UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

FLOW CHARACTERISTICS AND LIMITATIONS OF SCREW LIFT VERTICAL METERGATES

Hydraulic Laboratory Report No. Hyd-471

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO

CONTENTS

CONTENTS (Continued)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Office of Assistant Commissioner and Chief Engineer
Division of Engineering Laboratories
Hydraulic Structures and Equipment Section
Denver, Colorado

Laboratory Report No. Hyd-471
Compiled by: J. W. Ball
Checked by: J. W. Ball
Reviewed by: H. M. Martin
Submitted by: H. M. Martin

Subject: Flow characteristics and limitations of vertical screw lift metergates

PURPOSE

To determine the flow characteristics and establish operation and installation limitations and capacity curves for various sizes of screw lift vertical metergates (Figure 1).

CONCLUSIONS

1. The present commercial metergate design, with the downstream pressure tap located a constant distance of 12 inches from the pipe entrance, is not an optimum design for best flow measurement accuracy.

2. The practice of locating the downstream pressure tap 12 inches from the pipe entrance makes each gate size and setting a separate problem requiring strict operational limitations or individual calibration.

3. The influence of several factors on indicated capacity vary widely with gate size when the 12-inch pressure tap distance is used. The influence of these factors decreases rapidly as the gate closes from the wide-open position and becomes negligible at about 50 percent opening in all cases.

4. Appropriate and accurate location of pressure taps and accurate zeroing of gages and gate opening indicators are important factors influencing the flow-measuring accuracy of metergates.

5. The pressure distribution in the pipe near the entrance of a metergate determines the differential head for the gate, and any change in entrance condition that influences the pressure distribution influences the measured differential head. Although the changes in pressure distribution may not affect the flow quantity to any degree for a given headwater and tail water condition, the change in the measured differential head would be reflected in the discharge coefficient. In many cases, a rating curve made from calibrations on one inlet design cannot be used for another design without error being introduced, particularly if the gate is to be operated at openings greater than about 75 percent. This is especially true for small submergences (less than 1d) of the engrance.1/ The inlet design should be standardized and the various sizes made geometrically similar for best results.

6. The pressure distribution within the pipe of a metergate, and thus the discharge coefficient curve, is influenced to various degrees by the following:

a. Gate design

b. Approach design, including position of walls and floor relative to entrance

c. Relative submergence of entrance

d. The velocity of the flow

The shape of the gate (circular or flat bottom leaf) is a factor of gate design that affects the capacity. This factor has little if any influence at wide-open gate.

When the gate entrance is confined by the walls and floor of an approach, the degree of confinement influences the entrance contraction and thus the discharge coefficient and indicated capacity. The influence is evident at larger gate openings and decreases as the gate opening decreases, becoming negligible at about 50 percent gate opening (compare curves for 24-inch gate, Figures 20 and 21).

The nearness of the approach channel walls to the edges of the pipe inlet has minor influence on pressure distribution for wall distances of d/4 and greater when the upstream submergence is greater than about 1.0d.

1/Hydraulic Laboratory Report Hyd-422, "Flow Characteristics in a Pipeline Downstream from a Square Cornered Entrance."

The position of the approach floor with respect to the invert of the entrance affects the pressure distribution within the downstream pipe and thus changes the magnitude of the discharge coefficient. The effects of these confining factors are significant only at large gate openings.

The pressure distribution within the pipe near the entrance of a metergate is influenced greatly at upstream submergences less than 1.0d (relative to top of entrance). When the upstream water surface is less than one pipe diameter above the crown of the pipe entrance and the gate is at large openings, the discharge coefficient varies with the amount of submergence (Figures 6 and 7).

The pressure distribution varies slightly with velocity (viscosity or Reynolds number). When flow velocities are low (low Reynolds number), the discharge coefficient varies slightly from the constant value obtained with ample submergence at higher velocities, Figures 6 and 7. Viscous effects will be relatively small for most installations.

7. A metergate must have sufficient submergence of the pipe exit, or sufficient back pressure, to give a measurable water surface in the downstream measuring well. This required submergence, or back pressure, varies with differential head, gate size, gate opening, longitudinal location of the downstream pressure tap, and the height of the measuring well bottom above the crown of the pipe.

An outlet submergence of 1 foot above the crown of the pipe relative to the downstream tap location is sufficient for all gate sizes and openings at differential heads, ΔH, up to and including 18 inches, provided the bottom of the downstream measuring well is less than 6 inches above the crown of the pipe. If a depth of water is needed in the well to permit recording of the water surface by a gage, the bottom of the well should be set lower by the amount needed for the gage, or the submergence increased to provide the additional depth in the well. Greater submergences must be provided when higher differential heads are used.

8. The degree of submergence of the pipe exit does not in itself affect the accuracy of a metergate.

9. With minimum downstream submergence, the pipe downstream from the gate should be at least 7 pipe diameters long to assure that the discharge end will run full and at minimum velocity. This length is based on the data shown on Figure 25 and assumes a level installation.

10. The pressure tap to the downstream measuring well should be on the top vertical center line of the pipe. It is least affected by pressure distribution changes when placed in this location. The pressure tap to the upstream measuring well should be so located that it records the true head in the canal above the metergate approach.

11. An optimum metergate design that would provide best accuracy without strict limitations or individual calibration would be one which had complete geometric similarity including the position of the downstream pressure tap. For best results, the downstream pressure tap of the various gate sizes should be placed at geometrically similar locations, preferably where the hydraulic grade is not steep.

The optimum position for the downstream pressure tap is about $\frac{d}{3}$ from the entrance, where d is the pipe entrance diameter (Figure 14). This location of the tap allows the use of a general coefficient curve from which the capacity of any size gate can be determined within a reasonable degree of accuracy (perhaps to about plus or minus 2 and 1/2 percent) when the approach walls are approximately $\frac{d}{4}$ distance or greater from the edges of the entrance opening, the sloped floor is about 0.17d below the invert of the entrance opening, and the upstream submergence is one pipe diameter or greater. This is particularly true if the maximum gate opening is limited to about 75 percent.

The coefficient curve, Figure 20, is based on a tap located at the top center line and $\frac{d}{3}$ distance from the gate seat, with 8 to 1 flaring walls set $\frac{d}{4}$ distance from the edges of the opening, a floor that is 0.17d below the bottom of the opening and is on a 2 to 1 slope downward from the canal to the metergate, and submergences greater than 1 diameter above the top of the opening. Values from this curve can be used in the equation $Q = C_d A \sqrt{2g\Delta H}$ with the area for the particular size metergate to prepare discharge tables or curves for the various sized gates in similar settings.

12. The rating curves, Figures 27, 29, and 31, are for unconfined entrances with the tap located on the top center line and 12 inches from the inlet (standard for present commercial gates). Figures 28, 30, and 32 are for confined entrances similar to that shown on Figure 2.

ACKNOWLEDGMENT

Members of the Canals Branch and Hydraulic Laboratory Branch collaborated in the study of the screw lift vertical metergate. The

Morse Brothers Machinery Company, Denver, Colorado, supplied on loan the 18- and 24-inch gates used in the study.

INTRODUCTION

The problem of accurate and economical measurement of irrigation water has become more important in recent years. One of the main factors contributing success toward the solution to this problem has been the introduction of simpler and more accurate measuring devices. Because of its simplicity of design and low maintenance cost, the metergate is one of several devices used. The screw lift vertical gate (Figures 1 and 2) is one of several metergate designs. Flow quantity for a metergate is determined from the pressure differential between the canal or reservoir from which the flow is taken and a point within the metergate pipe a short distance downstream from the entrance and regulating gate. Two measuring wells, one connected to the canal and the other connected to the pipe downstream from the gate, are provided for determining the differential head. The location of these wells for the metergates tested is shown on Figure 2. The downstream well tap in most commercial gates is located 12 inches from the gate seat regardless of size. Since there was little information concerning the hydraulic characteristics or limitations of this type of metergate, a laboratory study was initiated to evaluate them. Accuracy and capacity of the gate were of particular interest. Two sizes of the gate, 18- and 24-inch, were tested and the data were used to prepare rating curves and determine the hydraulic characteristics of other sizes. A 10-inch transparent plastic conduit with numerous piezometers installed along its length was used to evaluate the influence of the entrance approach design on flow capacity. 1/

INVESTIGATION

The Problem

In order to use the data from metergate test installations to establish limitations of the design and prepare rating curves for the various sizes and settings, it was necessary to adopt some general method of analysis. The following relationship seemed most suitable and was used throughout the study.

1/Hydraulic Laboratory Report Hyd-422 "Flow Characteristics in a Pipeline Downstream from a Square Cornered Entrance."

$$Q = C_d \frac{\pi d^2}{4} \sqrt{2g \Delta H}$$

where

Q = discharge in cfs
C_d = discharge coefficient
d = nominal diameter of gate
g = acceleration of gravity (32.2 ft/sec^2)
ΔH = differential head, feet
(Canal water surface to pressure head at downstream tap)

Preliminary consideration of the problem indicated that the discharge coefficient, C_d, would be influenced by the upstream submergence, H_s; the gate opening, a; the entrance arrangement and configuration; the nominal diameter of the gate, d; the location of the pressure tap in the downstream pipe, x, measured from the gate seat; and the mean velocity in the pipe, V. To facilitate the use of the variables, they were expressed in dimensionless parameters as in the following relationship:

$$C_d = \phi \, (H_s/a, a/d, x/d, R_e)$$

Reynolds number, R_e, is a parameter of the following terms:

$$R_e = \frac{Vd}{\nu}$$

where

V = mean water velocity in the pipe in feet per second
d = nominal diameter of gate, feet
ν = kinematic viscosity of water

It was anticipated that there would be numerous variations in the metergate installations in irrigation systems so studies were made to determine the effect of the above-listed variables on the capacity of the metergates. Discussions of these studies are contained in subsequent sections of this report.

The Laboratory Installation

The laboratory installation used for the study of the metergate is shown schematically on Figure 3. Water to the test gate was supplied by three 12-inch and one 8-inch centrifugal pumps. Venturi meters in the supply systems near the pumps were used to determine the flow quantities. Accurate flow measurement was possible over a wide range of discharge because of the various sizes of Venturi meters available (6-, 8-, 12-, and 14-inch). Good flow distribution just upstream from the gate, with negligible velocity of approach, was obtained by passing the water through a rock baffle in the head box. The upstream end of the metergate pipe was placed in one side of a head box 7 feet wide, 11 feet long, and 10 feet deep with the gate over the entrance. The downstream end of the conduit terminated in a tail water box 4 feet wide, 6 feet long, and 6 feet deep. A hinged gate in the side of the tail water box opposite the pipe exit provided a means of varying the downstream submergence and changing the hydraulic grade in the pipe.

Piezometer taps were placed in the crown of the pipe at different distances from the gate seat to record the pressure gradient in the pipe and to provide a means of applying the data to other gate sizes. The pressure taps were confined to the crown of the pipe because this location had been determined to be the most desirable in previous metergate tests. Rubber tubing connected the taps to glass tubes mounted on a manometer board which was graduated in 0.01-foot increments. Carborundum disks inserted in short plastic cylinders, 3/4-inch inside diameter, were used in some of the piezometer lines to dampen pressure fluctuations and permit more accurate reading of the average pressures. In field installations, a 3/4-inch pipe connects to a 10-inch-diameter well; thus, a fairly constant average pressure will be expected.

Test Procedure

The laboratory tests were made over a range of differential heads of from 2 to 48 inches. The hydraulic gradient in the pipe was controlled by the hinged gate in the tail box to give readable water depths in the downstream measuring well.

The 18- and 24-inch gates were tested for every 2-inch increment of gate opening. The 24-inch gate installation is shown on Figure 4A. The gate position indicator is shown on Figure 4B. A section of transparent pipe was placed immediately downstream from the 24-inch gate so that flow conditions in the pipe below the gate could be observed. Smooth pipe was used downstream from the test gates.

Influence of Gate Design on Capacity

The main difference in metergate capacity due to gate design occurs at partial openings and results from the shape of the gate (whether the leaf is circular or has a square bottom). Some influence is also introduced by the configuration and relative sizes of the structural members of the gate framing and the gate seat casting. For a given head differential, the gate with a circular leaf will discharge about twice as much water at 20 percent gate opening as a gate with a square bottom leaf. The gate framing usually has a minor influence unless some of the framework is placed too close to the pipe entrance. Structural members of gate frames should be kept away from the edge of the opening to have the least influence.

The gate seat casting shape, including width of seat, its projection from the headwall to which it is attached, and its general configuration, will have some influence on the discharge coefficient. This factor should not be of major concern but may cause differences in discharge coefficient of 2 to 3 percent. The influence of variations in entrance configuration is illustrated to some degree in Figure 5 and Tables 1 and 2.

Influence of Upstream Submergence, H_s

In tests made previously, it was found that the discharge for comparable values of ΔH was affected at large gate openings by the amount of submergence of the pipe entrance. For a given installation, the discharge coefficient remained constant for large submergences and varied for small submergences. This effect of upstream submergence has also been observed by other investigators. 2/ The same characteristic was noted in tests on the screw lift metergates with a flat bottom leaf and in tests made on the 10-inch pipe entrance (Figures 6 and 7). In all cases, it was found that the coefficient of discharge varied widely for submergences less than 1.0d and that there was little variation in coefficient when the submergence was greater than d above the entrance crown. The effects of the submergence changed somewhat with pressure tap location, and approach wall and floor arrangements; however, the variation was always apparent. One means of illustrating the influence of small upstream submergences is to plot the ratio of the discharge coefficient for any submergence (C_d), and the average discharge coefficient for high submergences C_a, against the submergence expressed in terms of pipe diameter. Figures 8, 9, 10, and 11 show the submergence effect for the 24- and 18-inch gate 100 percent open and 10-inch pipe entrance for various locations of the downstream pressure tap. The data show that each geometric arrangement of the approach, the entrance configuration, and tap location will have an individual coefficient curve which may or may not vary widely. The effect of the various factors can be minimized by maintaining a submergence of at least 1 entrance diameter above the top of the entrance opening. The influence of the submergence decreases as

2/ "Ausfluss, Curchfluss, Strahlreaktion and Strahldruck in neuer Betrachtung" (Discharge, Underflow, Jet Propulsion and Jet Forces from a New Viewpoint) by Von Theodor Musterle, Die Wasserwirtschaft, September 1960.

Table 1

DISCHARGE COEFFICIENTS--VARIOUS WALL, FLOOR, AND PRESSURE TAP LOCATIONS

Wall position d	Floor position d	D.S. Tap position x	Coefficient of discharge 10-inch pipe	18-inch metergate	24-inch metergate
3	1.2	1/3d*	0.61		
3	1.0	1/3d*		0.62	
2-1/4	0.63	1/3d*			0.64
3	1.2	1/2d**	0.63		
3	1.0	1/2d**		0.71	
2-1/4	0.63	1/2d**			0.70
3	1.2	2/3d***	0.69		
3	1.0	2/3d***		0.76	
2-1/4	0.63	2/3d***			0.77
3	1.2	1.2d****	0.80		
3	1.0	1.2d****		0.81	
2-1/4	0.63	1.2d****			0.83
3	1.2	3.91d	0.81		
1.0	1.2	2/3d***	0.68		
1.0	1.0	2/3d***		0.75	
					<u>76</u>
1/2	1.2	2/3d***	0.69		
2/3	1.0	2/3d***		0.77	<u>78</u>
1/4	1.2	2/3d***	0.70		
1/3	1.2	2/3d***		0.76	
					<u>77</u>

<u>76</u> indicates coefficient estimated.
* Standard for 36-inch metergate.
** Standard for 24-inch metergate.
*** Standard for 18-inch metergate.
**** Standard for 10-inch metergate.

<u>Note:</u> Values are for upstream submergence greater than d above crown of entrance.

