UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GRAPHICAL AIDS FOR ESTIMATING GENERAL SCOUR IN LONG CHANNEL CONTRACTIONS

Open-File Report 77-837

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By Carl F. Nordin, Jr.

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Denver, Colorado

November 1977

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

For additional information write to:

U.S. Geological Survey
Mail Stop 413, Box 25046
Denver Federal Center
Denver, Colorado 80225

Contents

Illustrations

ENGLISH-METRIC CONVERSION

English	Multiply by	Metric
feet	0.3048	meters
feet per second	.3048	meters per second
tons per day per feet	.00148	metric tons per day per meter
°Fahrenheit	(°F-32)/1.8	°Celsius

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ABSTRACT

Graphs relating unit sediment discharge to mean velocity and mean depth for a range of water temperatures and particle sizes of bed material can be used to estimate the equilibrium depth of scour in long contractions. Working graphs are included for bed materials with median diamters from 0.1 to 0.8 millimeters and water temperatures from 32 degrees to 60 degrees Fahrenheit (0 degrees to 15 degrees Celsius).

INTRODUCTION

Brooks (1958) showed that for a given particle size and water temperature, the discharge of sand per foot of width, q_s, was a unique function of velocity, V, and depth, D. Colby (1965) presented graphs relating q_s to V and D for a water temperature of 60°F, with median sieve diameter of bed material, d_{50}, as a third variable. Colby provided nomographs to allow for temperature corrections and for the effects of high concentrations of clay. Colby's graphs were empirically defined, but they are consistent with Brooks' findings and they have proven to give as good estimates of sediment transport as any existing formulas.

Herein, Colby's graphs are replotted in a form that allows immediate application to predicting scour in long contractions. The graphs apply to a sand-bed stream where all material in the bed can be transported by the flow; that is, there is no armoring of the bed. For this report, a long contraction is defined as one having a length at least four times greater than its contracted width.

DEVELOPMENT

Consider the long contraction sketched in figure 1. The undisturbed flow at section 1 is Q, the section has width B_1, depth D_1, velocity V_1, and median diameter of bed material, d. A long contraction is constructed so that the channel width at section 2 is reduced to B_2.

After an initial period in which materials are scoured from the contracted section, equilibrium sediment transport is obtained; that is, the same quantity of sediment is transported past both cross sections. For the given bed material size and anticipated water temperature, Colby's curves are replotted as lines of equal sediment discharge per foot of width, q_s, on a velocity-depth field, as sketched in figure 2. Lines with slope of minus one are lines of equal unit water discharge, q. The velocity and depth at section 1 establish the unit sediment discharge, q_{s_1}, at section 1, and the unit sediment discharge at section 2 is

$$q_{s_2} = B_1 \, q_{s_1}/B_2.$$

The intersection of q_2 and q_{s_2} established V_2 and D_2. The depth of scour, S, is $D_2 - D_1$, as shown in figure 1.

Figures 3 through 6 give unit sediment discharge, in tons per day per foot of width, as a function of velocity and depth for particle sizes of 0.1, 0.2, 0.3, 0.4, 0.6, and 0.8 millimeter and for water temperatures of 32° F and 60° F. These figures can be used as working graphs as described in the above example and illustrated in figure 2. Linear interpolation between particle sizes or water temperatures and linear extrapolation to higher water temperatures are sufficiently accurate for preliminary estimates of scour depth. More refined estimates could be obtained using the temperature corrections given by Colby (1964).

