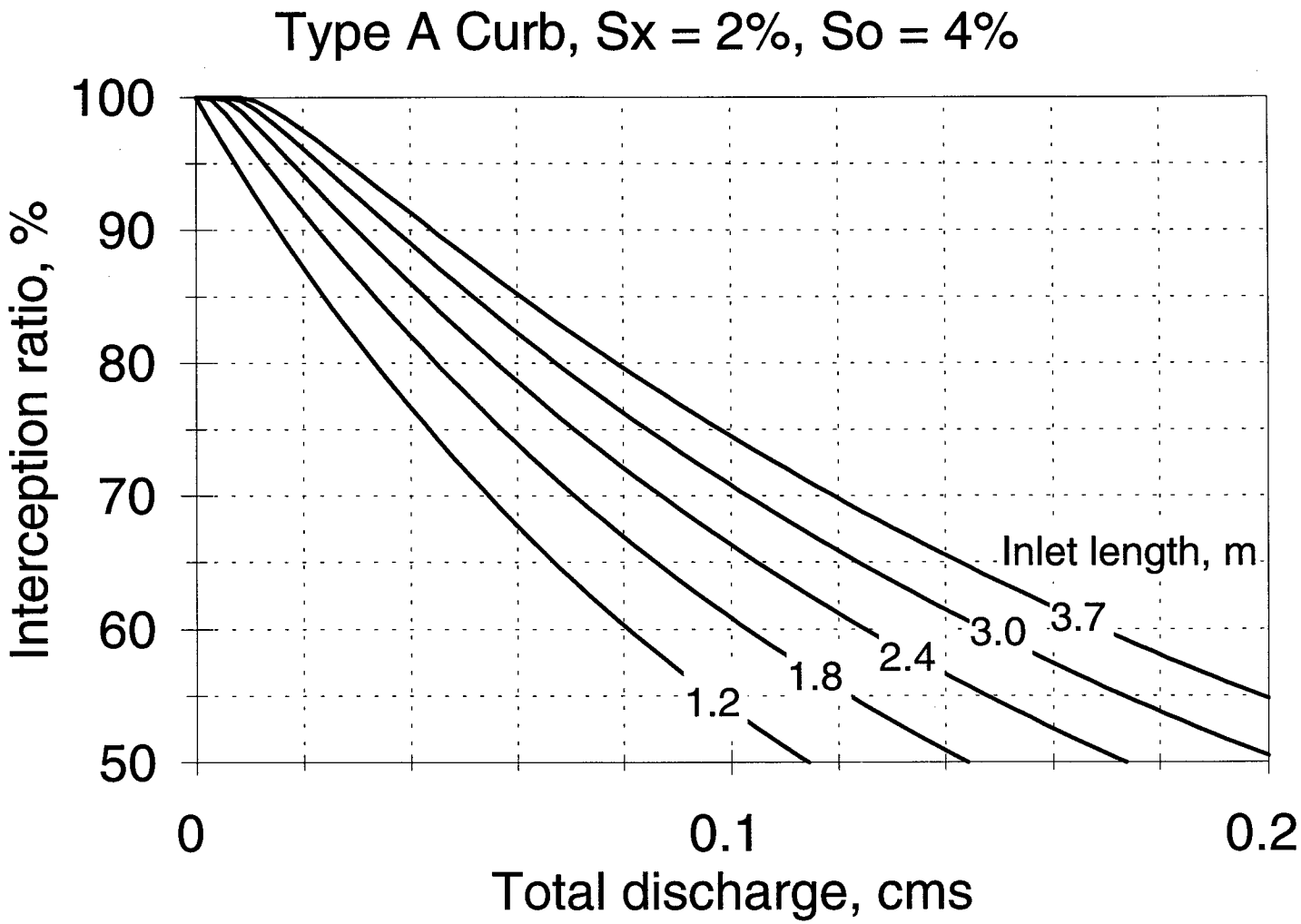

Type B Curb, Sx = 4%, So = 12%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

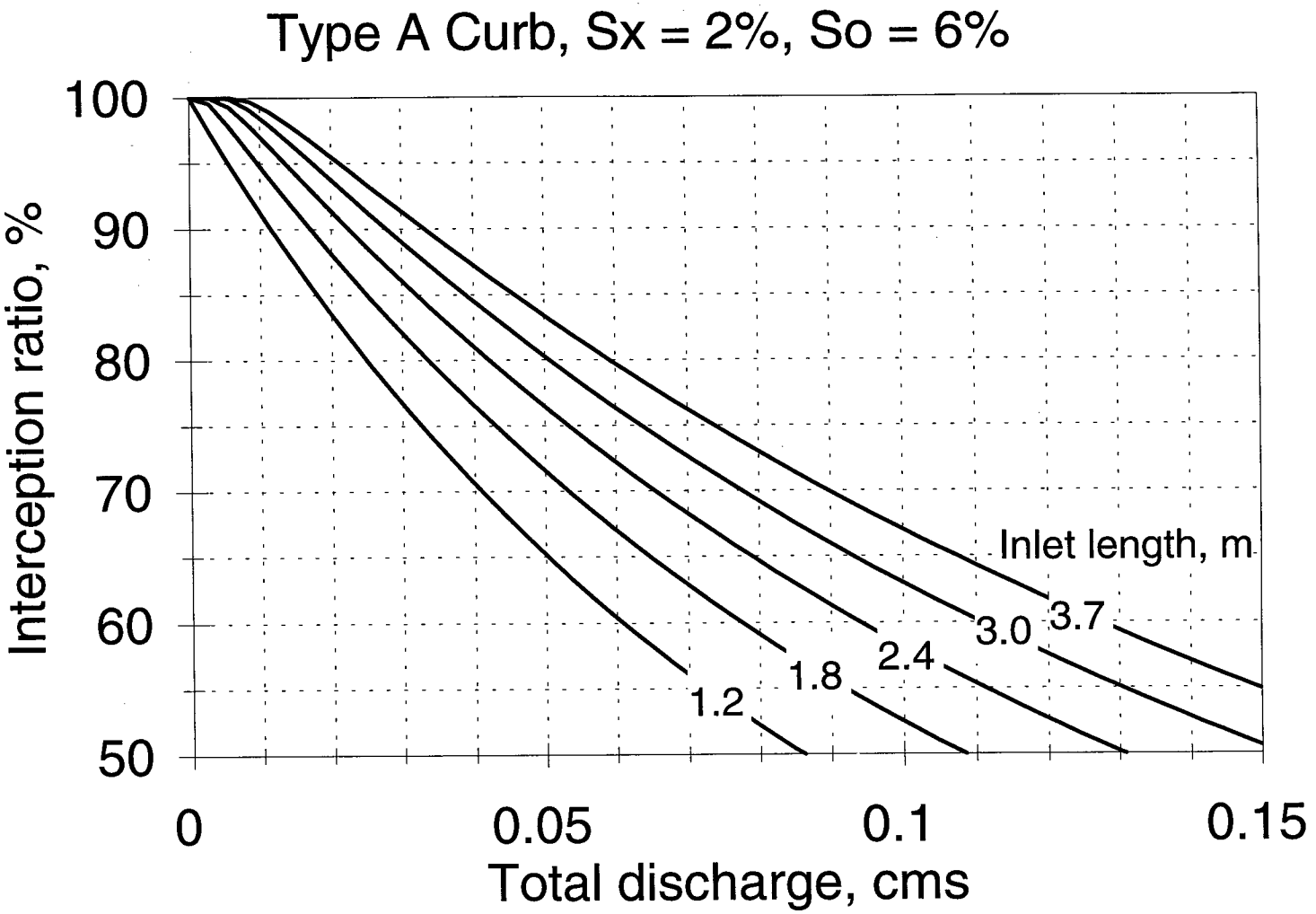

Type A Curb, Sx = 2%, So = 0.5%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