Table 2

DISCHARGE COEFFICIENTS--VARIOUS WALL, FLOOR, AND PRESSURE TAP LOCATIONS

Wall position d	Floor position d	D.S. Tap position x	Coefficient of discharge 10-inch pipe	18-inch metergate	24-inch metergate
1/4	0.17	1/3d*	0.60		
1/4	0.17	1/3d*		61	
1/4	0.17	1/3d*			0.61
1/4	0.17	1/2d**	0.61		
1/4	0.17	1/2d**		62	
1/4	0.17	1/2d**			0.63
1/4	0.17	2/3d***	0.63		
1/4	0.17	2/3d***		65	
1/4	0.17	2/3d***			0.66
1/4	0.17	1.2d****	0.74		
1/4	0.17	1.2d****		75	
1/4	0.17	1.2d****			0.76
1/4	0.17	3.91d	0.80		
1/4	0.17	3.91d		80	
1/4	0.17	3.36d			0.80

76 indicates coefficient estimated.
* Standard for 36-inch metergate.
** Standard for 24-inch metergate.
*** Standard for 18-inch metergate.
**** Standard for 10-inch metergate.

Note: Values are for upstream submergence greater than d above crown of entrance.

the gate is lowered over the entrance. It is believed that the influence becomes negligible when the gate is about 75 percent open.

The effect of the upstream submergence was indicated first by log plots of ΔH against discharge for various openings of the test gates. These plots gave straight lines for the higher values of ΔH, and a variable deviation from a straight line at small values of ΔH and H_s, particularly at large gate openings. An investigation made to learn the cause of this deviation showed that for the small values of ΔH and H_s, the value of ΔH could be changed by merely changing H_s, when the discharge was kept constant. In other words, the same discharge could occur at different values of ΔH, depending on the value of H_s when H_s was small. From this investigation, it was concluded that for small submergences of the metergate inlet and large gate openings the amount of submergence influenced the discharge coefficient.

Since the equation $Q = C_d \frac{\pi d^2}{4} \sqrt{2g\ \Delta H}$ was used in this case the Q, C_d, and ΔH were the only variables, any change in ΔH at a constant discharge must result in a change in C_d. It was found that as H_s was increased in the range H_s less than d, the deviation of the plot from a straight line decreased and became negligible when H_s was equal to or greater than d. The deviation was more noticeable on the 24-inch than on the 18-inch gate because of the difference in location of the taps for the downstream measuring wells. The distance was 12 inches in each case, which placed the taps at relatively different locations on the pressure grade lines. Measuring well taps placed at the same relative locations on the pressure grade lines of the various sizes should give comparable deviations. Placing the taps at distances which would give a constant value of $\frac{x}{d}$ for all sizes of gates would fulfill the condition. The influence of submergence on C_d for the 24-inch gate is shown on Figure 6. A more recent research study of this phenomenon made on a 10-inch pipe showed the same characteristics. Tests were made for numerous degrees of submergence for three different discharges. A plot of the data that includes the influence from both submergence and velocity is shown on Figure 7. These data indicated that the influence of upstream submergence was negligible for submergences greater than about 1 pipe diameter above the entrance crown, that the influence was appreciable at submergences less than 1.0d, and that the velocity (viscous) influence was minor.

The plots on Figures 8, 9, 10, and 11 show that the location of the pressure tap for the downstream measuring well influences the nature of the coefficient curve in the region of low submergence, This, in part, explains why the effect of submergence varied with metergate size.

Influence of Approach and Entrance Design

Initial tests to determine the effect of approach design on the capacity of the screw lift vertical metergate were made on the 24-inch installation with the approach having a 2 to 1 downward sloped floor and 8 to 1 flaring vertical sidewalls set 6 inches ($\frac{d}{4}$) from the edge of the pipe entrance (Figure 12). Tests were made with the floor and walls in place, the walls removed, and then the floor removed. The tests indicated that at large gate openings and upstream submergences less than 1.0d, the walls caused a substantial reduction in the coefficient for comparable values of ΔH and that the floor alone had little effect.

Tests on the 18-inch installation for similar upstream submergences without the sloping approach floor and with and without the 8 to 1 flaring walls were not in good agreement with those on the 24-inch gate. Tests on the 18-inch gate showed that 8 to 1 flaring walls placed at $\frac{d}{3}$, $\frac{2d}{3}$, and d distance from the edges of the entrance opening had very little influence on the discharge coefficient (Figure 13). The sloping floor was not installed in this case because tests on the 24-inch gate had indicated negligible influence and because of the additional work involved in making and changing the test setup.

Later tests on the 10-inch pipe entrance (without a gate), with and without the sloping floor, and with and without the flaring sidewalls placed at distances of $\frac{d}{4}$, $\frac{d}{2}$, and d from the edges of the entrance showed that for submergences of d or more, the walls in these positions had only minor influence on the coefficient (as in the tests on the 18-inch gate) and that the floor position had considerable influence regardless of wall position (Figure 14).

It is unfortunate that the sloping floor was not used for tests on the 18-inch installation so as to permit direct comparison of the floor's influence. However, with good agreement between tests on the 10- and 18-inch installations concerning the wall influence without the sloping floor it is difficult to account for a 9.5 percent change in discharge coefficient, attributed to the wall position, indicated by tests on the 24-inch metergate with the downstream tap 12 inches from the entrance. This discrepancy must necessarily go unexplained at this time. Moreover, the 9.5 percent wall influence indicated in the tests on the 24-inch gate must be considered in error (or not comparable due to physical differences in the setting) in light of the good agreement between other tests on the 10-inch pipe entrance and the 18- and 24-inch metergates.

A plot of the average value of C_d for submergences greater than 1.0d, against the relative position of the downstream pressure tap disclosed several interesting facts (Figure 5). One of the most important of these is that good agreement in capacity and pressure characteristics can be obtained only when the various size installations are geometrically similar. The solid lines of the graph show the variation in C_d for various tap positions with only the walls and floor of the head boxes forming the approach to the entrances of the 10-inch pipe and 18- and 24-inch metergates. There are several physical differences which contribute to the variations in the curves for the separate installations. First, the entrances varied; secondly, the relative distance of the sidewalls from the edges of the entrance openings varied; and thirdly, the relative distances of the floors from the bottom edges of the entrance openings varied. These physical differences are discussed below.

The structural angles and other physical features of the 24-inch gate in the vicinity of the entrance were not geometrically similar to those on the 18-inch gate and, of course, did not represent the unobstructed sharp entrance of the 10-inch pipe. Also, the metergate entrances were of nominal dimensions of 18 and 24 inches, while the 10-inch pipe entrance was an exact measured dimension.

The sidewalls of the head boxes were about 3, 3, and 2.25 pipe diameters from the edges of the openings of the 10-, 18-, and 24-inch installations, respectively. This factor, however, proved to be minor when negligible change in the coefficient was observed on the 10-inch pipe and 18-inch metergate when walls were placed within the boxes and 1 diameter from the edges of the entrances, and only slight changes resulted for walls placed as close as 1/4 diameter.

The floors of the head boxes were 1.2, 1.0, and 0.6 diameters below the inverts of the entrances for the 10-, 18-, and 24-inch installations. Comparison of the data used to plot the curves of Figure 5 shows that the floor position may affect the coefficient considerably. In fact, the agreement of the data from the 10- and 24-inch installations is quite good when the floors and walls were arranged geometrically similar (sloped floor 0.17 d below invert and 8 to 1 flaring walls at $\frac{d}{4}$ from edges of entrance) even though the configurations of the headwalls near the entrances were quite different (dotted lines, Figure 5 and Figure 20). The headwall for the 10-inch pipe was flat and smooth, while that for the 24-inch gate contained the support angles, seat casting, bolts, and gate. It is reasonable to conclude that very close agreement would result for all sizes in which good geometric similarity of the entrances exists. The foregoing discussion is limited to the case where the pipe entrances have submergences greater than 1.0d above their crowns.

Tests on the 10-inch installation, with the downstream pressure tap 12 inches from the entrance, showed little influence from the approach walls when the submergence was greater than about 1.0d, but showed considerable influence from the floor position (Figure 15). The tests also showed considerable influence from both the wall and floor positions for submergences less than 1.0d.

The influence of the wall and floor positions at submergences greater than 1.0d, particularly the floor position, varied with the positioning of the downstream pressure tap (measuring well), (Figure 14). Tests on the 18-inch metergate showed little influence from the walls for the one floor position tested (Figure 13). The floor arrangement in this case was not geometrically similar to any tested on either the 10- or 24-inch installations. The maximum wall influence for all positions of the downstream pressure tap and two floor arrangements in tests on the 10-inch pipe entrance was about 3 percent, while the maximum influence of the two floor arrangements for various positions of the walls and downstream pressure tap was about 10 percent (Figure 14). From the data on Figure 14, it is concluded that the influence of wall and floor positions can be minimized by placing the downstream pressure tap $\frac{d}{3}$ from the entrance near the lowest part of the hydraulic grade and providing submergences greater than d. Results were most inconsistent and the influence was most pronounced when the pressure tap was located on the steep portion of the pressure gradient from 0.4d to 1.5d from the entrance. The data also show that a minimum error in determining gate discharge at large gate openings (100 percent open in this case) will be realized for a wall position of $\frac{d}{2}$ from the edges of the entrance and a downstream pressure tap location of $\frac{d}{3}$. The influence of approach floor elevation is also a minimum. The maximum scatter of individual test points with this arrangement was approximately plus or minus 2 and 1/2 percent.

From the information and data presented above, it is concluded that a constant discharge coefficient of 0.61 can be used for 100 percent opening for all metergates which are geometrically similar and are contained in geometrically similar settings as shown in Figure 12, when the downstream pressure tap is a distance of $\frac{d}{3}$ from the entrance and the entrance submergence is d or greater.

Placing the downstream pressure tap a constant distance of 12 inches from the entrance and the use of submergences less than d make each installation and size a special problem and may necessitate special in-place calibration in cases which differ appreciably from the tested arrangements. The influence of the various factors decreases rapidly as the gate leaf is closed from the wide-open position, becoming minor at about 75 percent gate opening (Figures 13 and 16).

Influence of Outlet Submergence

The tests on the different size gates disclosed that submergence of the downstream end of the discharge pipe (h_s, Figure 3) would be an important factor in providing a measurable water surface elevation in the downstream measuring well. Because of structural limitations, it was assumed that the water surface within the downstream measuring well should be at least 6 inches above the inside surface at the crown of the pipe. The submergence needed to give this condition at various gate openings varied according to a pressure factor $\frac{\Delta H}{H_D}$ (Figures 17, 18, and 19). The plots of this factor against gate opening show that the greatest submergence of the downstream end of the discharge pipe is needed for gate openings between 60 and 80 percent. The outlet submergence required to give a measurable water surface in the downstream well is influenced by the position of the pressure tap along the hydraulic grade line. With all taps 12 inches downstream from the gate seat, relatively greater submergence is required for the larger gate sizes. However, the difference is small.

Since H_D is the difference between the pressure head upstream from the gate and the maximum pressure head in the pipe below the gate, the frictional resistance of the downstream pipe, particularly if the pipe is long, and the elevation of the center line both at the gate and at the pipe exit, are important factors to be considered. For a given gate size and discharge, the maximum value of ΔH and the minimum value of h_s (downstream submergence) can be computed to give a downstream measuring well water surface 6 inches above the crown of the pipe at the measuring well connection. This is illustrated in Figure 26.

Influence of Velocity

In the tests on metergates there was an indication that flows at very low velocities affected the capacity of the metergate when it was operating at large openings. The effect of velocity, or variation with Reynolds number, however, could not be isolated using the data taken. By exercising extreme care in obtaining the pertinent data in a more recent study concerning the pressure distribution in a 10-inch pipe entrance placed flush with a headwall, 1/ it was possible to isolate the effect of low velocities for small submergences and large gate openings. The influence was noticeable at very low values of R_e only, in this case below about 2.0×10^5 for the unobstructed entrance. The influence of R_e would vary some with downstream pressure tap location, but would be minor in any case.

1/Hydraulic Laboratory Report Hyd-422, "Flow Characteristics in a Pipeline Downstream from a Square Cornered Entrance."

Influence of Downstream Head-measuring Pressure Tap Location

The nature of the pressure grade line in the crown of the pipe line immediately downstream of a metergate leaf results in a change in differential head, ΔH, with location of the downstream pressure tap. This is particularly true for large gate openings. With the pressure tap located 12 inches from the gate seat for all sizes of gates, it is not possible to make a direct comparison of the coefficient curves for the various sizes. However, with taps placed at relative positions along the pressure grade lines (at same value of $\frac{x}{d}$), a comparison can be made. The variation of the discharge coefficient with tap position for a 10-inch pipe, and 18-inch gate, and a 24-inch gate for various openings is shown on Figures 20, 21, 22, and 23. The comparison of the coefficient curves for the 18- and 24-inch gates based on pressure taps placed at the same $\frac{x}{d}$ value is shown also. There is good agreement considering the various differences in the test installations. Excellent agreement was noted between the 24-inch gate and the 10-inch pipe when the settings were geometrically similar (Figure 20). Calibration curves for one gate may be applied to another only when the pressure taps have the same relative locations (same value of $\frac{x}{d}$). From these data, it is evident that the differential head, and thus the coefficient of discharge, varies with pressure tap location. Therefor, it is important that calibration curves or tables be based on the particular tap location for the gate in question.

The data from the 10-inch pipe entrance indicated that the positioning of the downstream pressure tap for the measuring well is extremely important when the distance from the entrance to the tap is from about 0.4 to 1.5 pipe diameters. In this range, the tap will be in the region where the hydraulic grade line is steep and a small mislocation can introduce a substantial difference in pressure head and error in indicated discharge.

Locating the tap for the downstream head-measuring well a constant distance of 12 inches from the entrance for all gate sizes places them at different relative positions along the hydraulic grade line. This in effect makes a special problem for each size. For example, an 8-inch gate will have a tap position 1.5d from the entrance with a coefficient for full opening of about 0.80, a 24-inch gate will have a tap position 0.5d from the entrance on the steep part of the hydraulic grade line with a coefficient of about 0.65, and a 48-inch gate will have a tap position 0.25d from the entrance on a fairly flat portion of the hydraulic grade line with a coefficient of about 0.60. The exact location of the tap would be less critical for the 8- and 48-inch size than the 24-inch size. With the constant tap distance of 12 inches, the coefficient will vary with metergate size from about 0.6 to 0.8. The logical conclusion is that the tap should be placed at a geometrically similar position, such as $\frac{d}{3}$ for all sizes. The position chosen should be that which would be least affected by the physical characteristics of the entrance. It was concluded that locating the downstream tap at $\frac{d}{3}$ would accomplish this. The differential head for this location would be about the maximum, and more accurate readings would be expected. While tap positions beyond about 1.5d would give fairly constant values of the discharge coefficient, the differential head for a given discharge would be a minimum and less accuracy for small discharges would be expected. In either case, it is believed that one coefficient curve could be used for all sizes of gates provided the entrances have reasonably close geometrical similarity, the tap is located at a constant relative distance from the entrance, and the upstream submergence is maintained greater than about 1.0d above the top of the entrance. A plot of all values of the ratio $\frac{C_d}{C_a}$ against submergence in terms of d for the 10-inch pipe entrance with various wall and floor distances is shown on Figure 24. The plot shows that nearly all points fall within plus or minus 2 and 1/2 percent for upstream submergences greater than d above the top of the entrance and a tap distance of $x = \frac{d}{3}$. The same is true for similar data taken from the 18- and 24-inch metergates (Figures 8, 9, 10, and 11).

Point of Pressure Recovery Downstream of Gate

It is important that an installation have sufficient pipe length below the gate to prevent drawing the water out of the downstream measuring well at partial gate openings and to minimize erosion when the water is released into an earthen ditch. For a given average velocity, the erosion of an earthen ditch will be a minimum when the velocity leaving the end of the pipe is uniform. Such a uniform distribution is not attained until the point of pressure recovery on the hydraulic grade line is reached. The point of pressure recovery was noted for various openings and discharges for both the 18- and the 24-inch gates. From the results shown on Figure 25, it was concluded that 7 pipe diameters could be used as a criterion. This is in good agreement with similar data obtained previously for metergates with circular leaves. The plotted points in both cases were based on interpolation of piezometric data and thus the curves are not as smooth as might be expected.