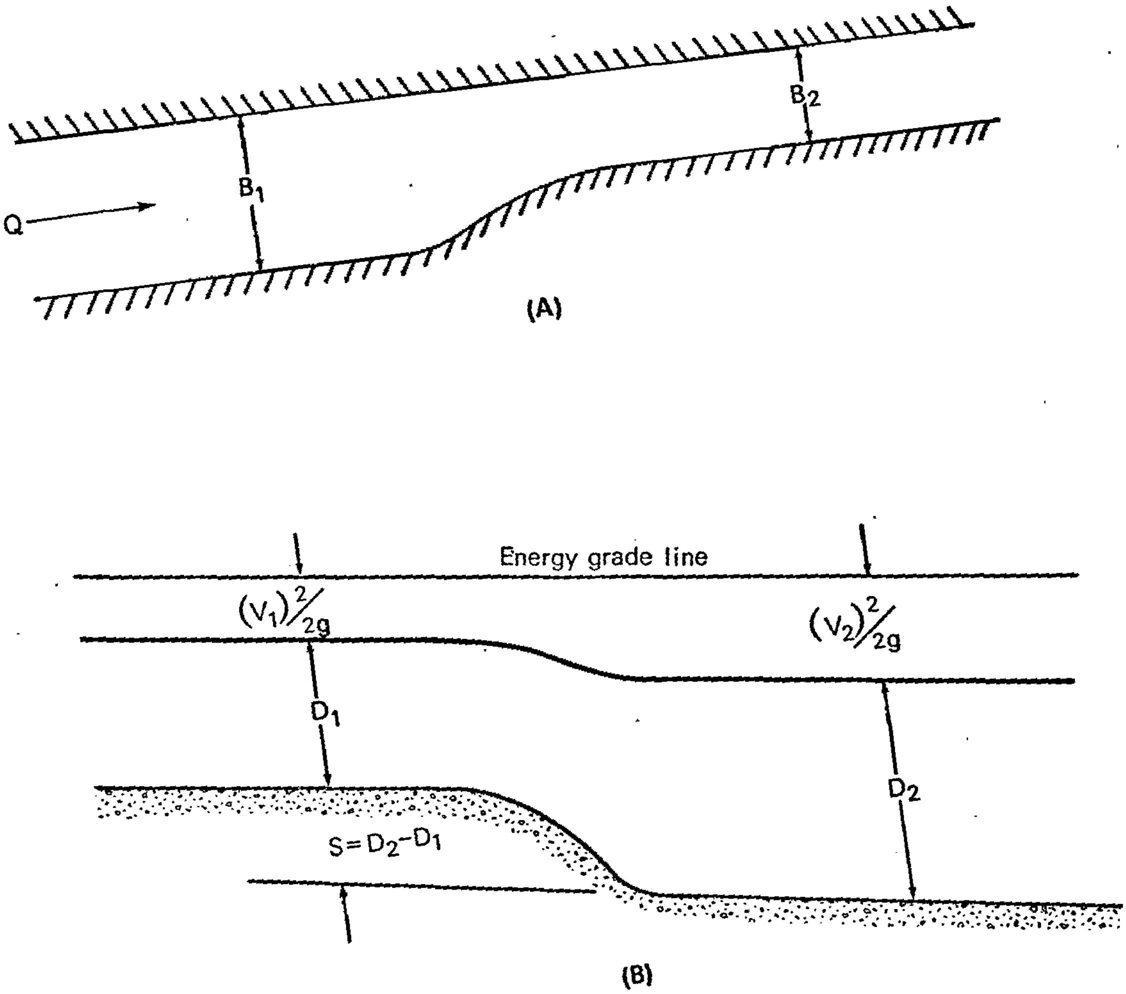

Figure 1.--Definition sketch of a long channel contraction.