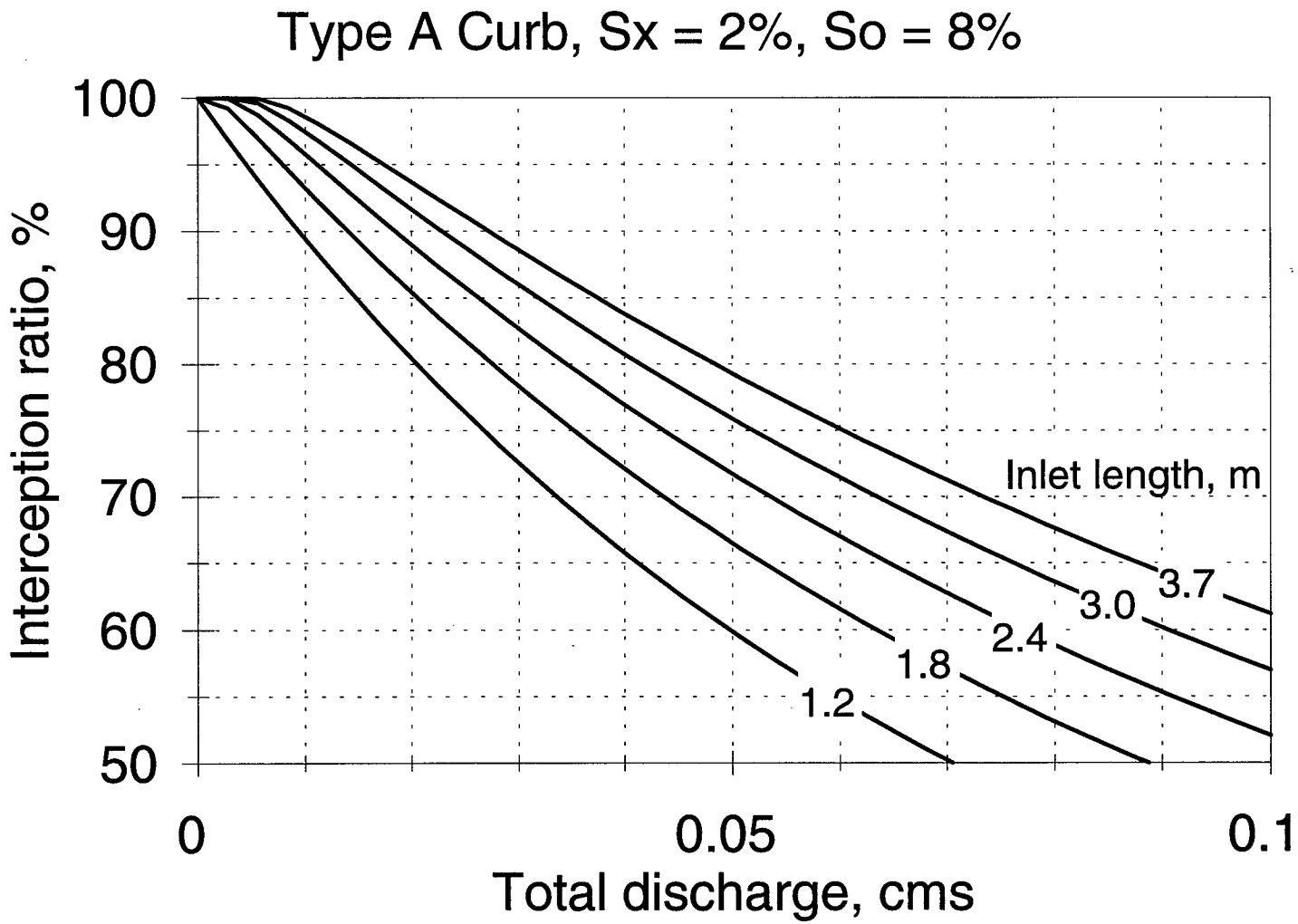

Type A Curb, Sx = 2%, So = 1%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