Installation Instructions

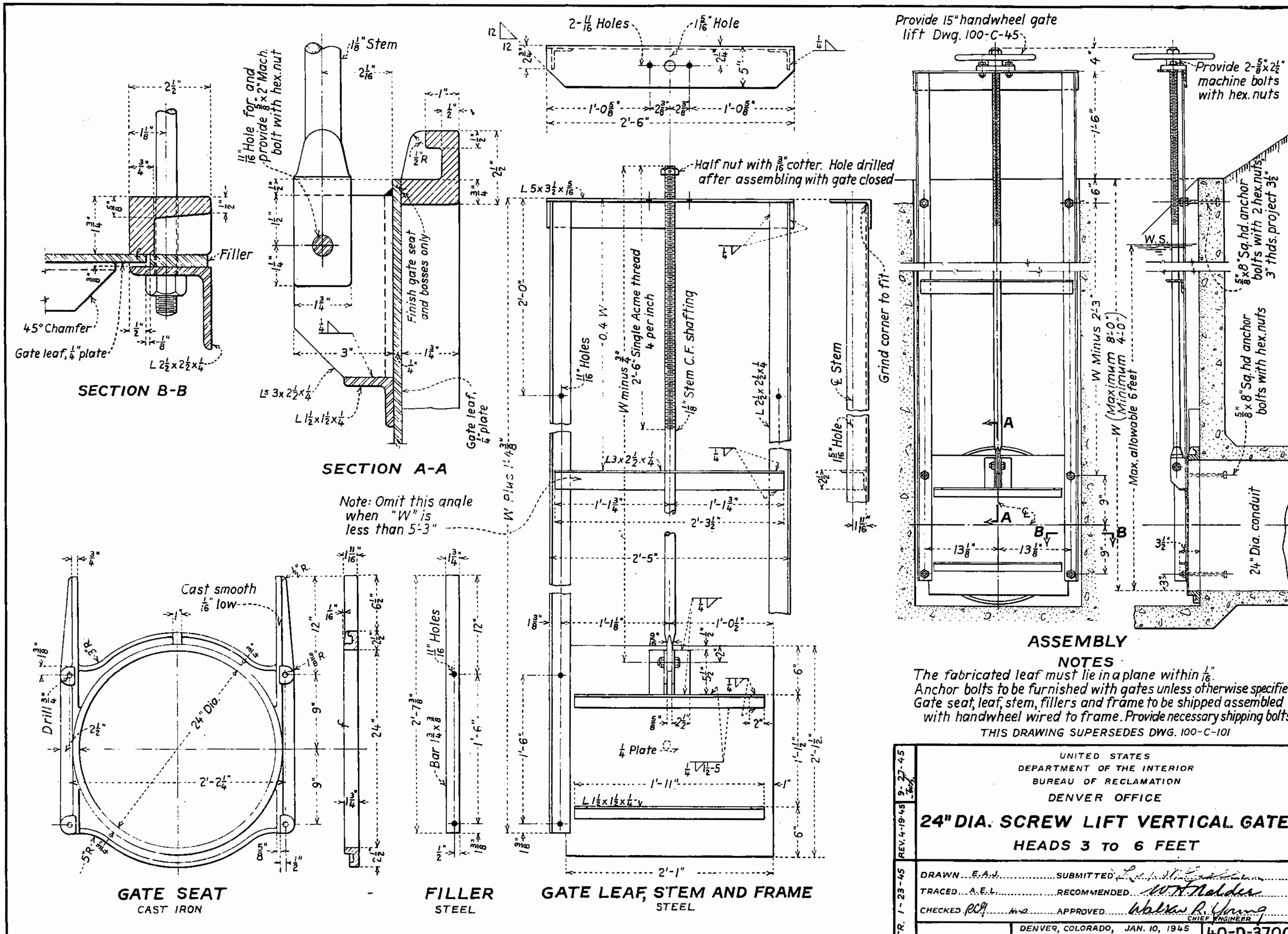
A typical metergate installation, which will meet discharge requirements and have all operating characteristics within the limitations indicated from these studies, can be determined from Figure 26.

Rating Curves

Rating curves for the 18- and 24-inch gates were obtained by laboratory calibration of these gates. Discharge curves for differential heads up to 18 inches and various gate openings for metergates with and without confined approaches have been prepared from the test data (Figures 27 through 30). By knowing the gate opening and differential head for a given installation, the discharge can be obtained from the curves. The curves are based on data which minimize the influence of upstream submergence (submergences greater than d).

The rating curves for the 30-inch gate (Figures 31 and 32) were developed from the pressure data taken from the 18- and 24-inch gates. The data were plotted in dimensionless form and values for an $\frac{x}{d}$ of 0.4 used to compute points for the rating curves. The discharges obtained by using these curves should be quite accurate for settings similar to the test facility.

Appropriate location of pressure taps and accurate zeroing of gages and gate opening indicators are important factors in assuring the accuracy of metergate installations. Zero gate opening is defined as position of gate when bottom of leaf is level with entrance invert.



NOTES

The fabricated leaf must lie in a plane within 1/16".
Anchor bolts to be furnished with gates unless otherwise specified.
Gate seat, leaf, stem, fillers and frame to be shipped assembled with handwheel wired to frame. Provide necessary shipping bolts.

THIS DRAWING SUPERSEDES DWG. 100-C-101

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER OFFICE

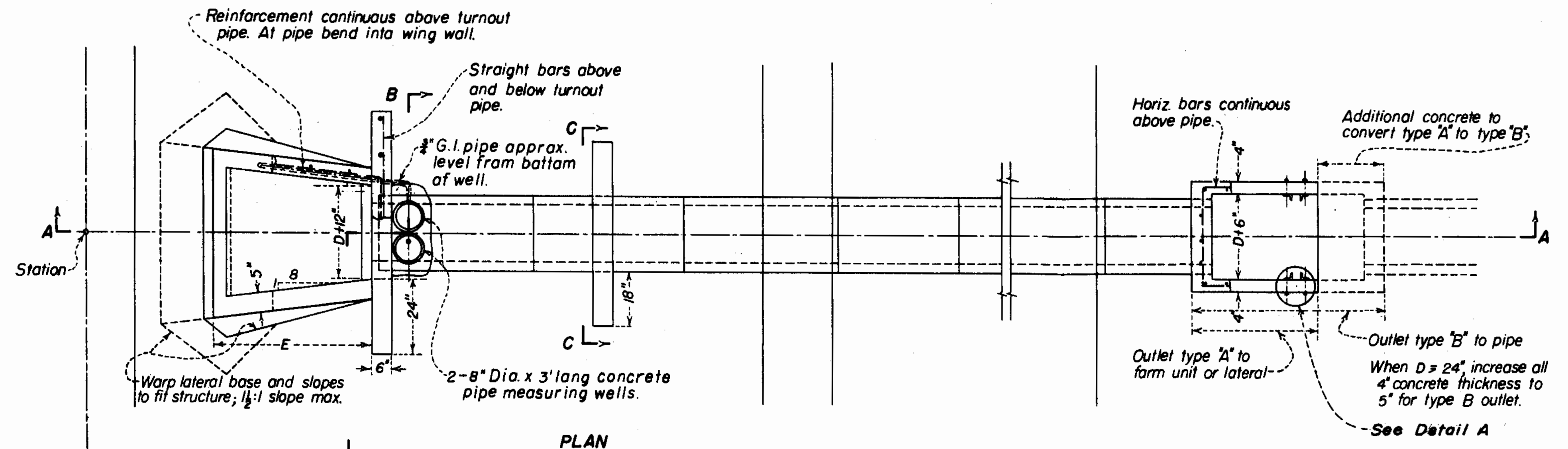
24" DIA. SCREW LIFT VERTICAL GATE
HEADS 3 TO 6 FEET

DRAWN E.A.J. SUBMITTED [signature]
TRACED A.E.L. RECOMMENDED W. H. Nalder
CHECKED RCH APPROVED Walker R. Young CHIEF ENGINEER

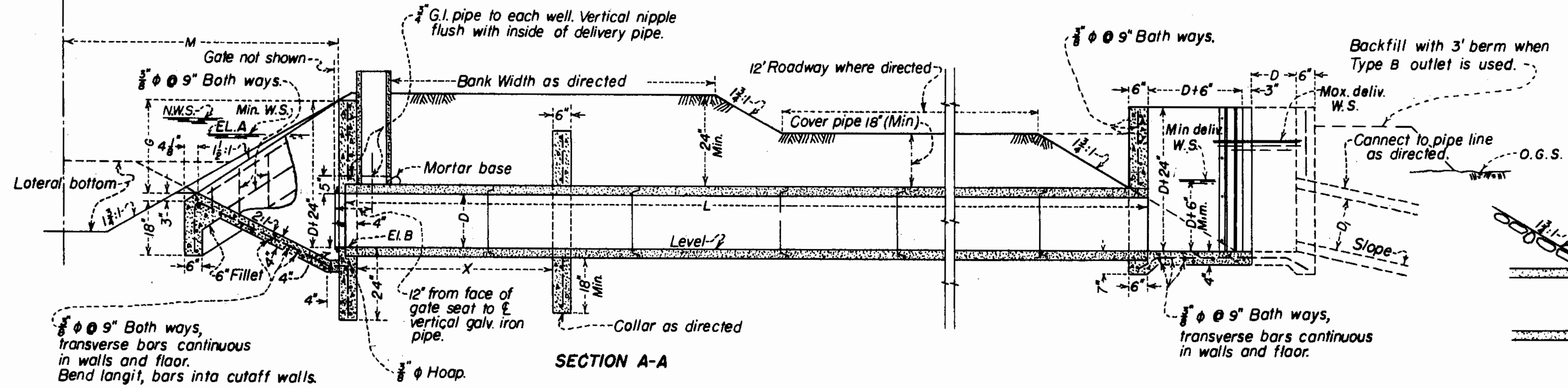
DENVER, COLORADO, JAN. 10, 1945 40-D-3700

TR. 1-23-45 REV. 4-19-45 9-27-45

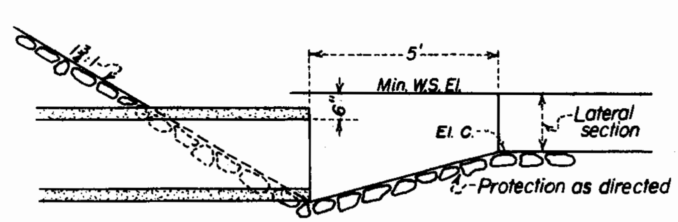
FIGURE 1
REPORT HYD. 471



PLAN



SECTION A-A



OUTLET TYPE "C"
TO LATERAL OR WEIR POOL ONLY

TABLE OF LOCATIONS, TYPES, DIMENSIONS & ELEVATIONS															
LATERAL	STATION	T.O. to Lateral or F.U. No.	Rt. or Lt.	M	ELEVATIONS A	ELEVATIONS B	Outlet Type	PIPE D	PIPE L	Collar Dist. X	DELIVERY Max. Q	DELIVERY Max. Del. W.S. El.	TYPE C El. J	TYPE C Slope	TYPE C El. C
EL 6	1 + 43.73		Rt.	*	1308.70	1305.95	A(2)	18"	00'*		4	1308.36	—	—	—
EL 6.9	15 + 75.00	EL 6.9A	Rt.	11.88	1306.41	1304.03	A(2)	21"	16'		5	1306.08	—	—	—
EL 6.9	42 + 22.50	EL 6.9B	Rt.	11.77	1306.41	1303.69	A (2)	18"	12'		5	1305.99	—	—	—
EL 6.9	62 + 70	EL 6.9D	Rt.	11.81	1306.31	1303.52	C (1)	15"	8'	T.O. & WEIR	5	1302.82	—	—	1300.93
EL 6.9	74 + 00		Rt.	10.23	1305.58	1303.02	A	18"	20'		4	1305.30	—	—	—
EL 6.9	104 + 50		Rt.	10.23	1305.58	1301.91	A	24"	16"		6	1305.31	—	—	—
EL 6.9	117 + 86	EL 6.9E	Rt.	10.23	1304.57	1301.64	A	24"	16'		10	1304.15	—	—	1302.84
EL 6.9	135 + 39.35	EL 6.9EE	Rt.	10.22	1304.57	1301.72	A	18"	16'		6	1304.17	—	—	—
EL 6.9	152 + 70.53	EL 6.9F	Lt.	10.25	1304.57	1301.41	C	18"	12'		4	1304.30	—	—	—
EL 6.9	180 + 49.35		Lt.	*	1293.74	1289.74	C	18"	8'		6	1293.36	—	—	—
EL 6.9	180 + 49.35		℄	*	1293.74	1289.74	B	30"	8'		24	1292.93	30"	.1471	—
EL 6.9	210 + 76.29		Lt.	*	1285.25	1282.75	A	18"	28'		6	1284.79	—	—	—
EL 6.9E	14 + 35.55		℄	*	1302.19	1299.69	C	18"	8'		5	1301.93	1299.20		—
EL 6.9E	21 + 75.8		Lt.	*	1297.43	1294.43	C	24"	8'		4	1297.16	1294.07		—
EL 6.9H	26 + 27.97		℄	*	1287.80	1283.80	A	18"	20'		5	1287.50	—	—	—
EL 6.9H	35 + 66.14		Lt.	*	1283.56	1279.31	A	18"	8'		5	1283.28	—	—	—
EL 6.9H	57 + 50		Rt.	*	1280.50	1278.00	C	18"	20'		2	1280.24	—	—	—
EL 6.9H	57 + 50		Lt.	*	1280.50	1278.00	A	18"	8'		3	1280.24	—	—	—
EL 6.9H	94 + 11.6	EL 6.9H1	Lt.	*	1273.00	1269.00	C	21"	24'		13	1271.97	—	—	1270.37
EL 6.9H	94 + 11.6		Rt.	*	1273.00	1269.00	C	18"	20'		4	1272.74	—	—	—
EL 6.9H	106 + 84.07		℄	*	1266.74	1263.74	C	15"	12'		4	1266.41	—	—	—
EL 6.9H	122 + 61.47		Rt.	*	1262.83	1260.33	C	18"	20'		4	1262.55	1260.00		—
EL 6.9H	137 + 50.17		Rt.	*	1255.80	1253.30	C	18"	8'		4	1255.54	1252.85		—
EL 6.9H1	13 + 77.25		Rt.	*	1268.67	1266.42	C	15"	12'		4	1268.37	1265.90		—
EL 6.9H1	25 + 64.98		℄	*	1266.52	1263.52	A	15"	14'		4	1266.20	—	—	—
EL 6.9H1	34 + 77.48		Lt.	*	1265.68	1263.43	A	15"	12'		4	1265.37	—	—	—
EL 6.9H1	46 + 33.38		Rt.	*	1263.84	1261.10	A(2)	18"	8'		5	1263.36	—	—	—

* T.O. from division box. See Division Box drawing for gate data. (1) Omit Measuring Wells. (2) Outlet Str. to be placed at end of Road Crossing.

NOTES

All reinforcement shall be placed in the center of slab unless otherwise shown.

All exposed bolts to be galvanized.

Turnout shall be connected to road crossing at "L" distance from headwall where directed.

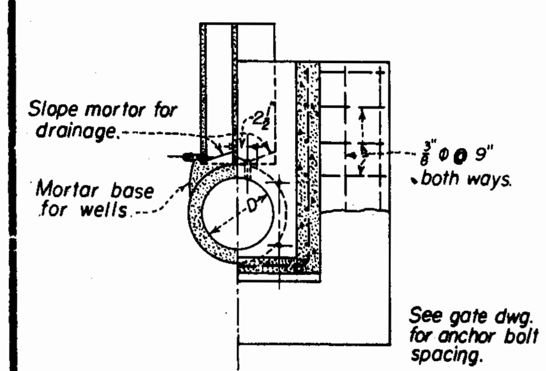
Number and location of collars to be as directed.