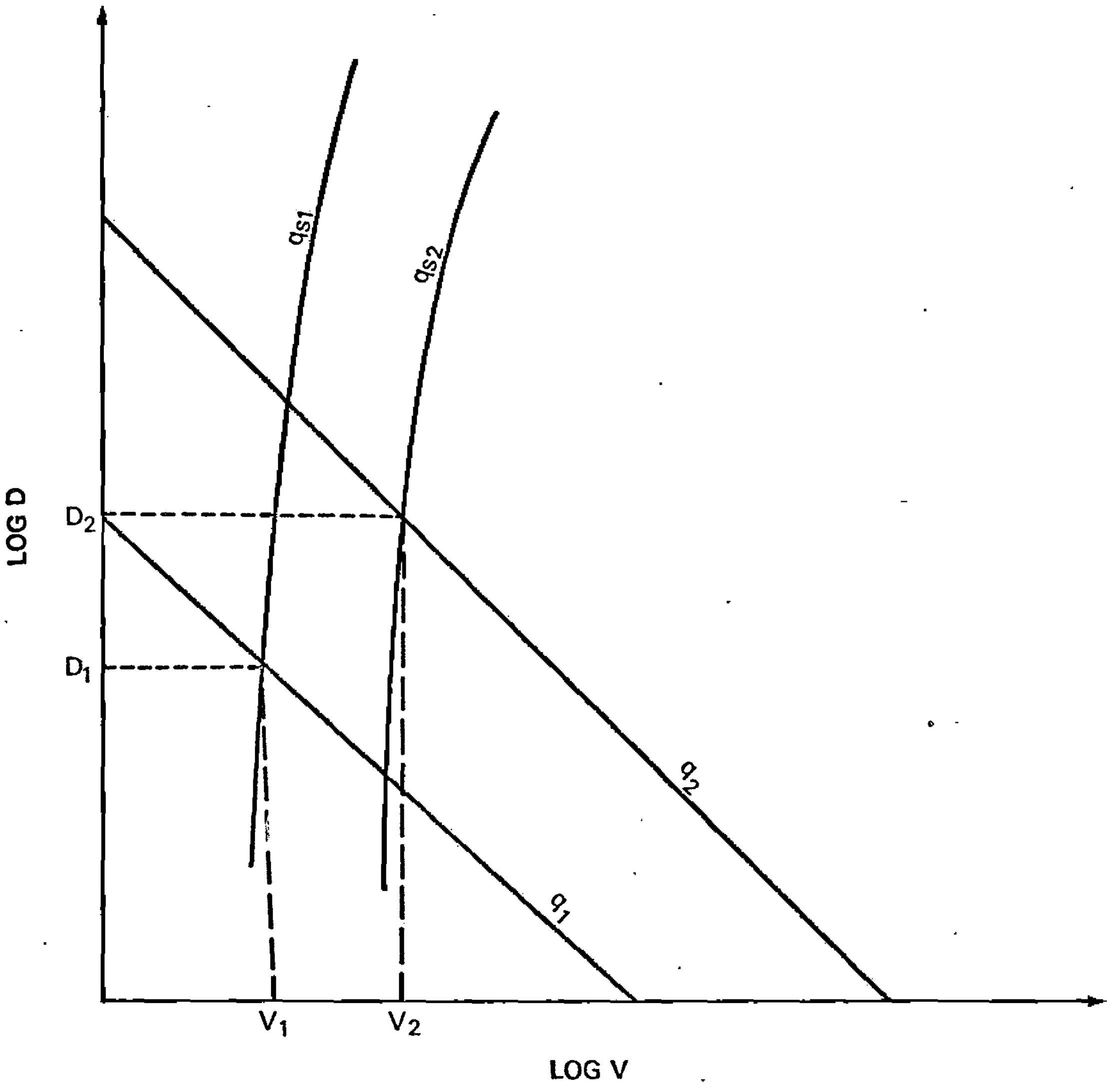

Figure 2.--Estimating the depth of scour, $S = D_2 - D$, from velocity-depth-transport relations. Water temperature and particle size are assumed constant.