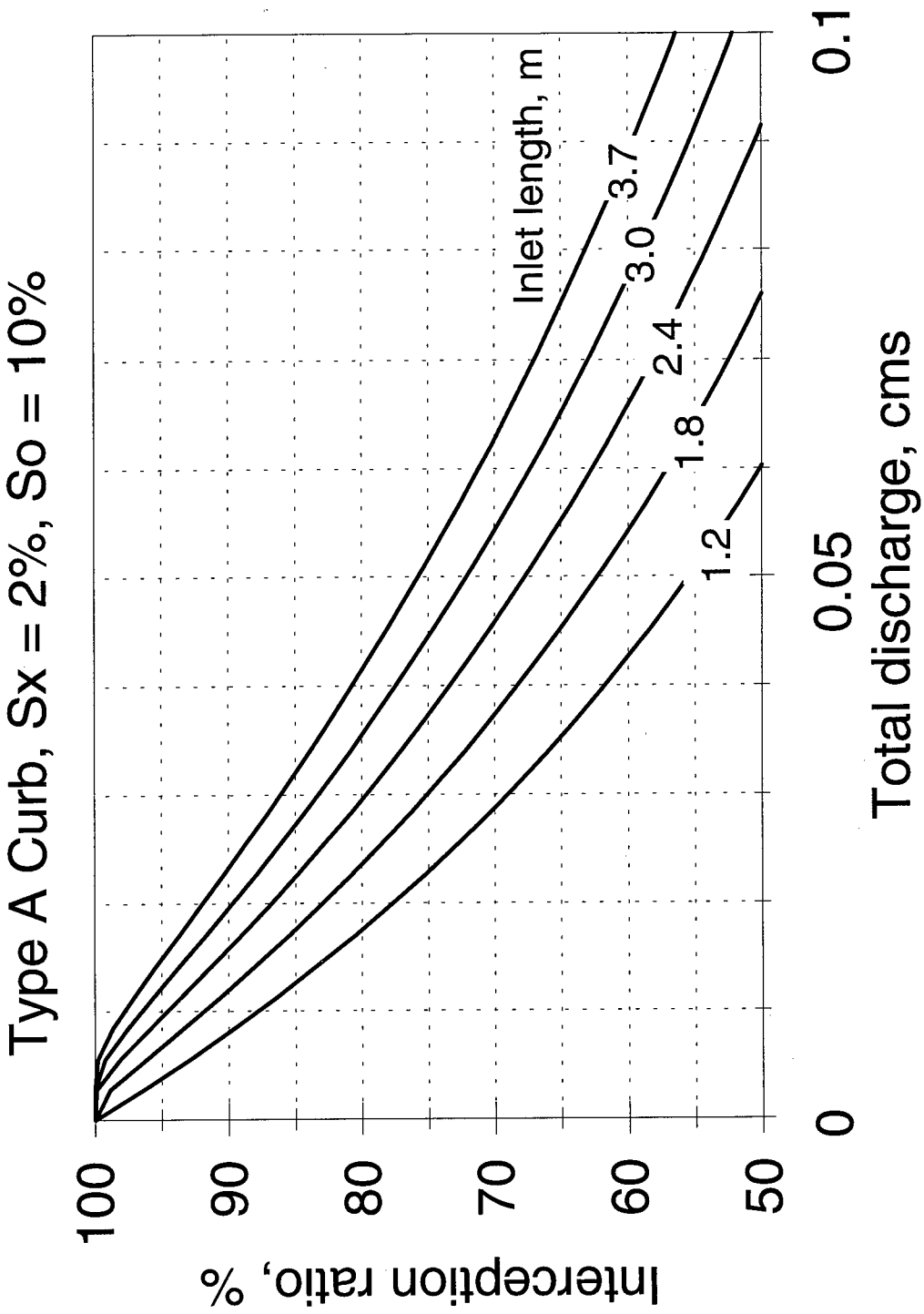

Type A Curb, Sx = 2%, So = 2%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

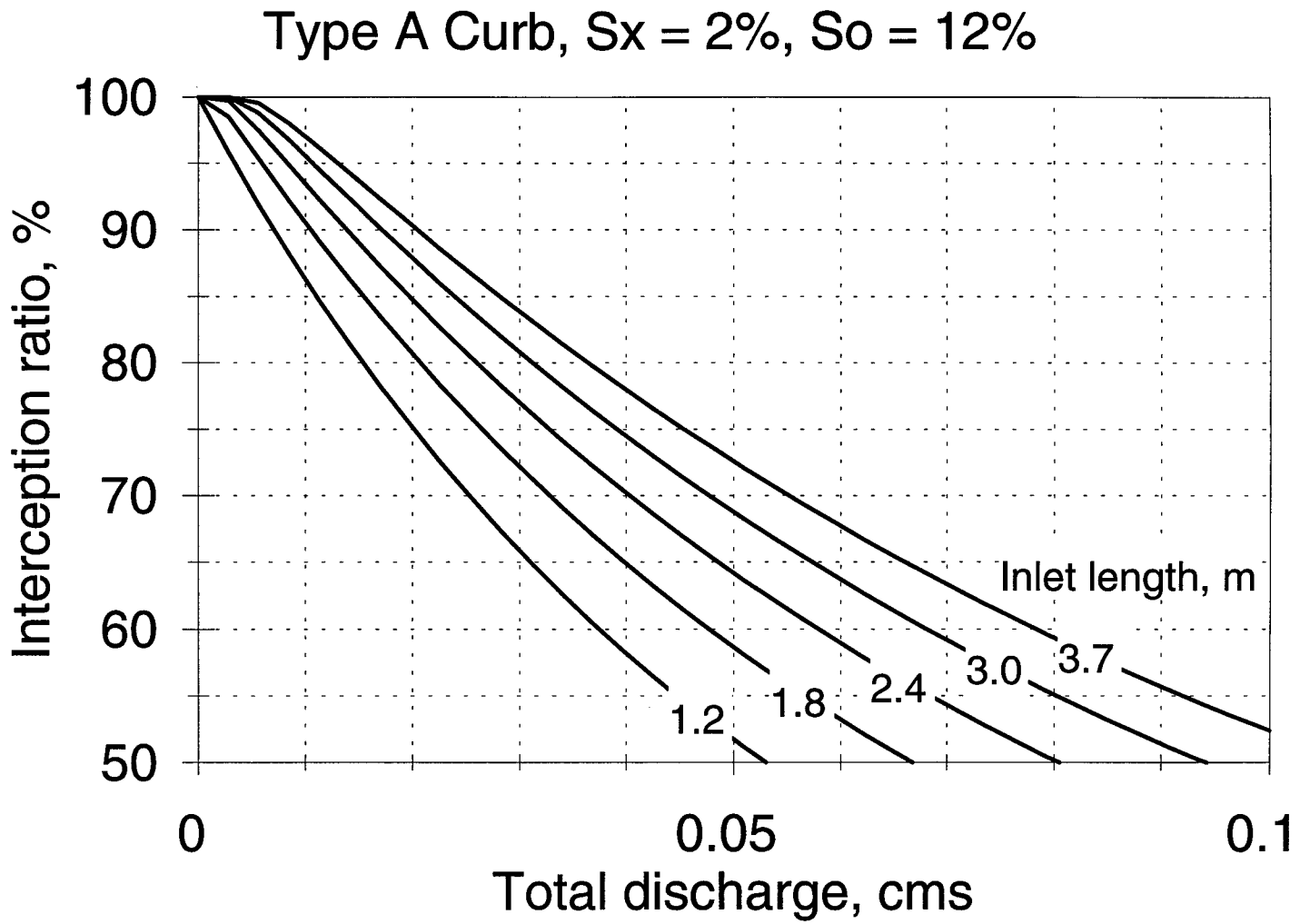

Type A Curb; Sx = 2%, So = 3%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