This structure limited to D of 30".

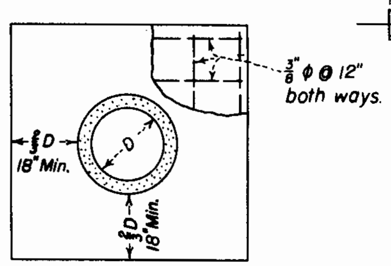
Measuring wells to be omitted where directed.

Gate anchor bolts to be set in position before concrete is placed.

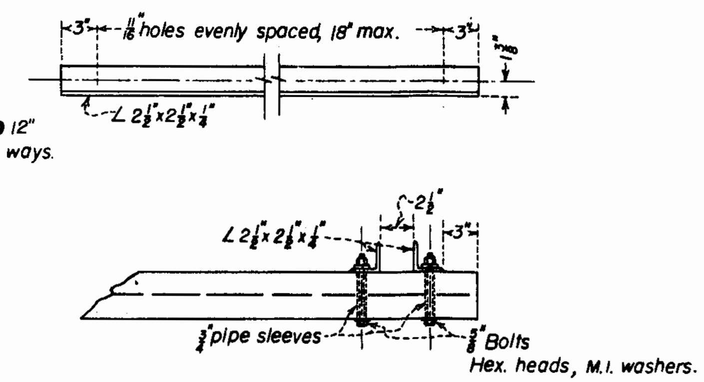
* Pipe shown on Rd.-X-ing Dwg. 222-116-8589



SECTION B-B



SECTION C-C



DETAIL "A"
STOP PLANK GROOVE

D	TURNOUT STRUCTURE G	TURNOUT STRUCTURE E	TURNOUT STRUCTURE Conc. Cu. Yds.	TURNOUT STRUCTURE Reinf. Steel Lbs.	GATE Frame Ht.	GATE Wt.	OUTLET TYPE A Conc. Cu. Yds.	OUTLET TYPE A Reinf. Steel Lbs.	Misc. Metal Lbs.	OUTLET TYPE B Conc. Cu. Yds.	OUTLET TYPE B Reinf. Steel Lbs.
12"	2'-0"	3'-4"	0.9	59	5	80	0.3	20	55	0.5	34
15"	2'-1¾"	3'-6¾"	1.0	65	5	90	0.4	23	59	0.6	41
18"	2'-3½"	3'-9¼"	1.1	72	5	149	0.4	28	63	0.8	48
21"	2'-5"	3'-11¾"	1.2	78	5	175	0.5	32	69	0.9	57
24"	2'-7"	4'-2½"	1.3	86	5	200	0.6	35	74	1.0	65
30"	2'-10½"	4'-7½"	1.6	102	5	365	0.7	46	83	1.3	86

TABLE OF DIMENSIONS AND ESTIMATED QUANTITIES*

* Exclusive of collars

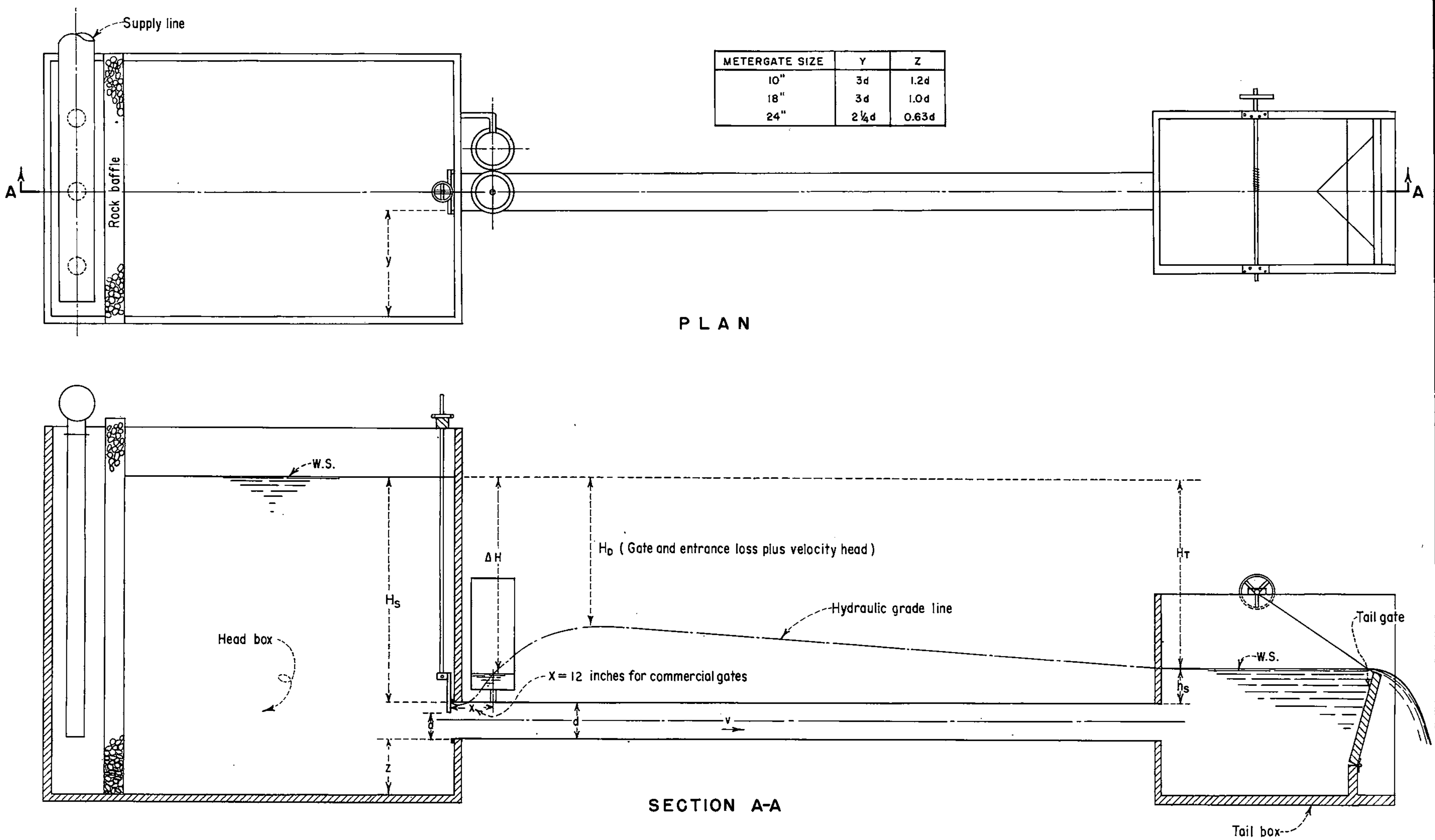
1-26-56 D. C.P.M. — AS BUILT BY 116 - LTR. 2-19-54

6-12-50 A.J.D. | REVISED 12-7-49 A.J.D. S.W.A. | 8-30-50 S.W.A. A.J.D. | 1-17-50 S.W.A. A.J.D. | 6-9-53 HS H.E.M.G. | 2-27-50 S.W.A. A.J.D.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT—WASHINGTON
EAST LOW CANAL LATERALS – AREA E-1
PIPE TURNOUTS WITH MEASURING WELLS
TYPE 2 – EL.6 TO EL.6.9 H1

DRAWN J.C.P.-R.G.M. SUBMITTED A.J. Davidson
TRACED H.E.M. RECOMMENDED E.F. Rice
CHECKED E.R.B. APPROVED L.N. McClellan
CHIEF ENGINEER