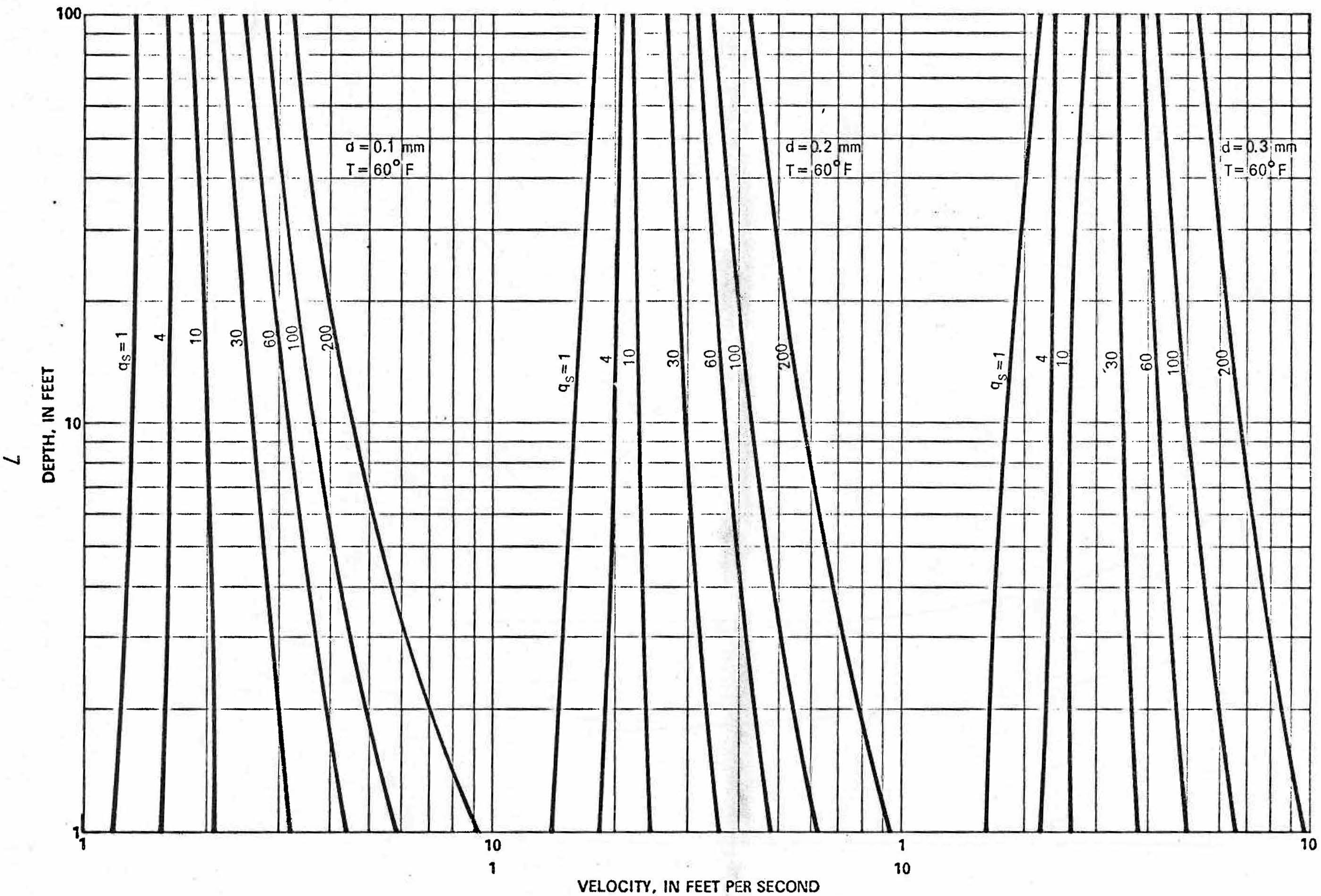

Figure 3.--Working graphs showing the relation of unit sediment discharge in tons per day per foot of width to velocity and depth for a water temperature of 60°F and for particle sizes of 0.1, 0.2, and 0.3 mm.