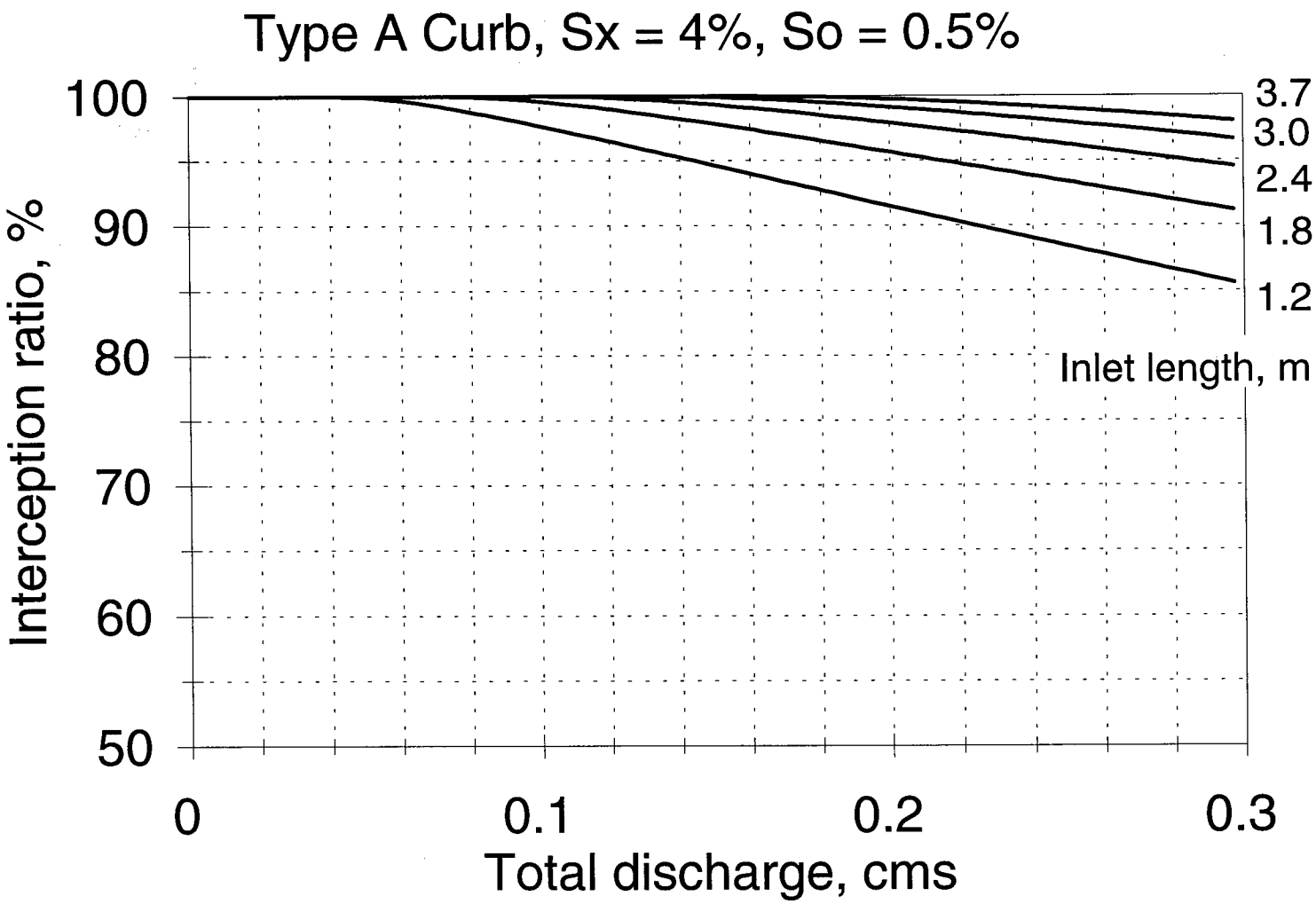

Type A Curb, Sx = 2%, So = 4%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
Total discharge, cms
Inlet length, m
1.2
1.8
2.4
3.0
3.7

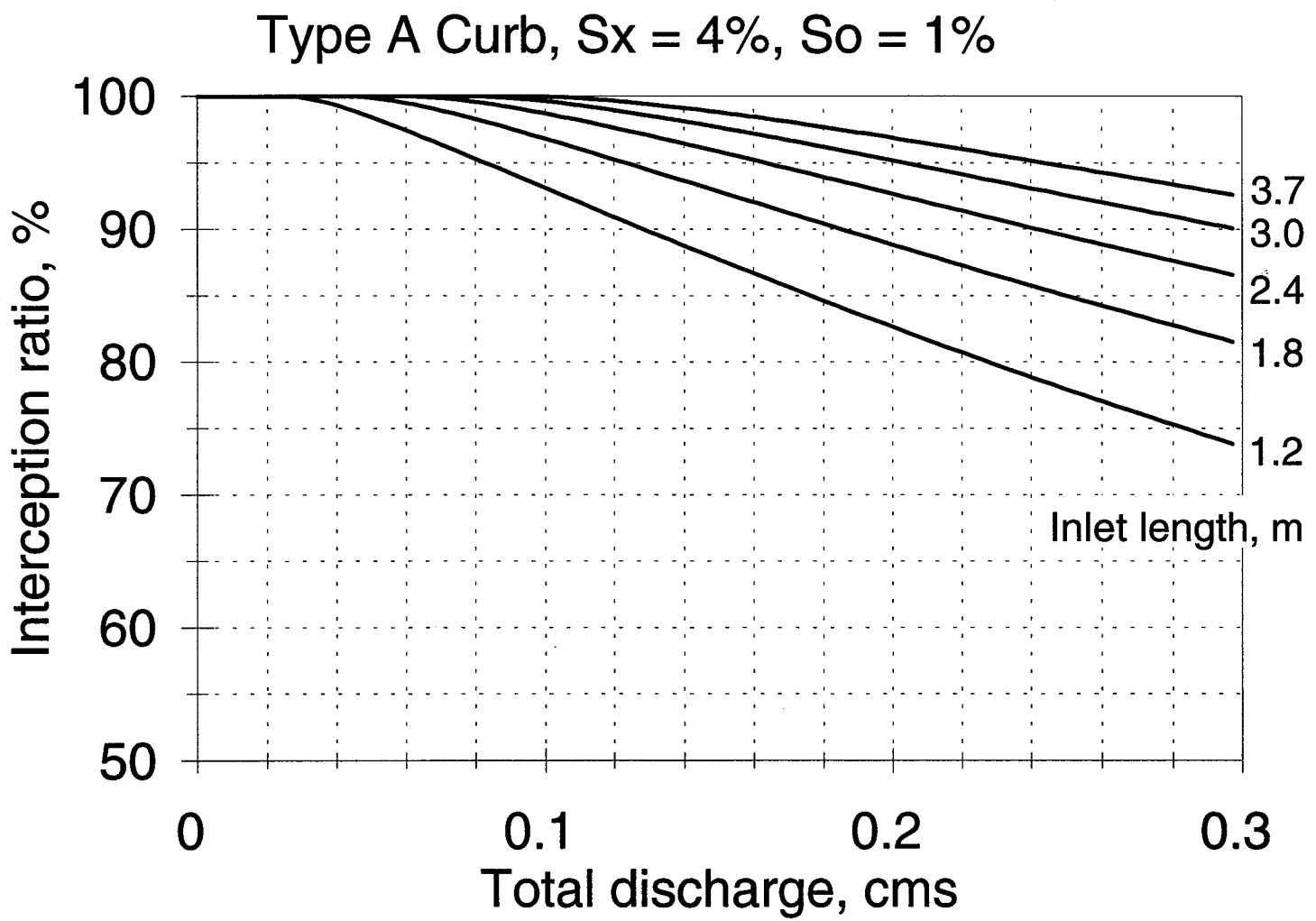

Type A Curb, Sx = 2%, So = 6%
Interception ratio, %
100
90
80
70
60
50
0
0.05
0.1
0.15
Total discharge, cms
Inlet length, m
1.2
1.8
2.4
3.0
3.7