222-P-8034 | EPHRATA, WASHINGTON SEPT. 30, 1949 SHEET 1 OF 5 | 222-D-14571



METERGATE SIZE	Y	Z
10"	3d	1.2d
18"	3d	1.0d
24"	2¼d	0.63d

SCREW LIFT VERTICAL METERGATE

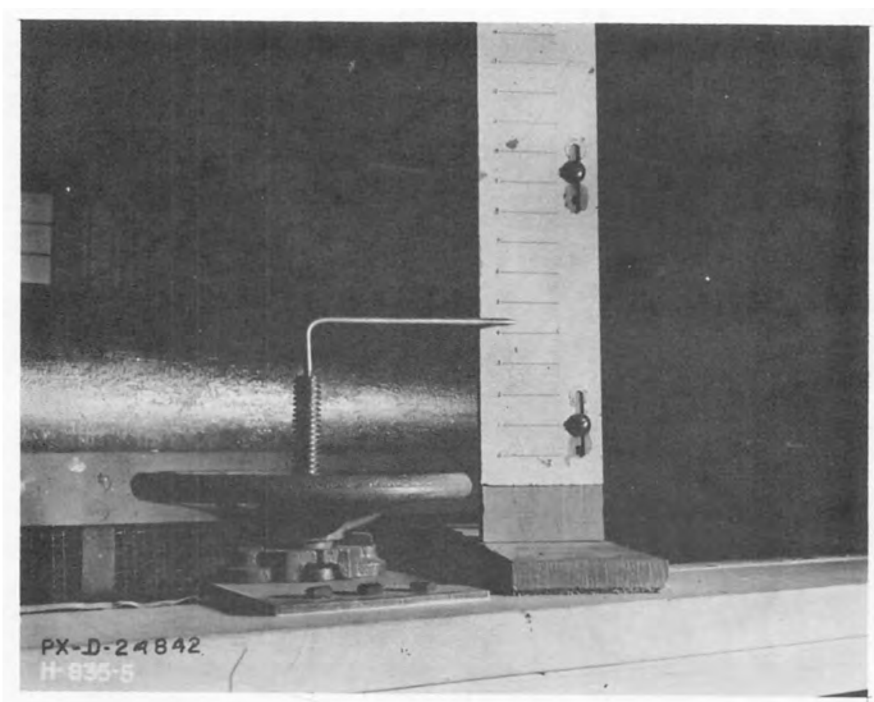
LABORATORY TEST INSTALLATIONS

573

FIGURE 3
REPORT HYD. 471

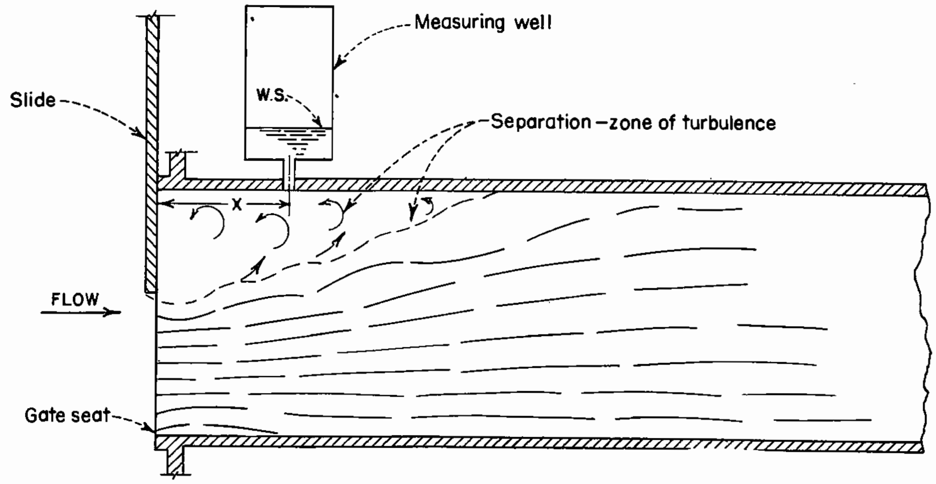
Figure 4
Report Hyd 471

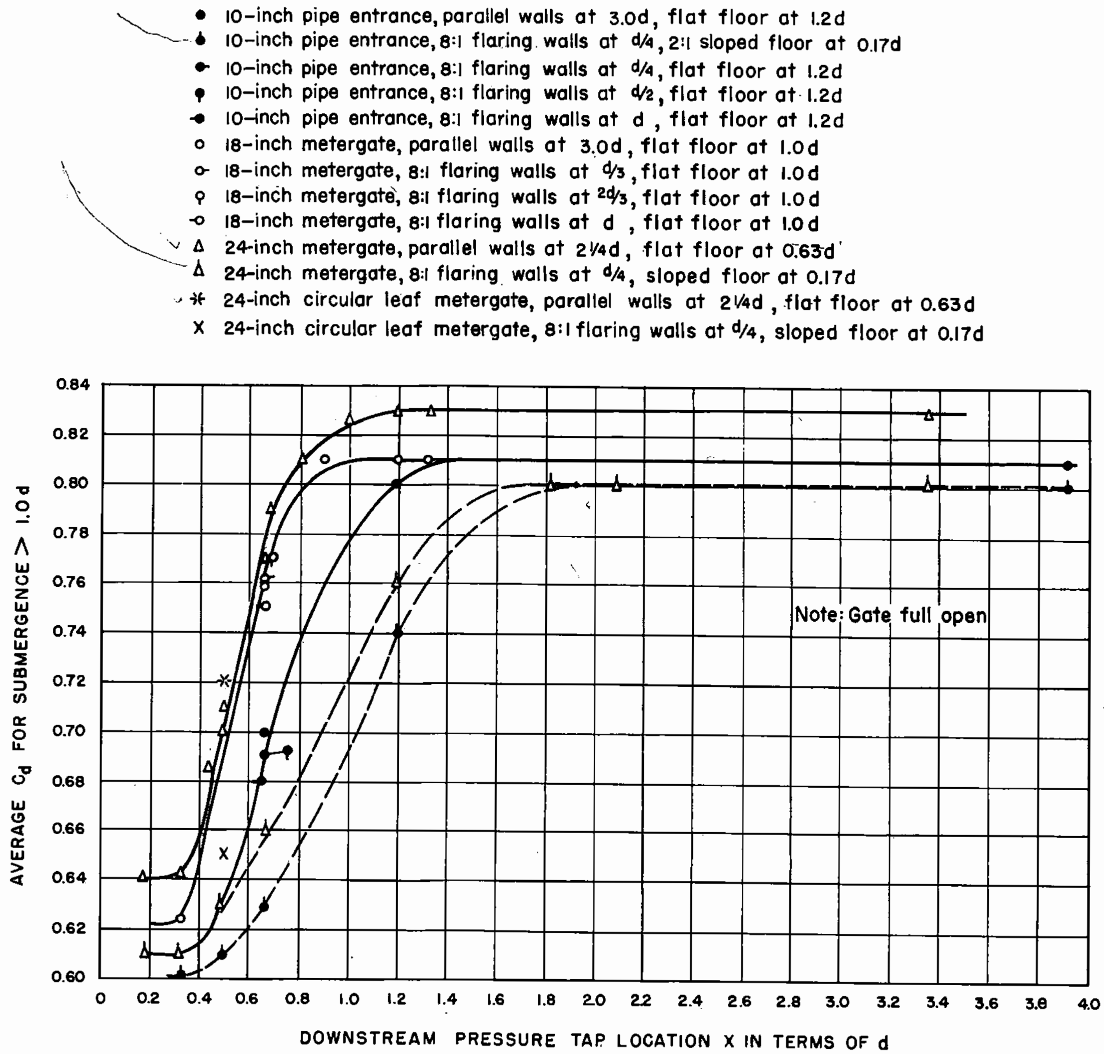
A. 24-inch laboratory test installation



B. Gate opening indicator

Screw Lift Vertical Metergates
Laboratory Test Facility

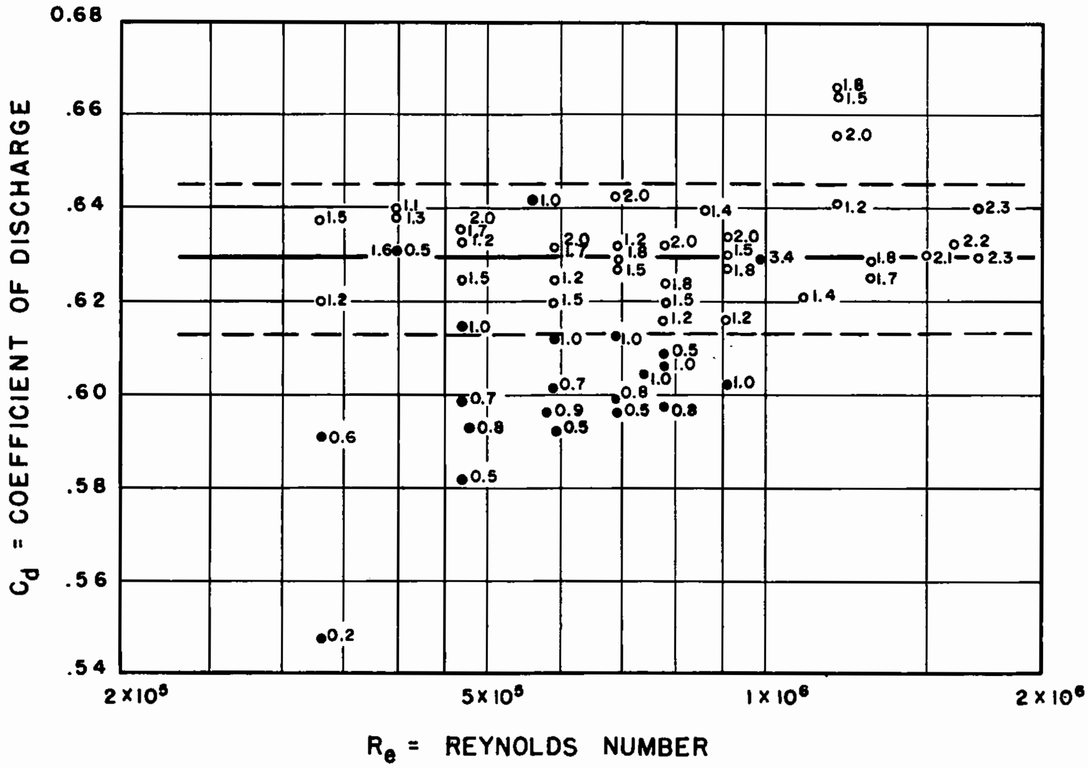




SCREW LIFT VERTICAL METERGATE

DISCHARGE COEFFICIENTS

18- AND 24-INCH METERGATES AND 10 INCH PIPE ENTRANCE



EXPLANATION

o	Submergence > 1.0 d
•	Submergence ≤ 1.0 d
•1.0	Submergence in terms of d
———	Average coefficient for submergence > 1.0 d
— — —	Dashed lines lie 2½% above and below the average coefficient for submergence > 1.0 d

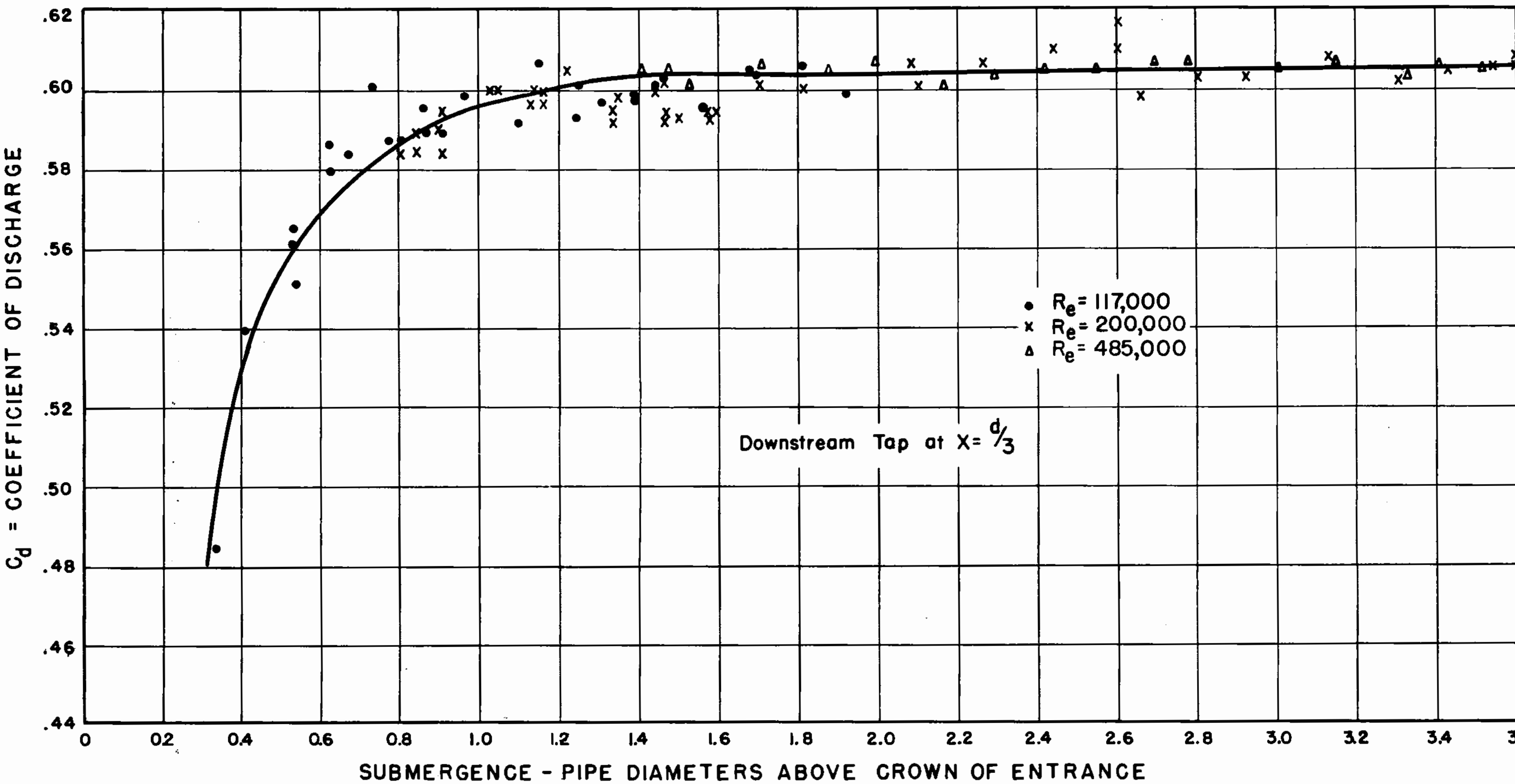
NOTES

2:1 Sloping floor 0.17d below entrance invert
8:1 Flaring walls d/4 from edges of entrance