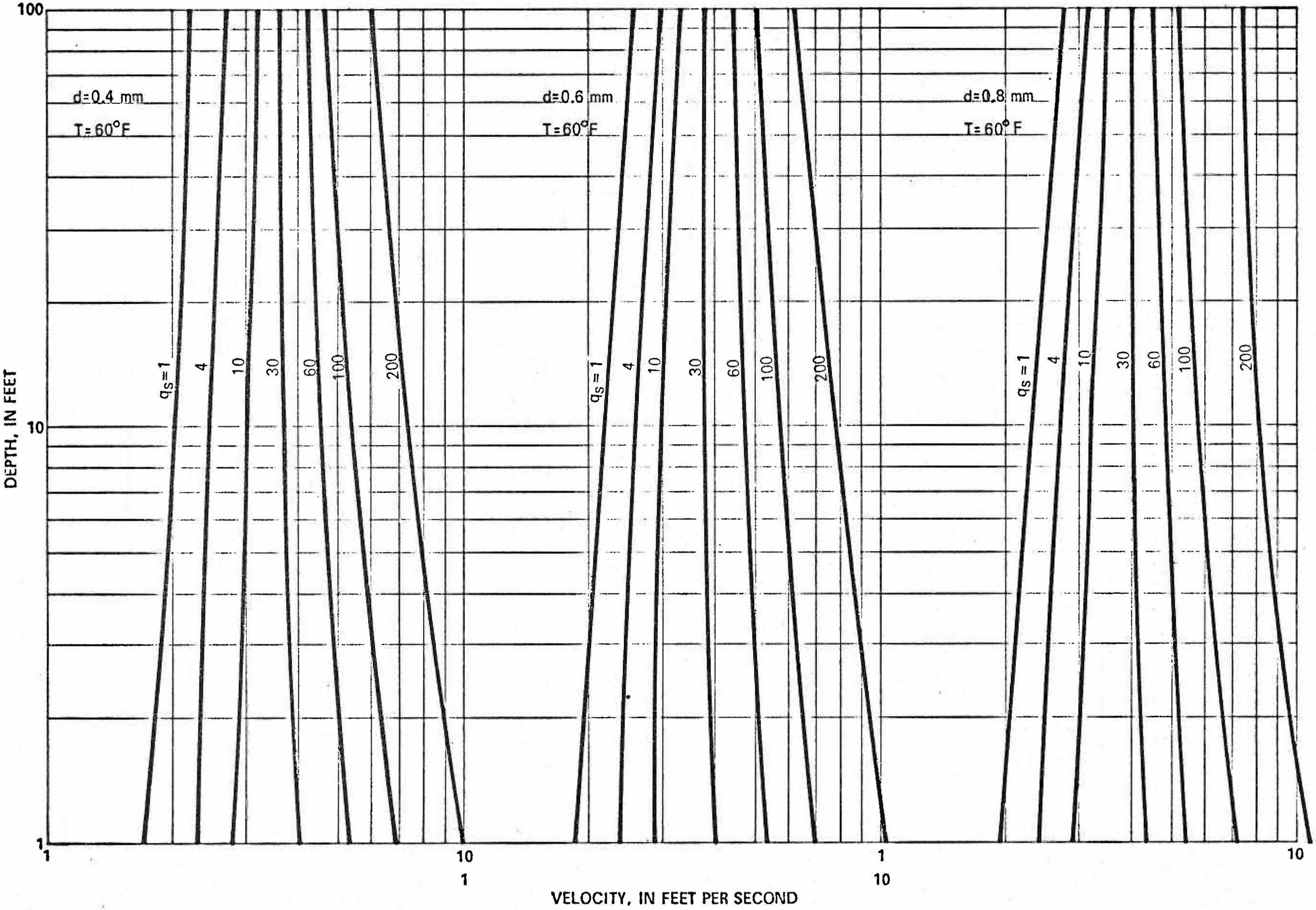

Figure 4.--Working graphs showing the relation of unit sediment discharge in tons per day per foot of width to velocity and depth for a water temperature of 60°F and for particle sizes of 0.4, 0.6, and 0.8 mm.