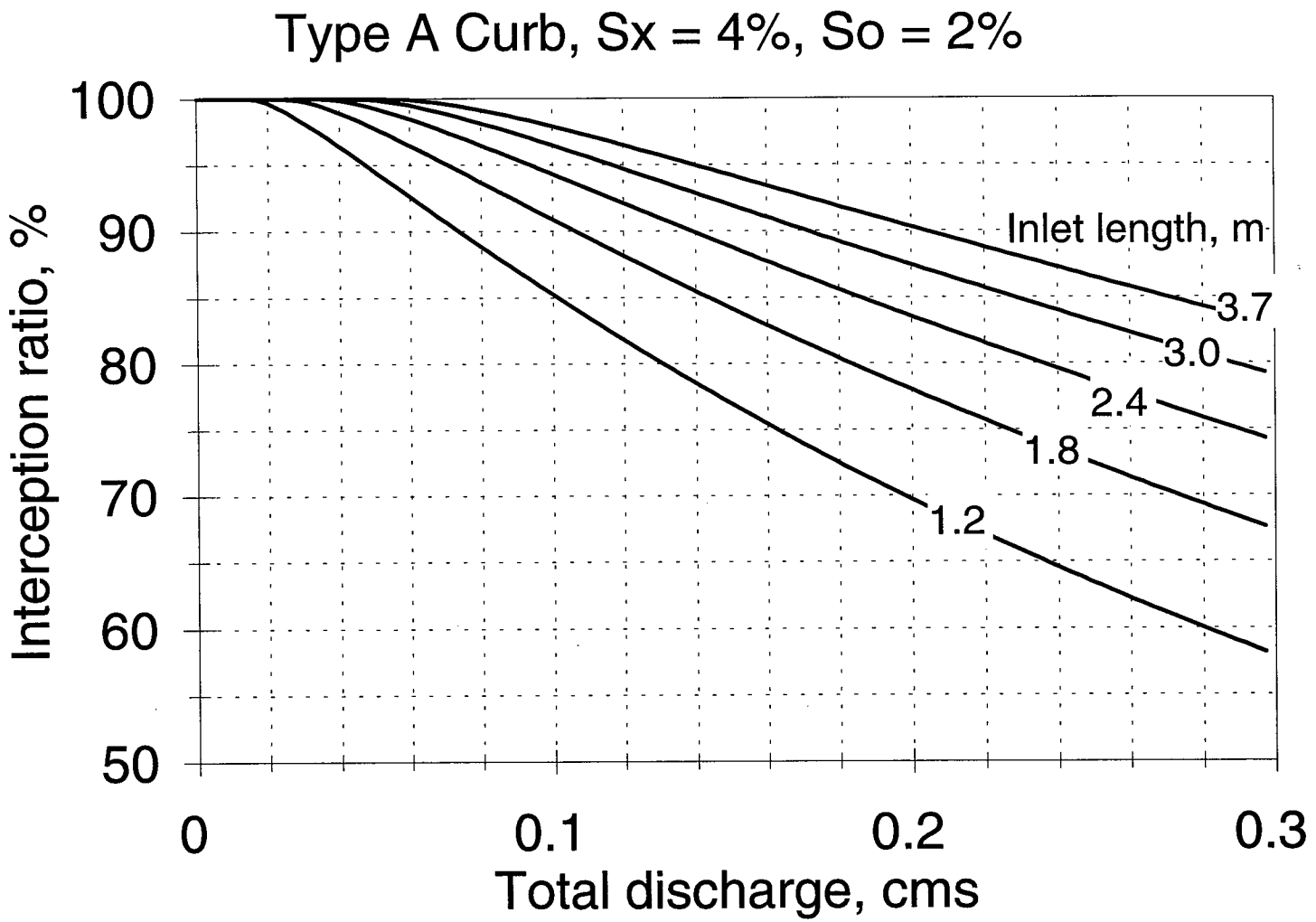

Type A Curb, Sx = 2%, So = 8%
Interception ratio, %
100
90
80
70
60
50
0
0.05
0.1
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

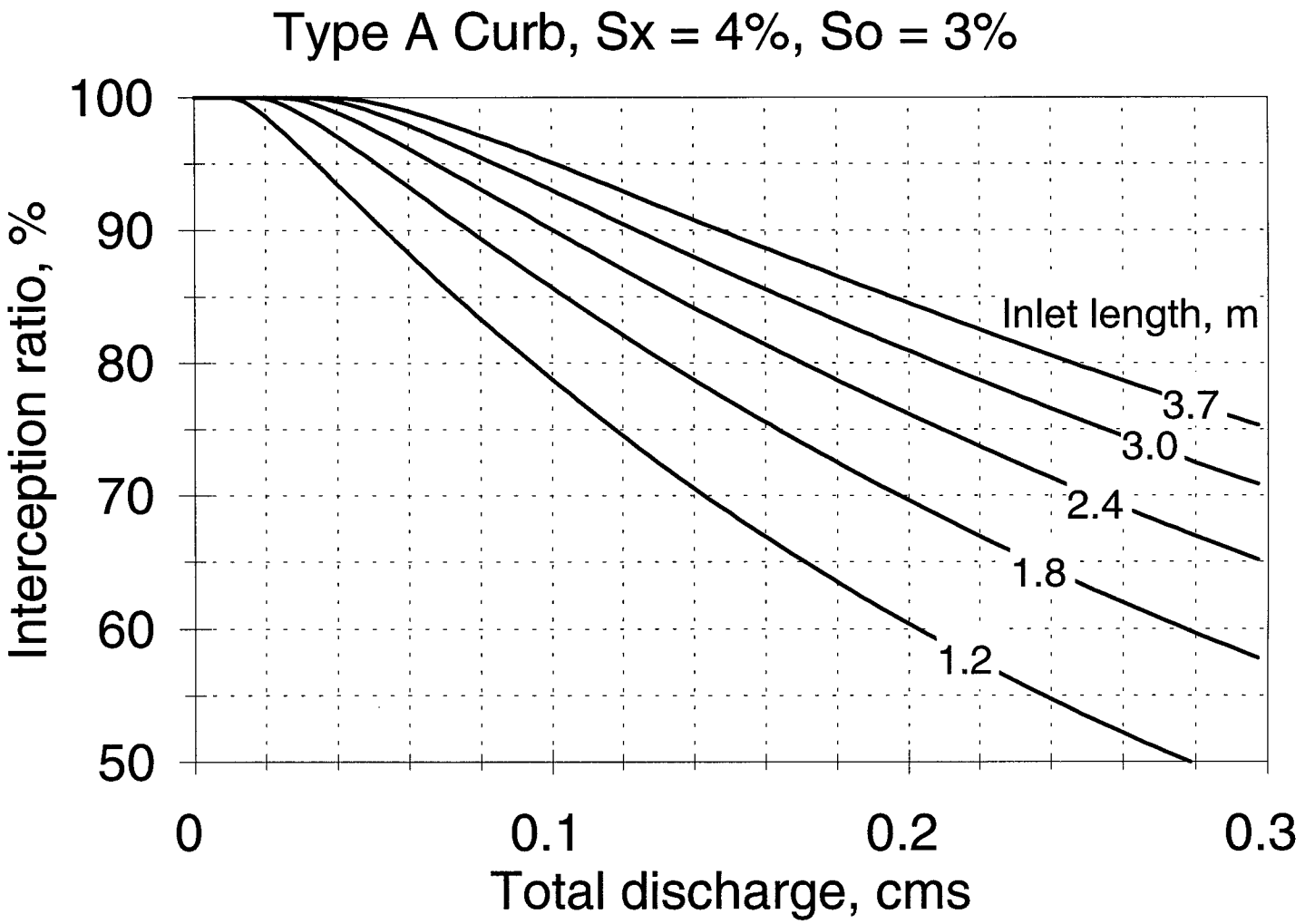

Type A Curb, Sx = 2%, So = 10%
Inlet length, m
3.7
3.0
2.4
1.8
1.2
100
90
80
70
60
50
Interception ratio, %
0
0.05
0.1
Total discharge, cms