SCREW LIFT VERTICAL METERGATE

INFLUENCE OF UPSTREAM SUBMERGENCE AND VELOCITY ON CAPACITY

24" METERGATE FULL OPEN



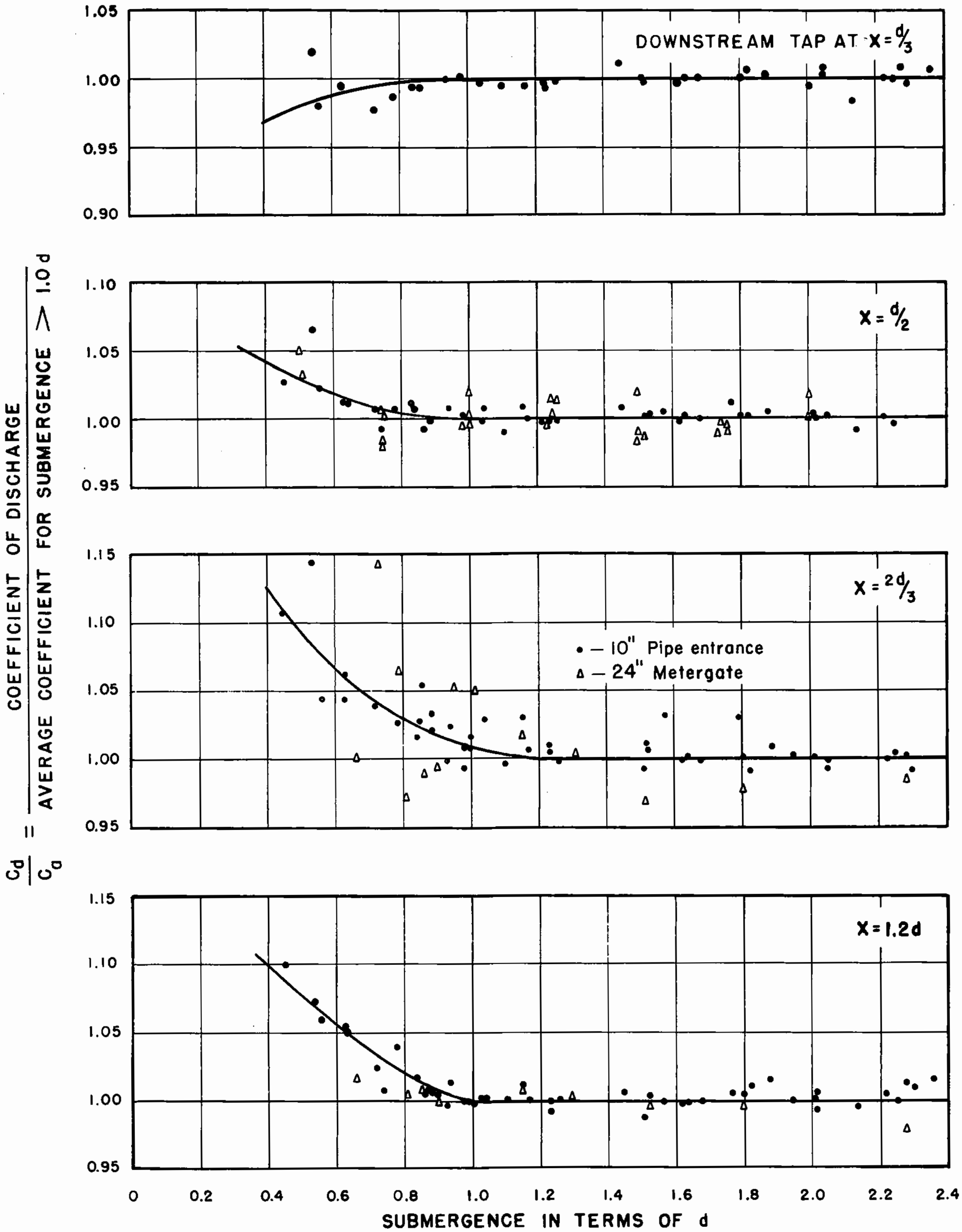
SCREW LIFT VERTICAL METERGATE

INFLUENCE OF UPSTREAM SUBMERGENCE

10-INCH ENTRANCE

FIGURE 7
REPORT HYD 471

573

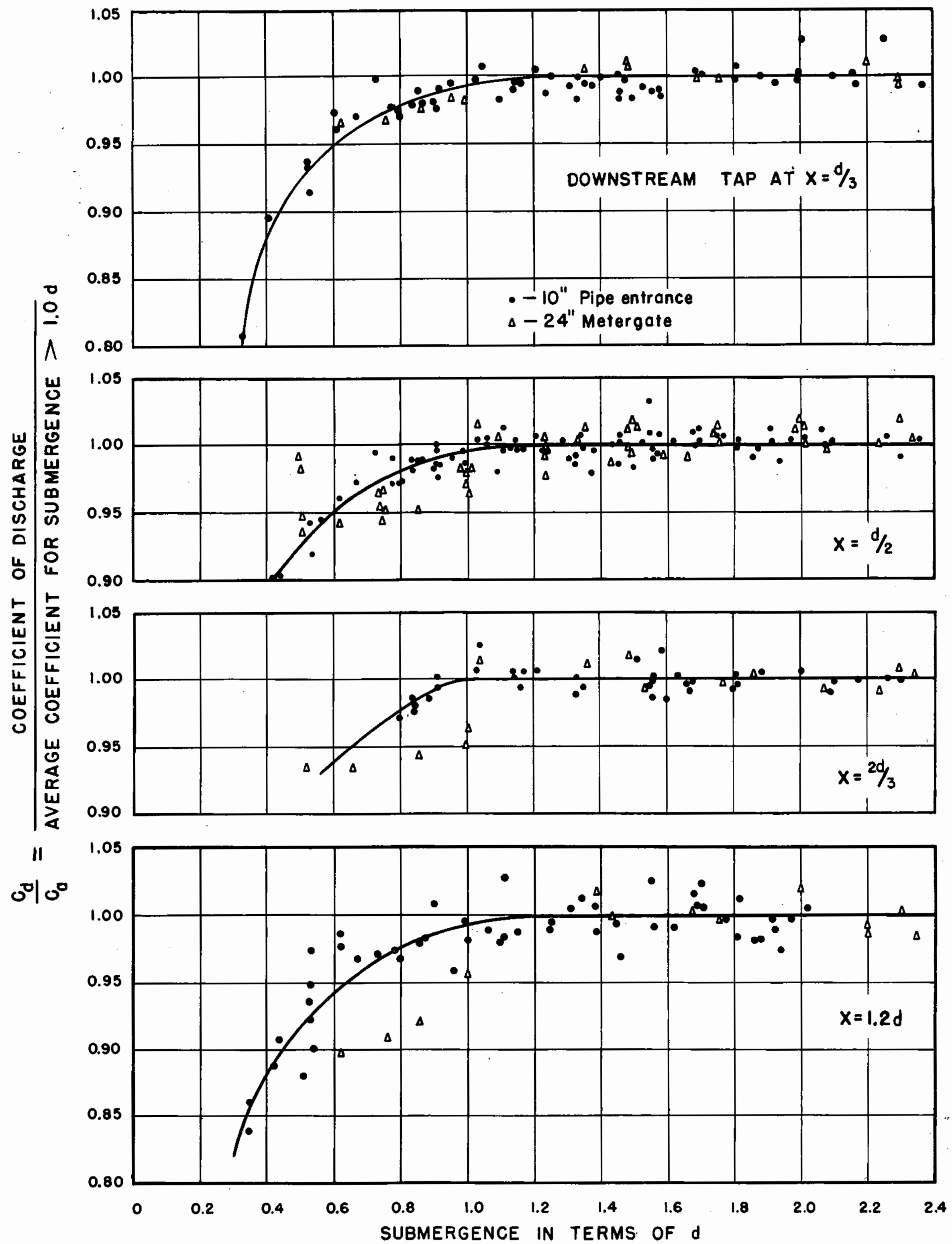


SCREW LIFT VERTICAL METERGATE

INFLUENCE OF UPSTREAM SUBMERGENCE ON CAPACITY

GATE WIDE OPEN, 2:1 SLOPED FLOOR

WITHOUT APPROACH WALLS

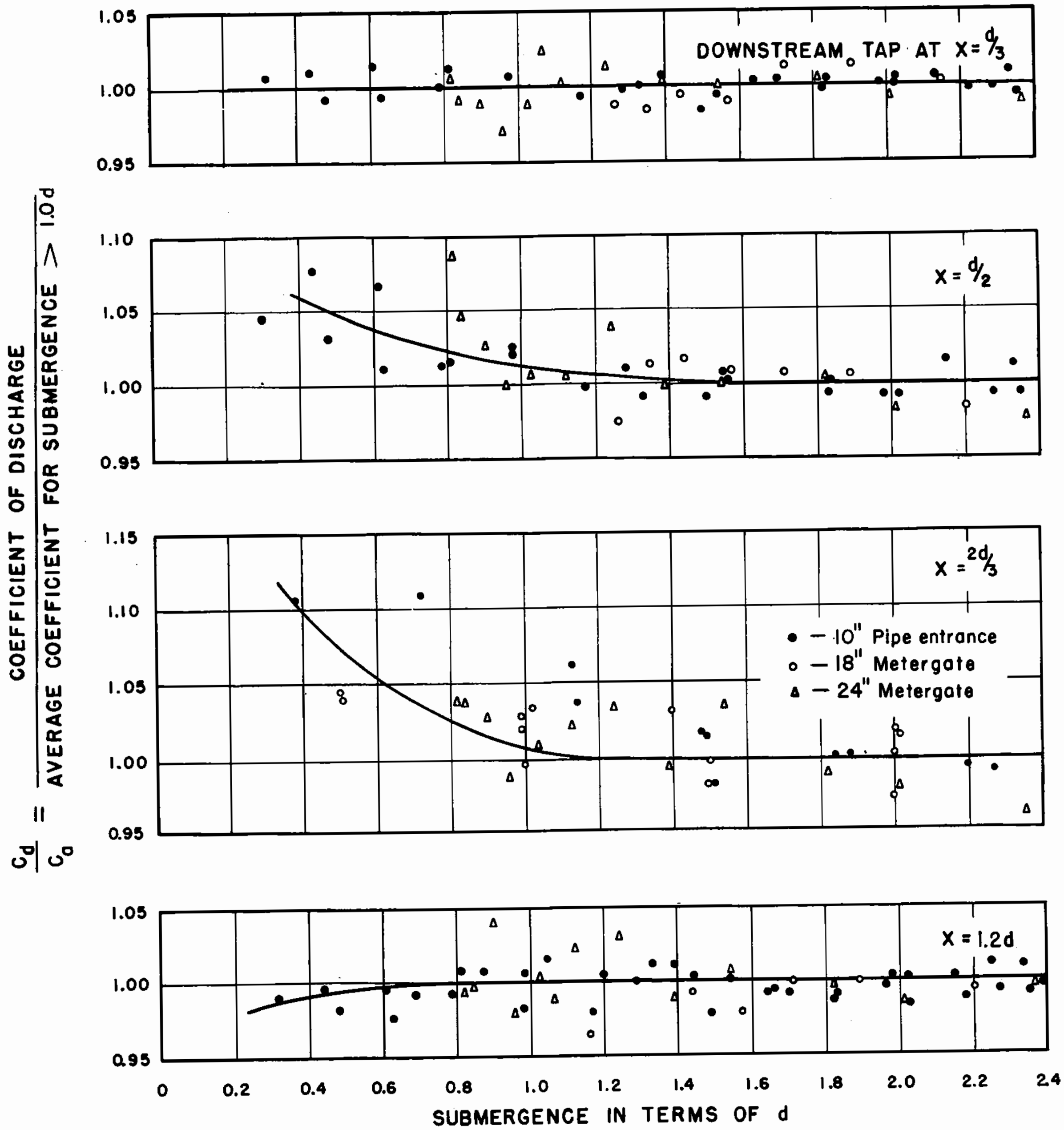


SCREW LIFT VERTICAL METERGATE

INFLUENCE OF UPSTREAM SUBMERGENCE ON CAPACITY

GATE WIDE OPEN, 2:1 SLOPED FLOOR

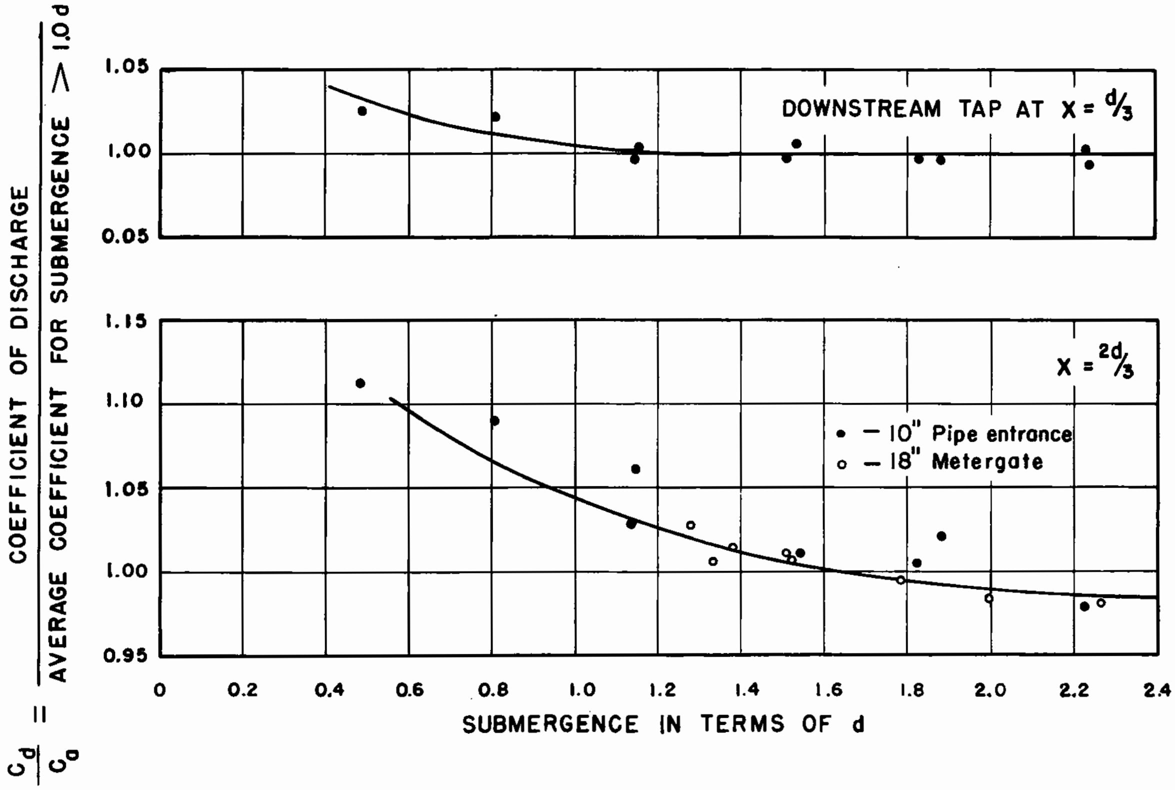
8:1 FLARING APPROACH WALLS AT d/4 FROM ENTRANCE



SCREW LIFT VERTICAL METERGATE

INFLUENCE OF UPSTREAM SUBMERGENCE ON CAPACITY

GATE WIDE OPEN, LEVEL FLOOR
AND WITHOUT APPROACH WALLS

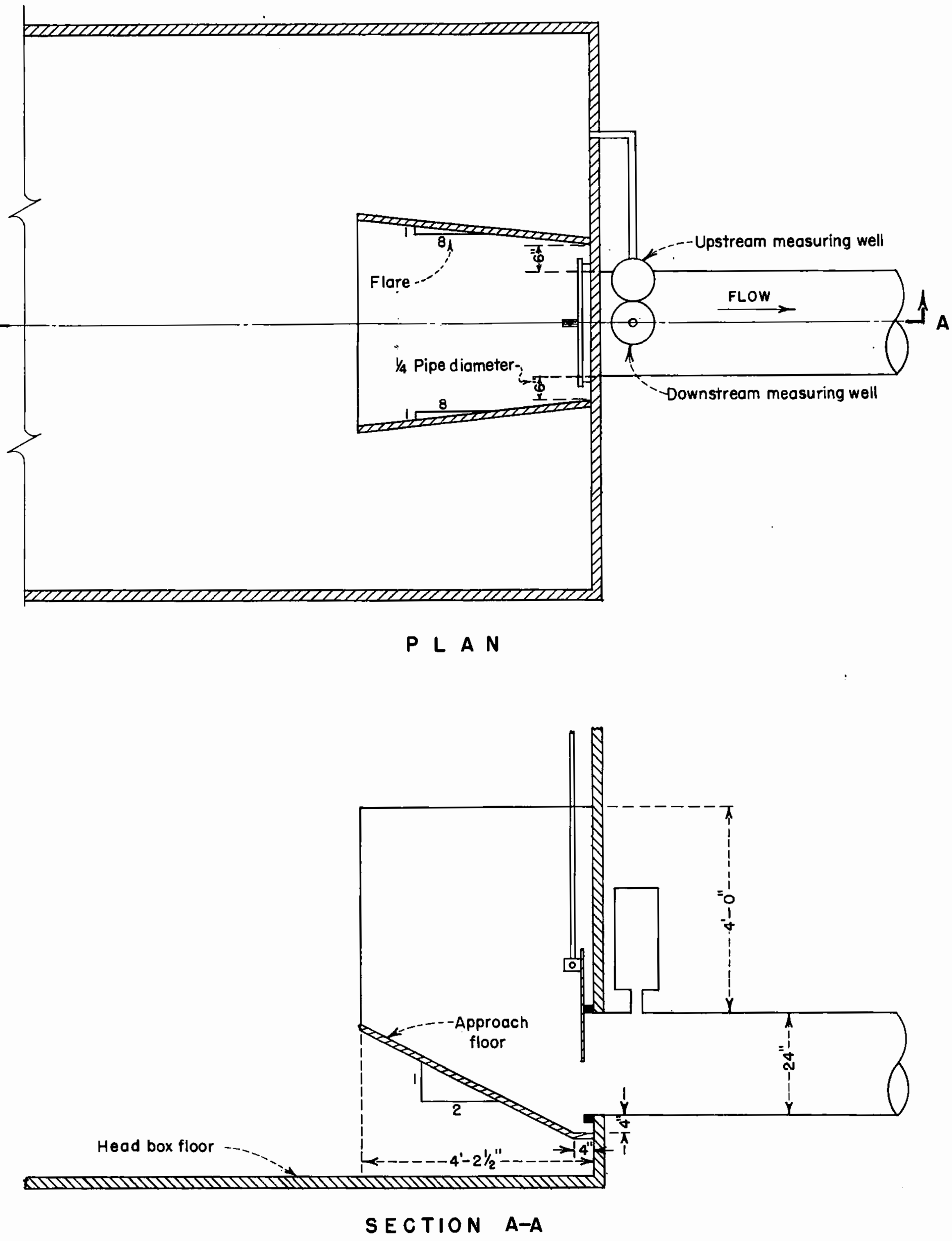


SCREW LIFT VERTICAL METERGATE

INFLUENCE OF UPSTREAM SUBMERGENCE ON CAPACITY

GATE WIDE OPEN, LEVEL FLOOR WITH 8:1 FLARING

APPROACH WALLS AT d/4 FROM ENTRANCE



SCREW LIFT VERTICAL METERGATE
APPROACH ARRANGEMENT TESTED
24-INCH METERGATE

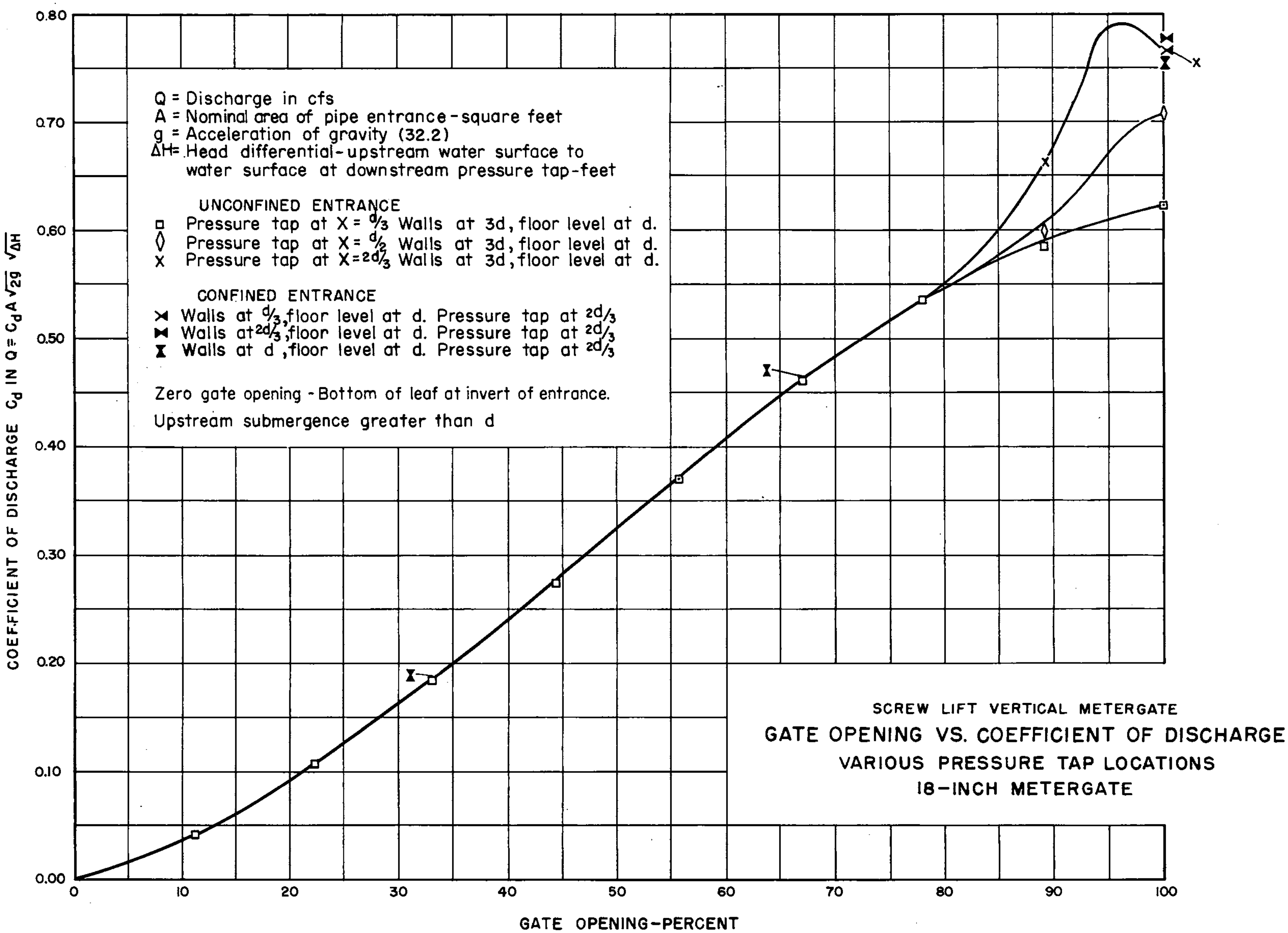
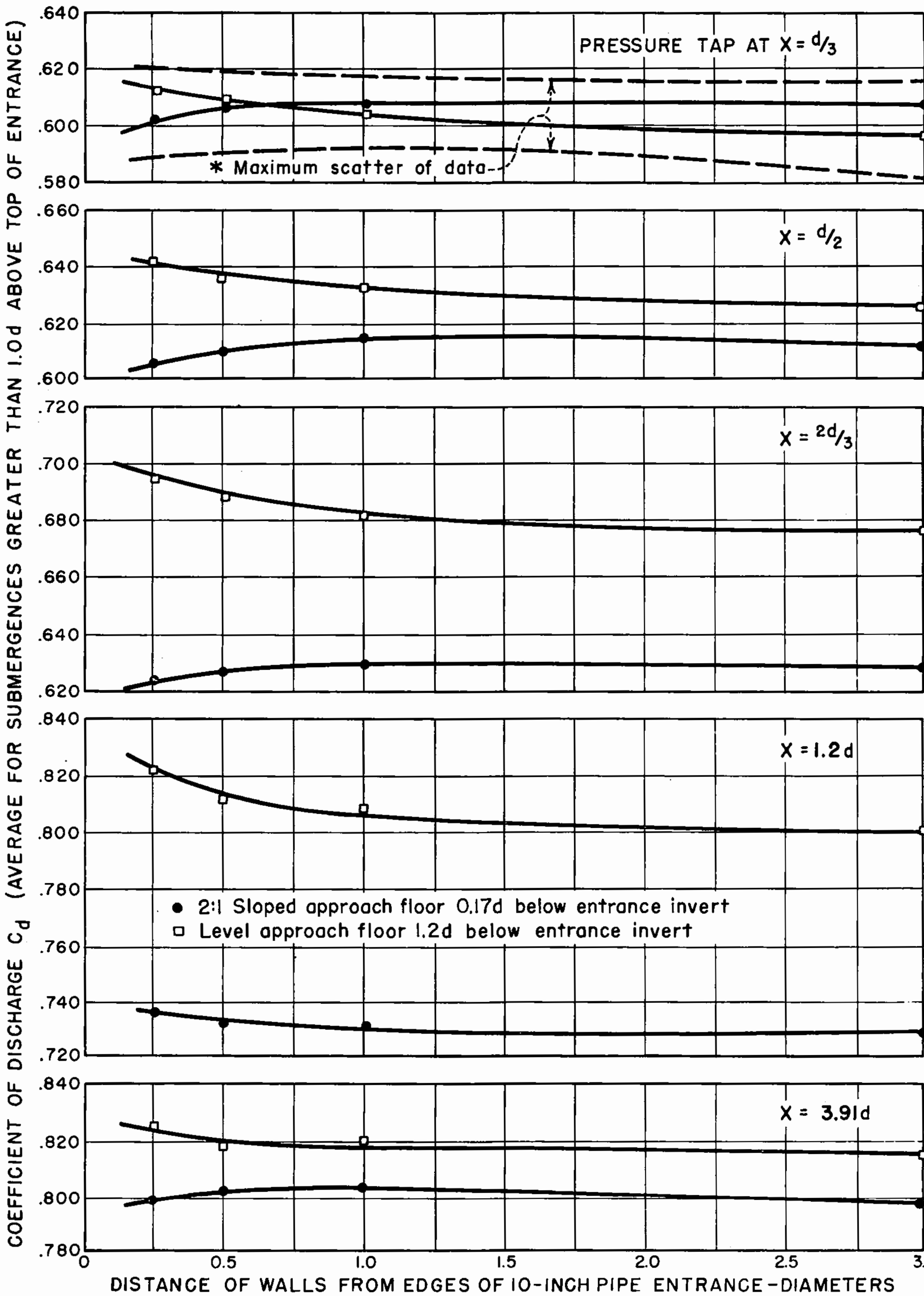