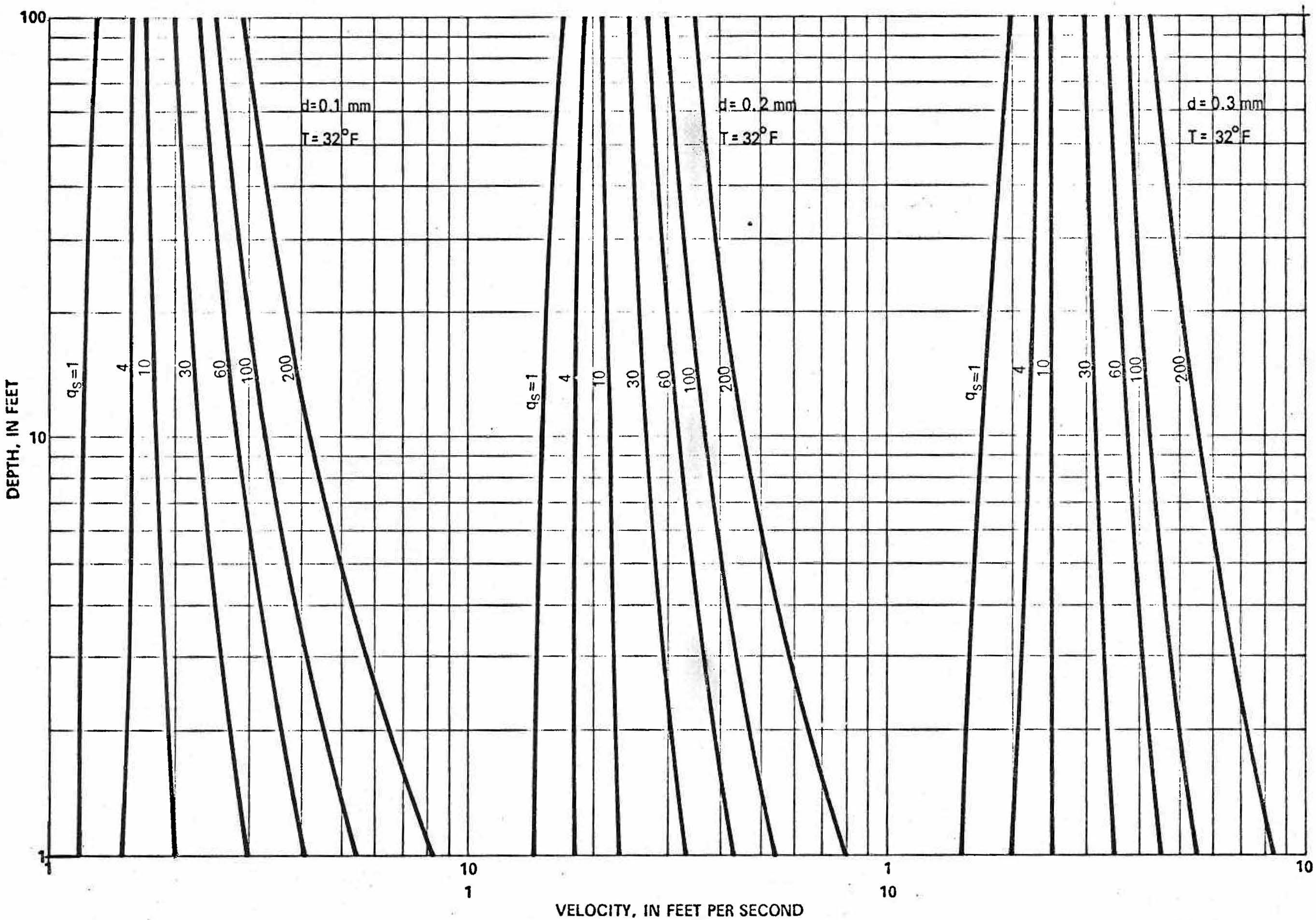

Figure 5.--Working graphs showing the relation of unit sediment discharge in tons per day per foot of width to velocity and depth for a water temperature of 32°F and for particle sizes of 0.1, 0.2, and 0.3 mm.