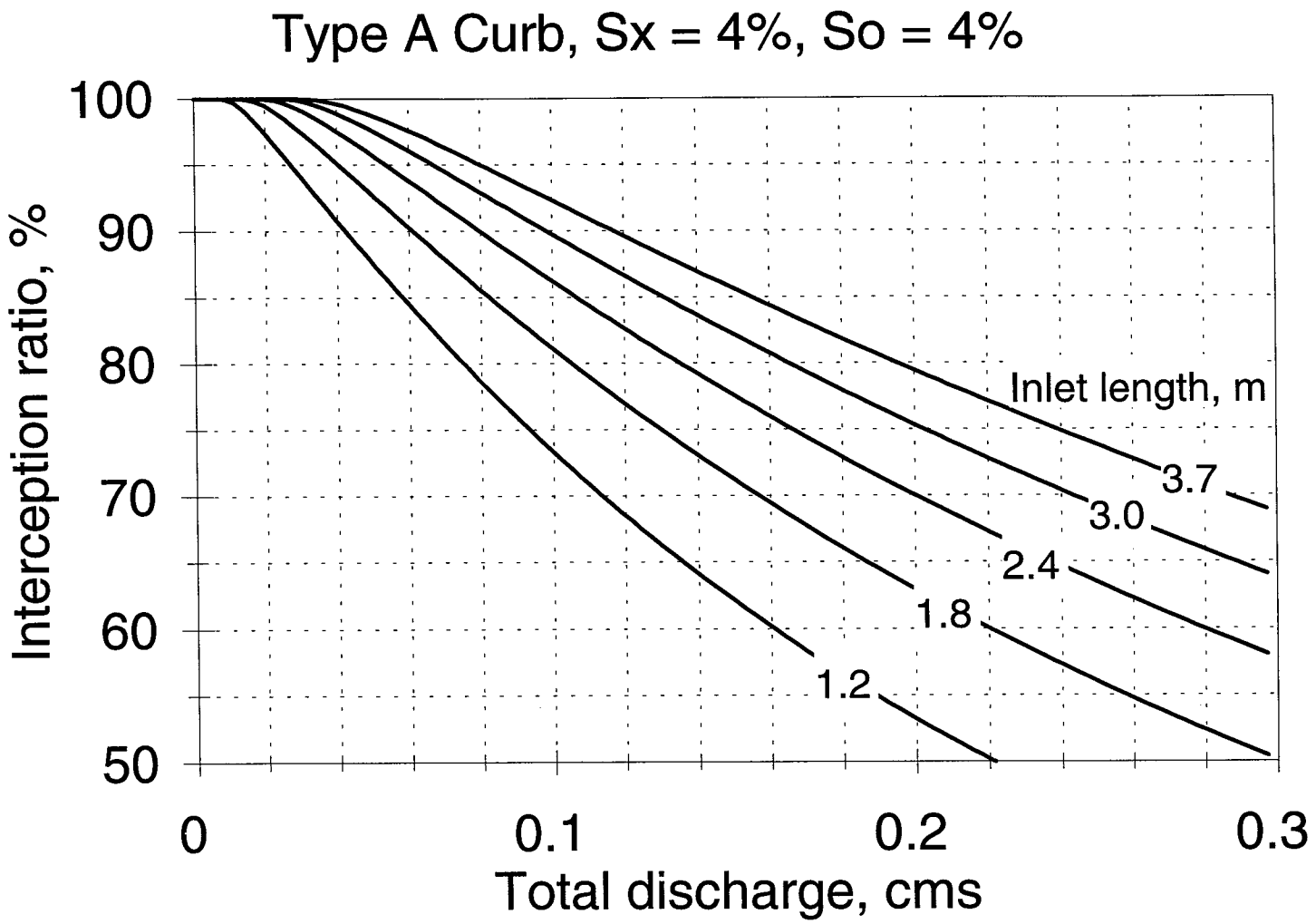

Type A Curb, Sx = 2%, So = 12%
Interception ratio, %
100
90
80
70
60
50
0
0.05
0.1
Total discharge, cms
Inlet length, m
1.2
1.8
2.4
3.0
3.7