FIGURE 13
REPORT HYD. 471

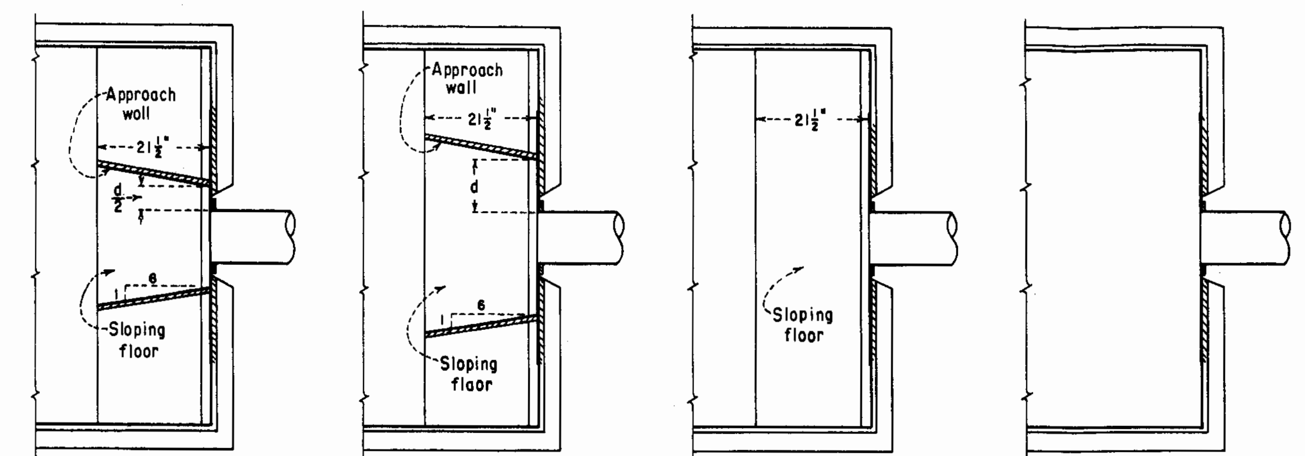


* Maximum scatter of data from average about ± 3% for all tap locations.

SCREW LIFT VERTICAL METERGATE

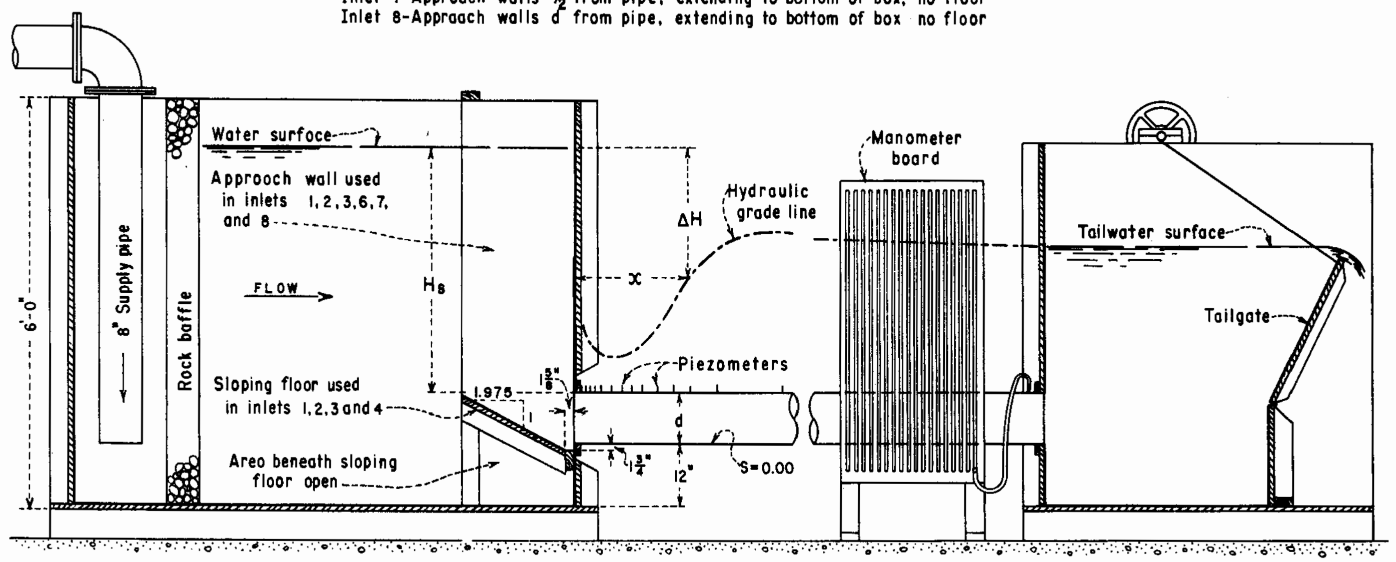
COEFFICIENT OF DISCHARGE

INFLUENCE OF APPROACH WALL, FLOOR AND PRESSURE TAP LOCATION

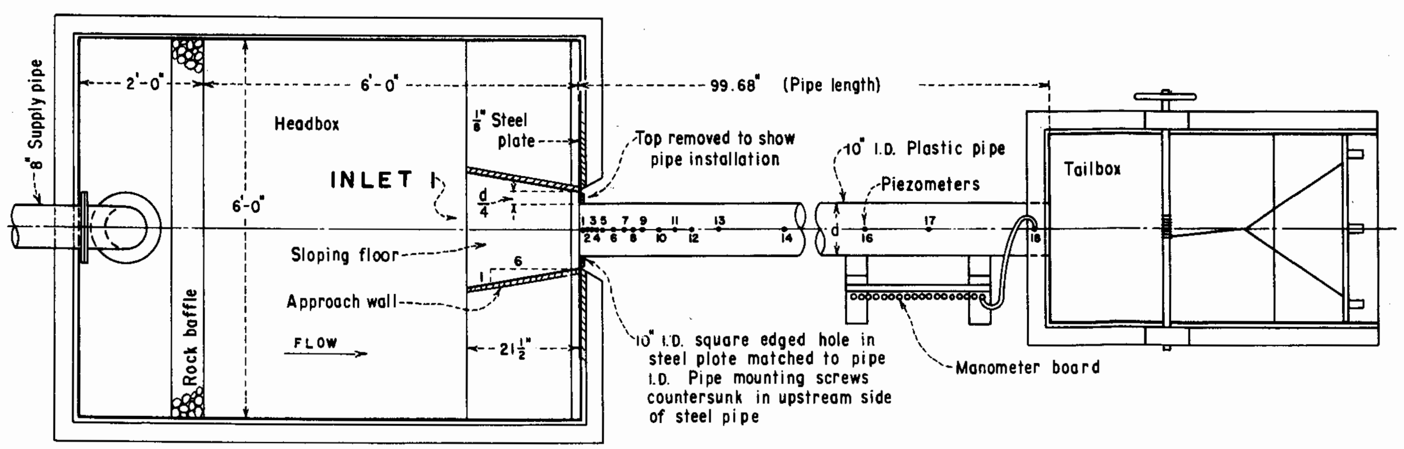


INLET 2 INLET 3 INLET 4 INLET 5

Inlet 6-Approach walls d/4 from pipe, extending to bottom of box, no floor
Inlet 7-Approach walls d/2 from pipe, extending to bottom of box, no floor
Inlet 8-Approach walls d from pipe, extending to bottom of box no floor



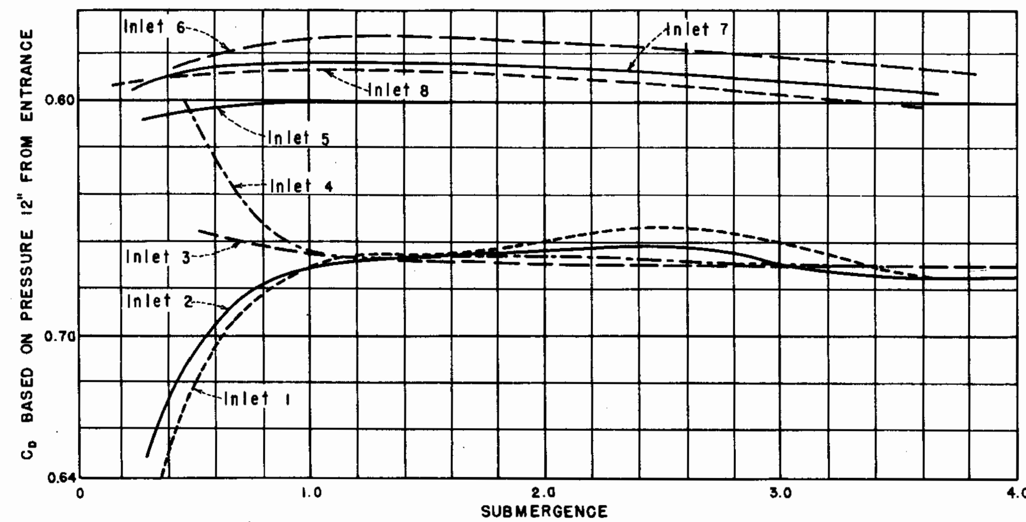
LONGITUDINAL SECTION OF TEST ARRANGEMENT



PLAN OF TEST ARRANGEMENT
(WITH INLET 1 IN PLACE)

PIEZOMETER LOCATIONS FROM UPSTREAM END OF PIPE

PIEZOMETER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
X/d	0.061	0.136	0.236	0.334	0.436	0.638	0.838	1.038	1.238	1.538	1.838	2.139	2.693	3.908	5.095	6.292	7.462	9.687
X INCHES	0.61	1.36	2.36	3.34	4.36	6.38	8.38	10.38	12.38	15.38	18.38	21.39	26.93	39.08	50.95	62.92	74.62	96.87



MEDIAN VALUES FOR DIFFERENT APPROACH CONDITIONS

EXPLANATION

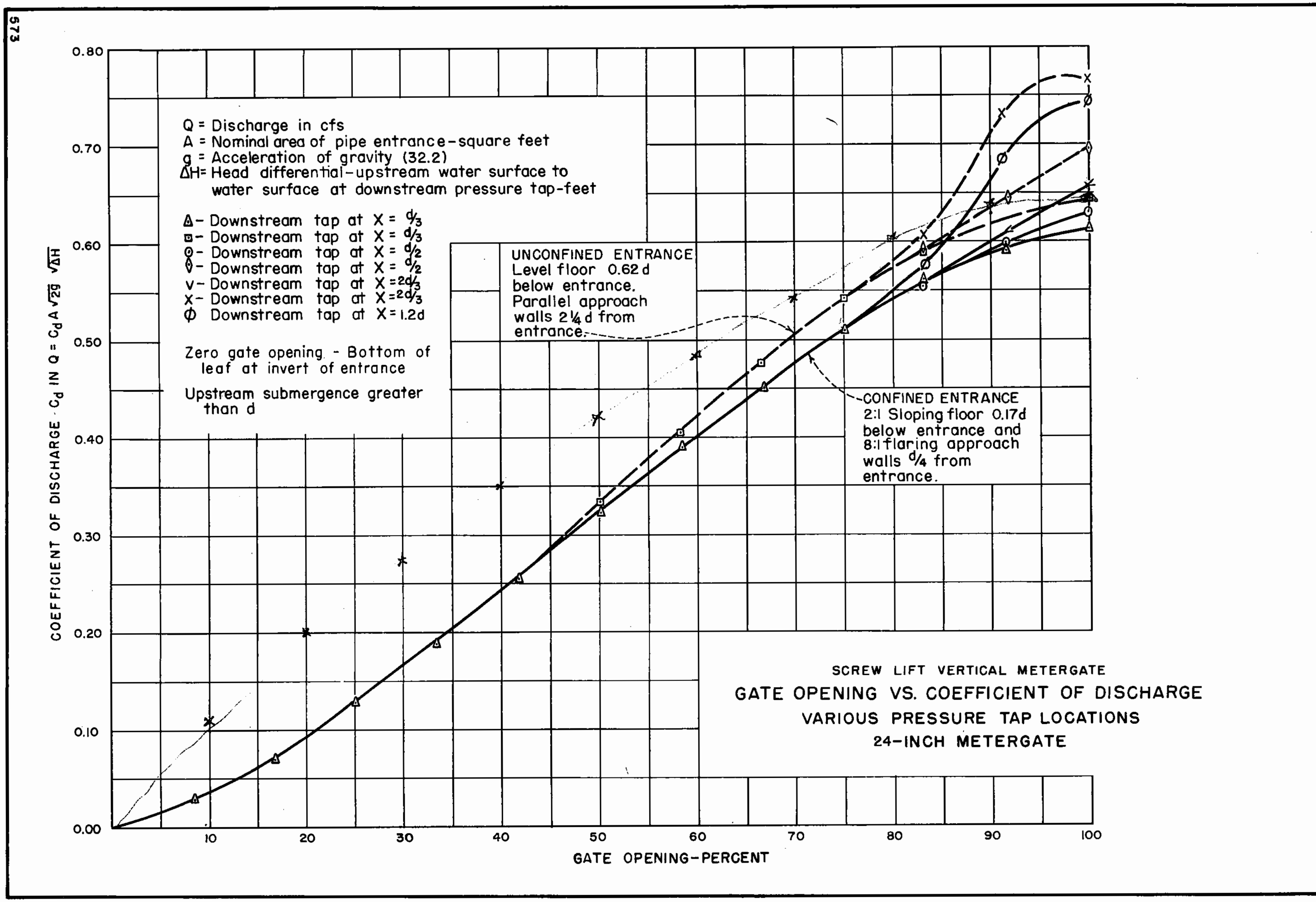
Coefficient of discharge, $C_d = \frac{Q}{A\sqrt{2g\Delta H}}$ where —

Q is the rate of flow, c.f.s.
A is the pipe cross section area in square feet, and
ΔH is the difference in hydraulic grade from the headwater to a point on the pipe crown 12 inches from the inlet in feet of water.

$$\text{Submergence} = \frac{\text{depth of water above crown of pipe entrance}}{\text{diameter of pipe}}$$