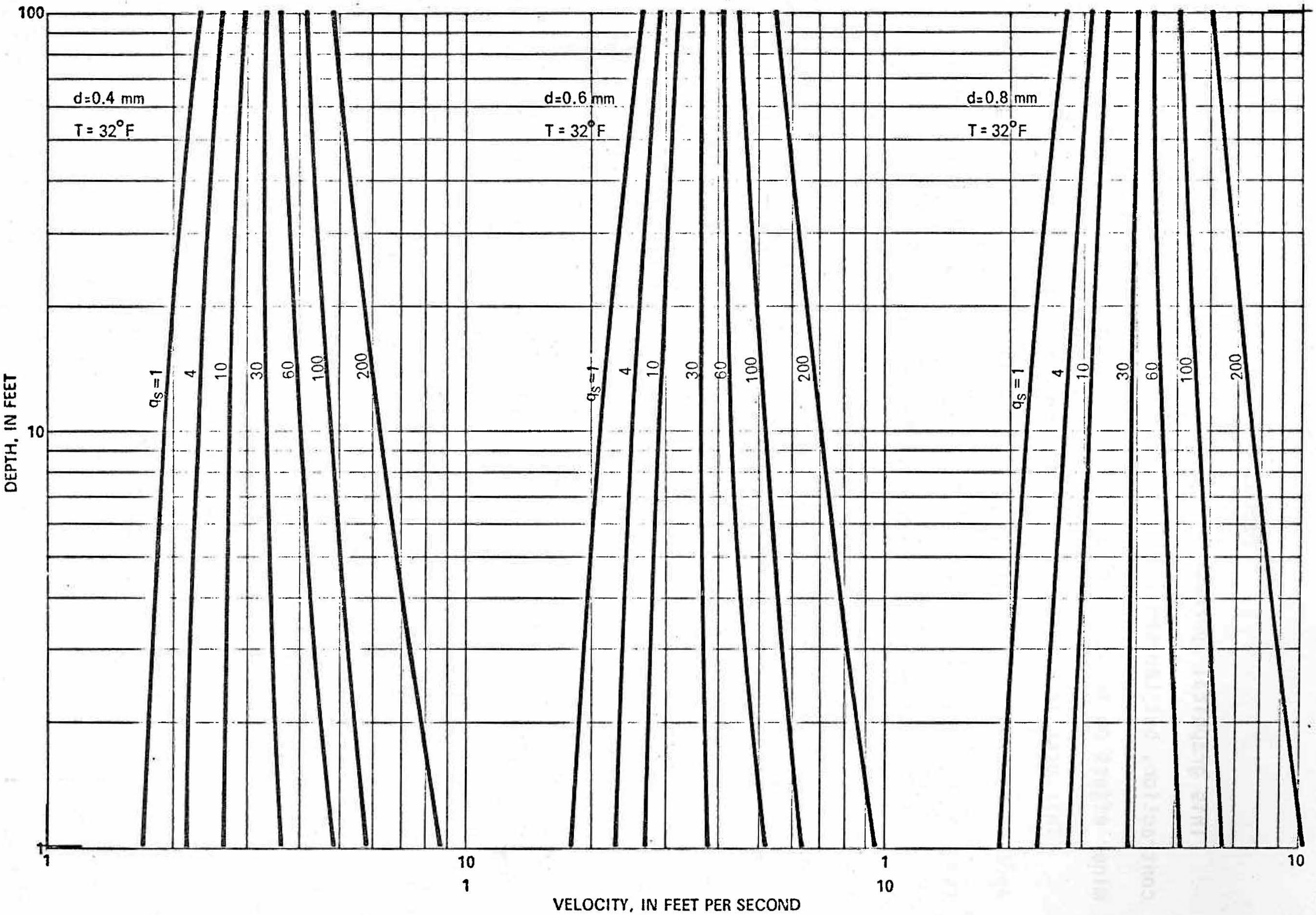

Figure 6.--Working graphs showing the relation of unit sediment discharge in tons per day per foot of width to velocity and depth for a water temperature of 32°F and particle sizes of 0.4, 0.6, and 0.8 mm.

DISCUSSION

This graphical approach does not consider energy losses at the contraction, but Laursen (1963) has shown these losses to have only minor effect on the equilibrium scoured depth.

This graphical method should be used with care. The method applies only to sand-bed streams and probably will give more reliable results for reasonably regular sections in which the flow field can be characterized by its mean velocity and mean depth than for irregular cross sections.

The equilibrium depth in the contracted section is the mean depth in the cross section. No consideration is given to local variations in bed level due to alternate bars and a meandering thalweg or to migrating dunes. For reasonably straight channels with width-to-depth ratios greater than about 40, the ratio of maximum depth to mean depth ranges from about 1.3 to 3.0, and averages about 1.8. These values are probably a fair estimate of local variations in bed level due to bed configurations, bars, and a meandering thalweg in straight reaches. At bends, the ratio of maximum to mean depth increases with increasing bend curvature, and generally is greater than the value given above for straight channels.

References

Brooks, N. H., 1958, Mechanics of streams with moveable beds of fine sand: Am. Soc. Civil Engineers Trans., v. 123, p. 526-594.

Colby, B. R., 1964, Discharge of sands and mean-velocity relationships in sand-bed streams: U.S. Geol. Survey Prof. Paper 462-A, 47 p.

Laursen, E. M., 1963, Analysis of relief bridge scour: Am. Soc. Civil Engineers Proc., v. 89, no. HY3, p. 93-118.