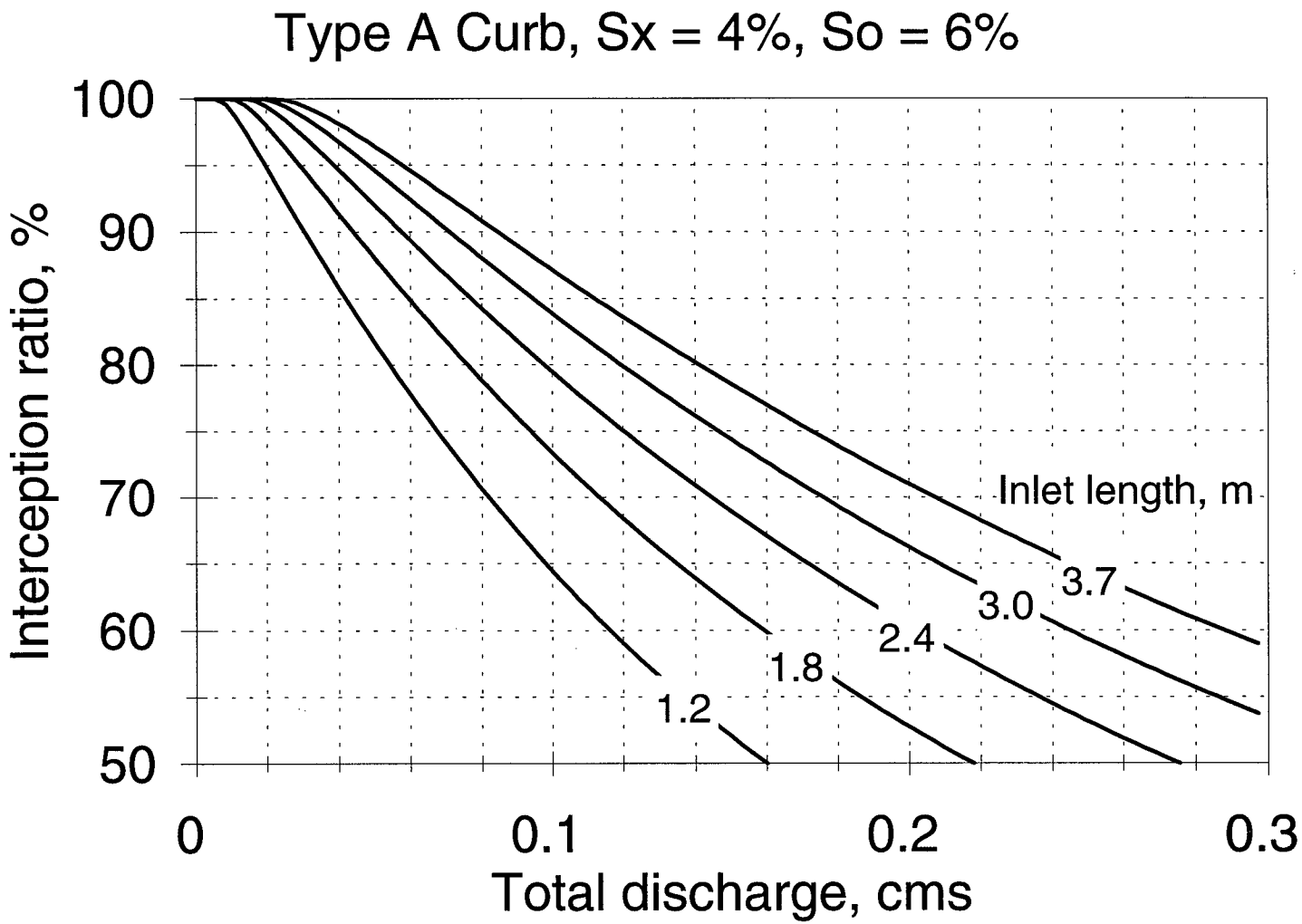

Type A Curb, Sx = 4%, So = 0.5%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
3.7
3.0
2.4
1.8
1.2
Inlet length, m

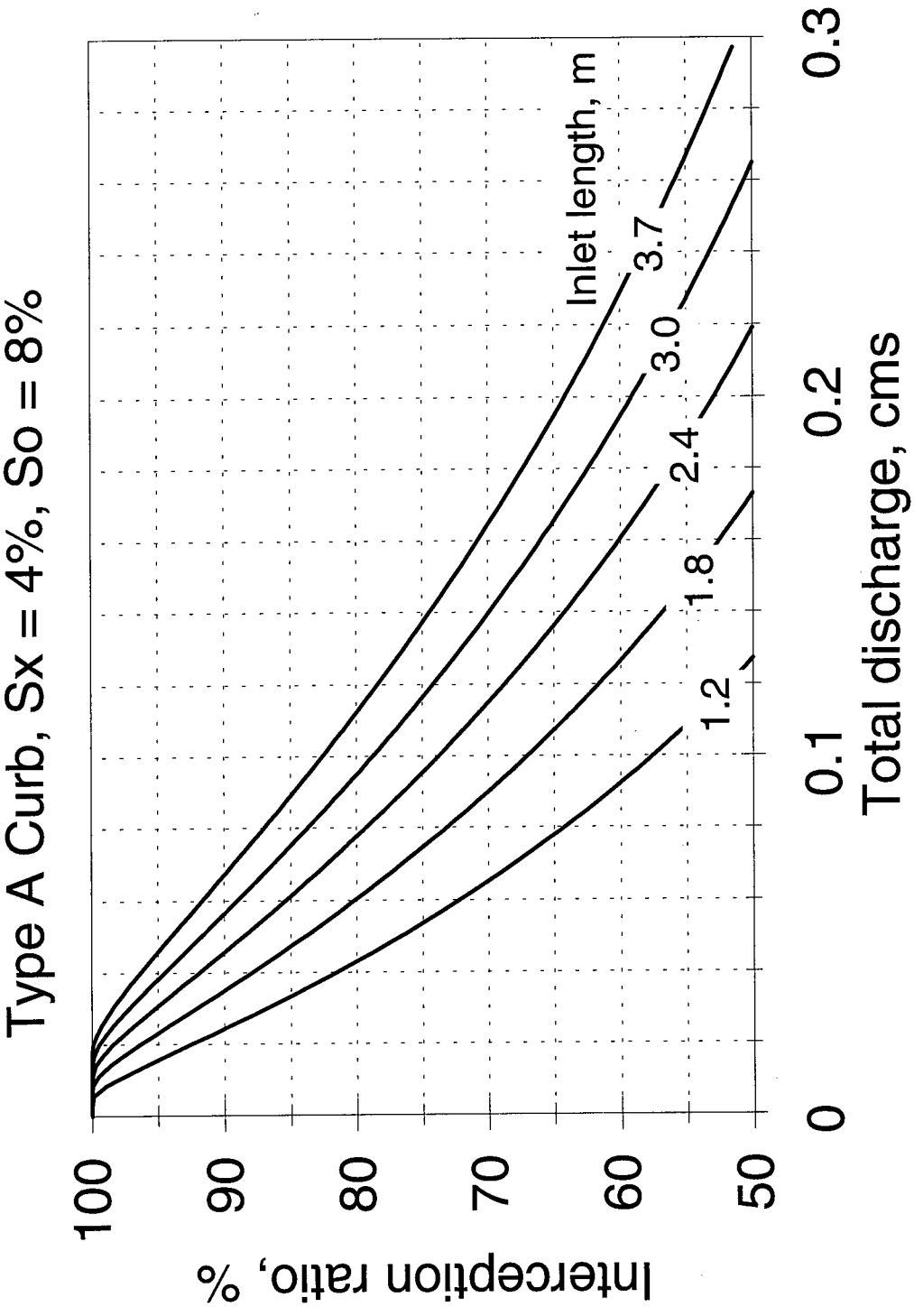

Type A Curb, Sx = 4%, So = 1%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
3.7
3.0
2.4
1.8
1.2
Inlet length, m

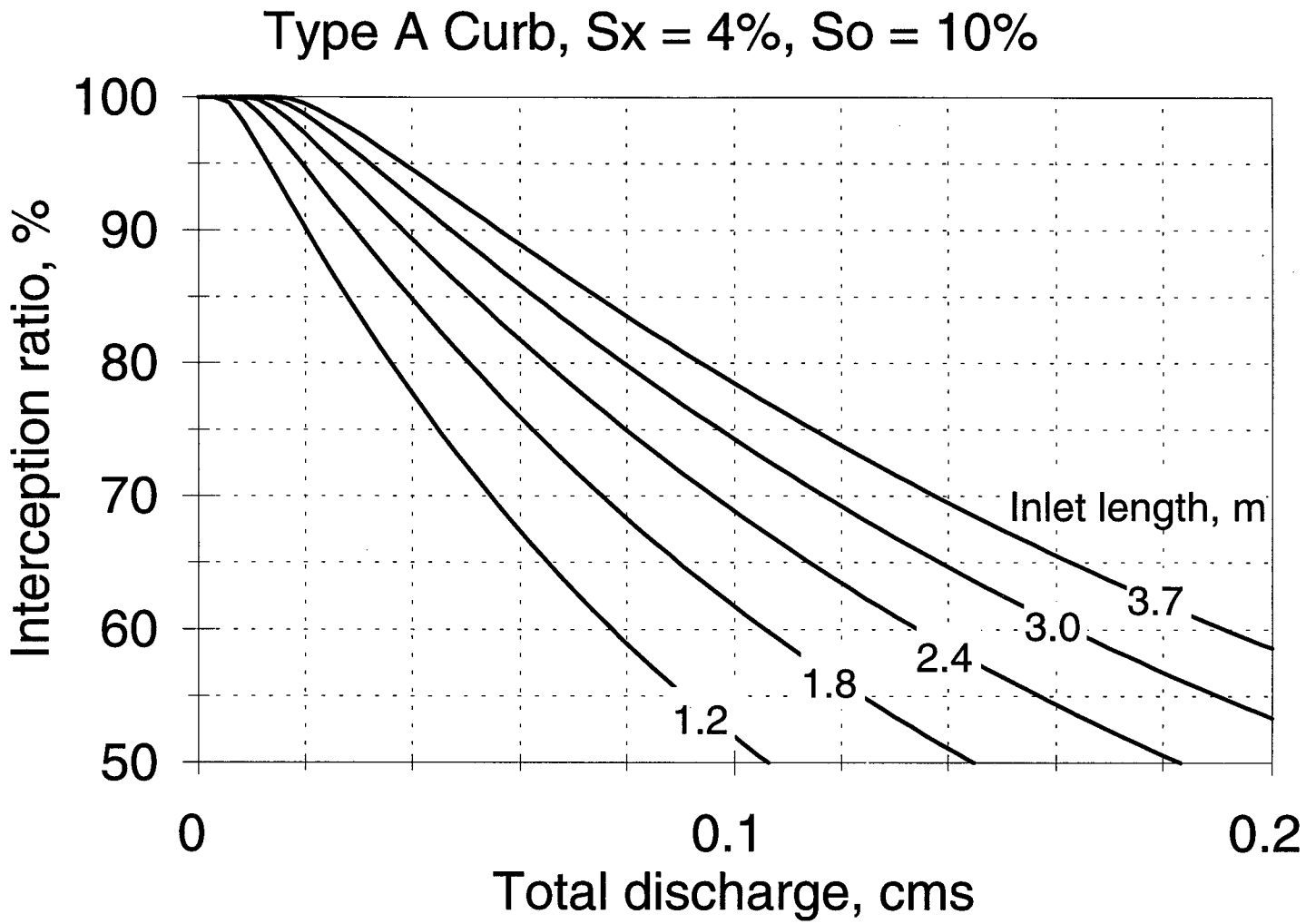

Type A Curb, Sx = 4%, So = 2%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2

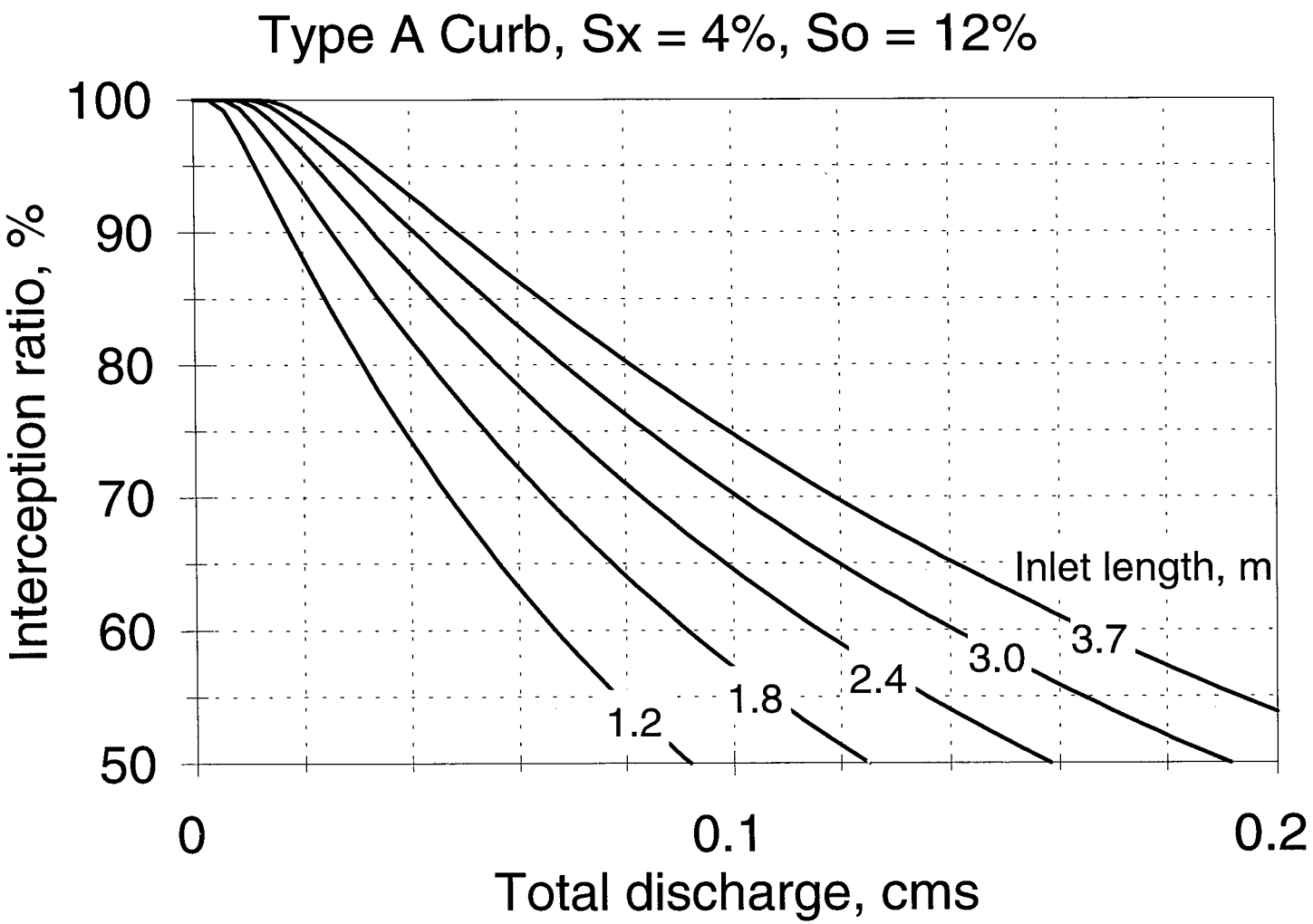

Type A Curb, Sx = 4%, So = 3%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2


Type A Curb, Sx = 4%, So = 4%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2


Type A Curb, Sx = 4%, So = 6%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2


Type A Curb, Sx = 4%, So = 8%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
0.3
Total discharge, cms
Inlet length, m
1.2
1.8
2.4
3.0
3.7


Type A Curb, Sx = 4%, So = 10%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
Total discharge, cms
Inlet length, m
3.7
3.0
2.4
1.8
1.2


Type A Curb, Sx = 4%, So = 12%
Interception ratio, %
100
90
80
70
60
50
0
0.1
0.2
Total discharge, cms
Inlet length, m
1.2
1.8
2.4
3.0
3.7