SCREW LIFT VERTICAL METERGATE
COEFFICIENT OF DISCHARGE VS. SUBMERGENCE
10-INCH INLET DESIGNS — 1 THROUGH 8

573



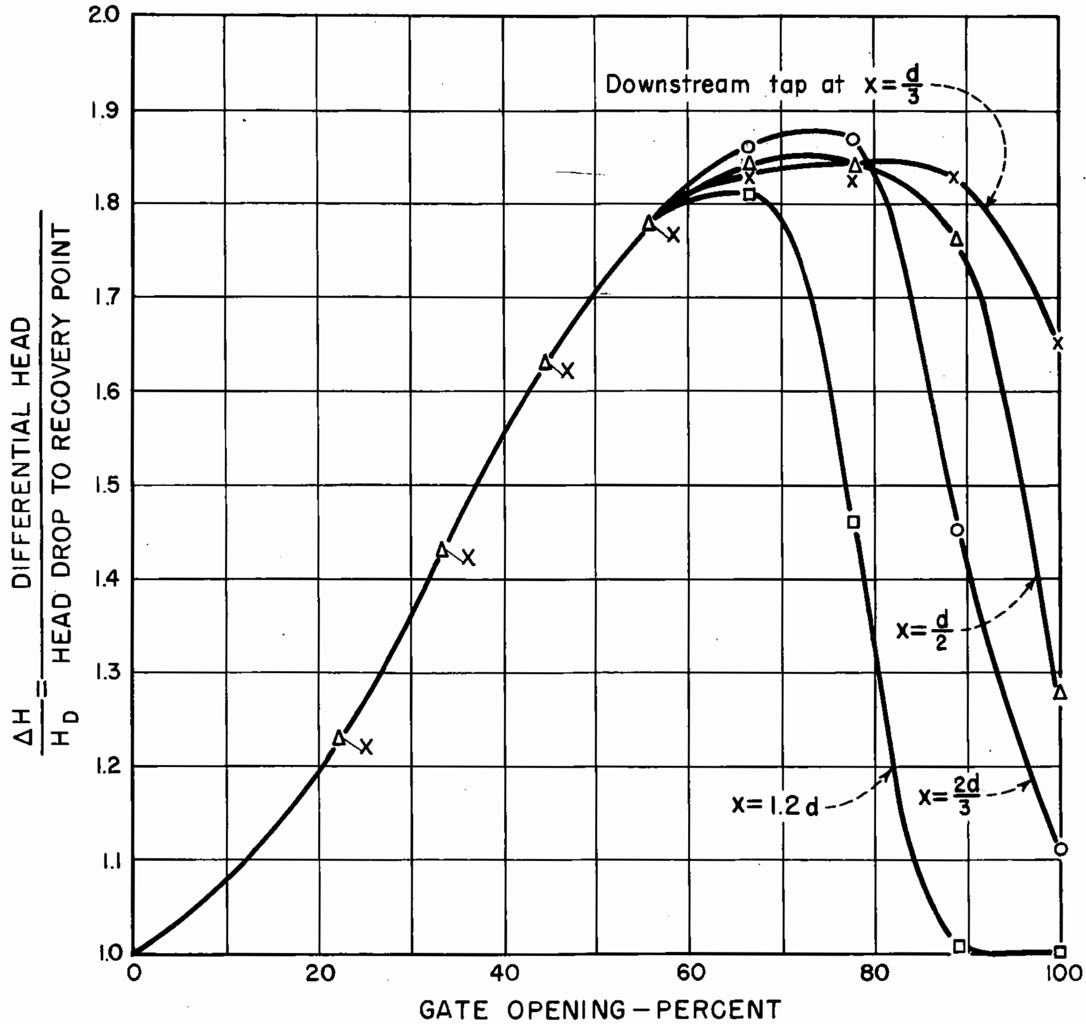
SCREW LIFT VERTICAL METERGATE

GATE OPENING VS. COEFFICIENT OF DISCHARGE

VARIOUS PRESSURE TAP LOCATIONS

24-INCH METERGATE

FIGURE 16
REPORT HYD. 471



NOTES

Upstream submergence greater than 1.0d

Floor 1.0d below invert of entrance and walls 3.0d from edges of entrance.

Zero gate opening – Bottom of leaf at invert of entrance.

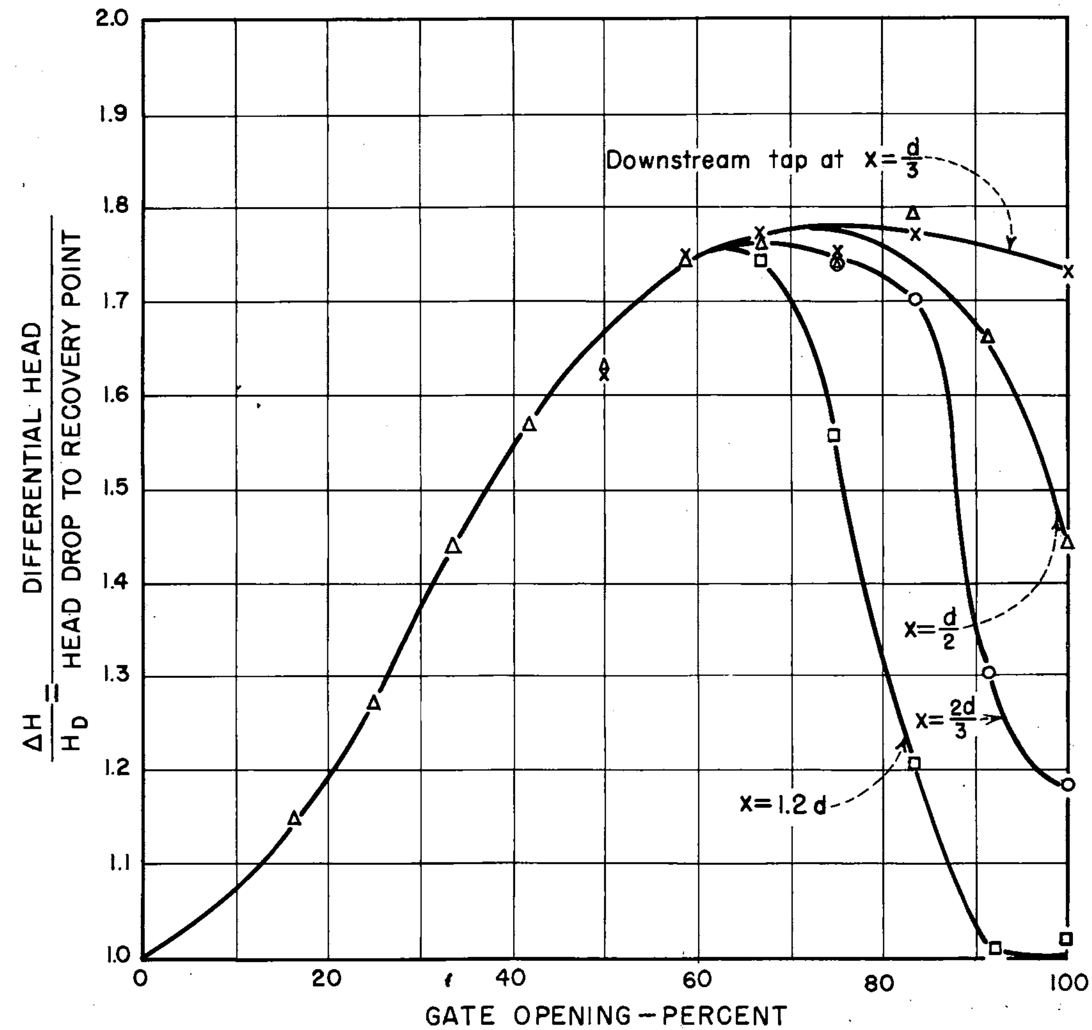
SCREW LIFT VERTICAL METERGATE

GATE OPENING VS. $\Delta H/H_D$

VARIOUS PRESSURE TAP LOCATIONS

18-INCH METERGATE

LEVEL FLOOR AND PARALLEL WALLS



NOTES

Upstream submergence greater than 1.0d

Floor 0.63d below invert of entrance and walls 2¼d from edges of entrance.

Zero gate opening - Bottom of leaf at invert of entrance.

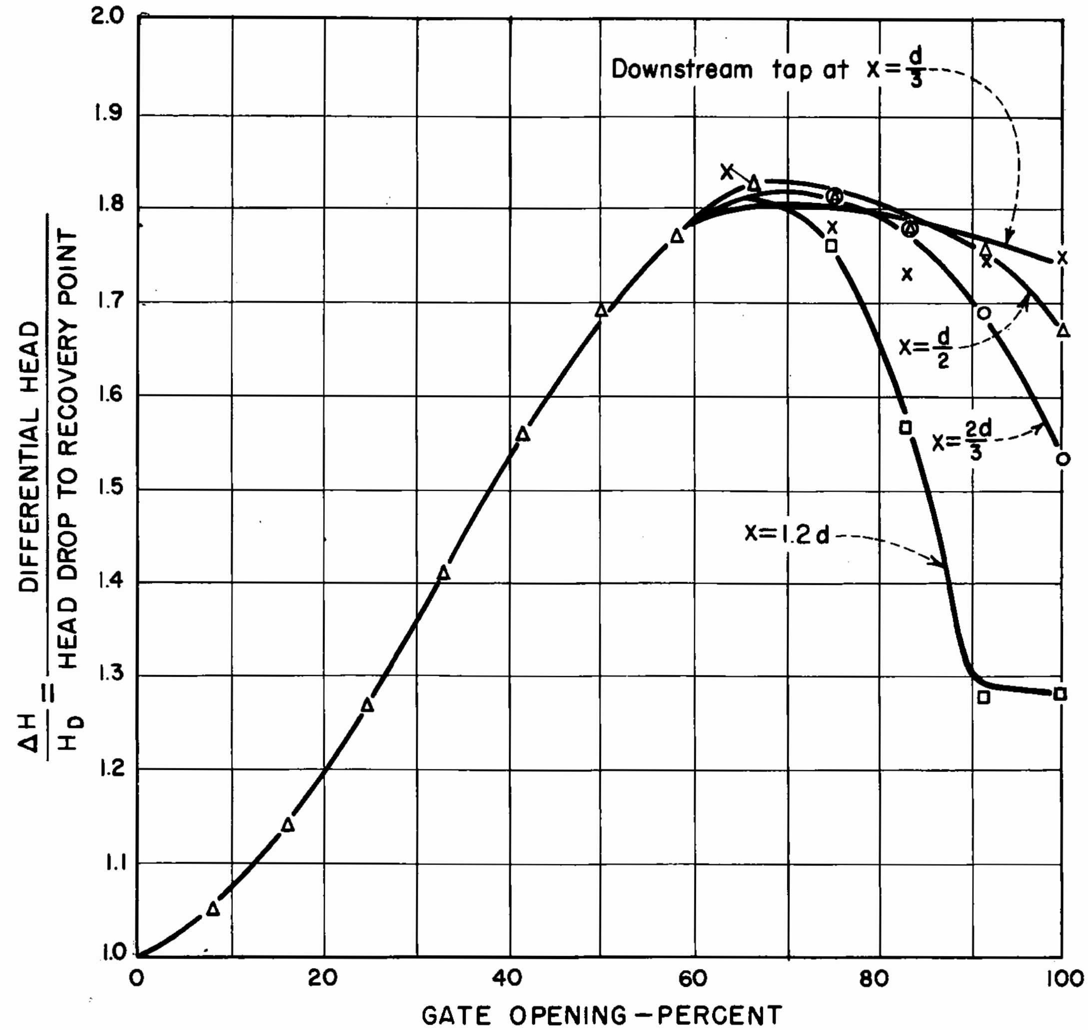
SCREW LIFT VERTICAL METERGATE

GATE OPENING VS. $\Delta H/H_D$

VARIOUS PRESSURE TAP LOCATIONS

24-INCH METERGATE

LEVEL FLOOR AND PARALLEL WALLS



NOTES

Upstream submergence greater than 1.0d

Floor 0.17d below invert of entrance and 8:1 flaring walls d/4 from edges of entrance.

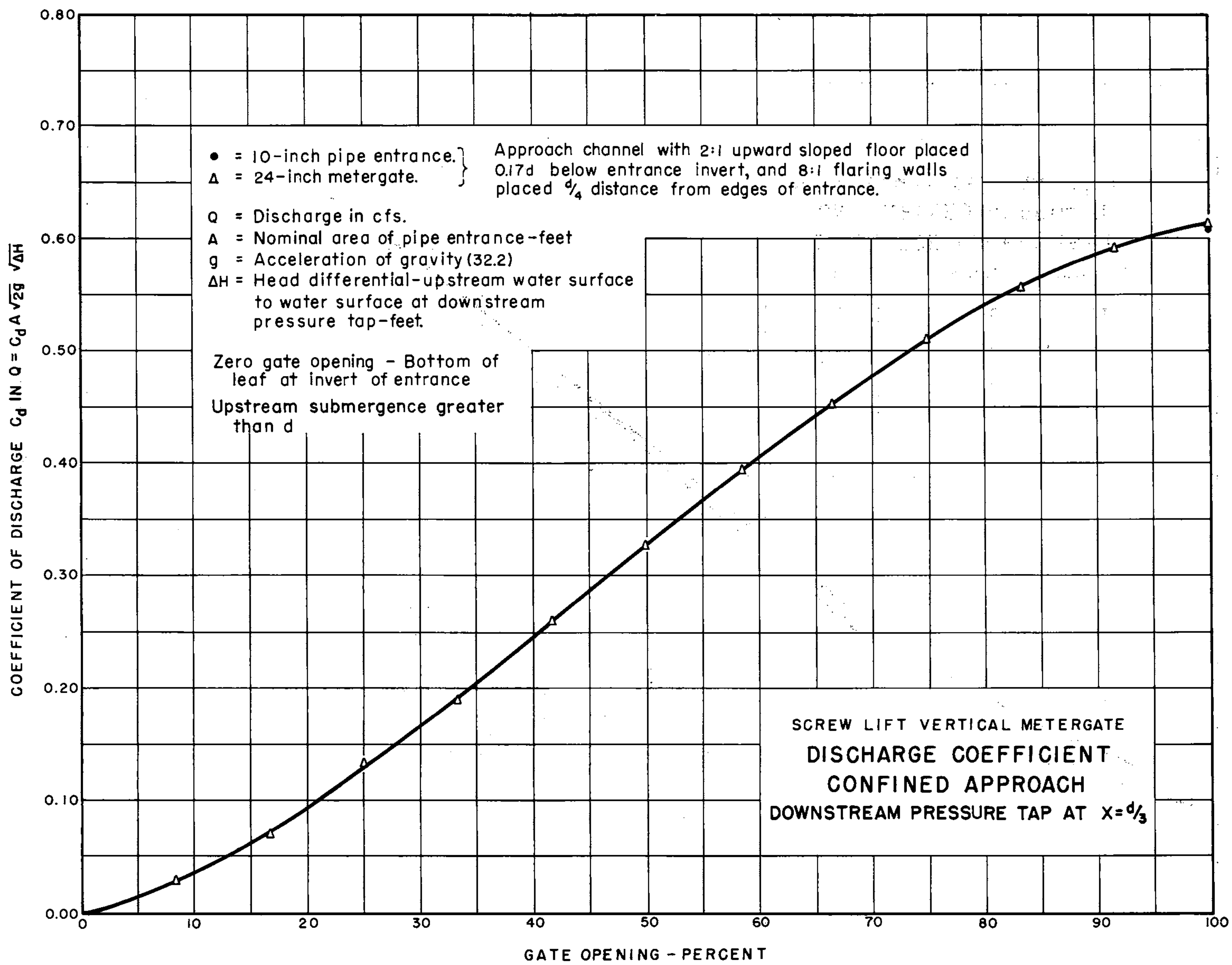
Zero gate opening – Bottom of leaf at invert of entrance.

SCREW LIFT VERTICAL METERGATE

GATE OPENING VS. $\Delta H/H_D$
VARIOUS PRESSURE TAP LOCATIONS

24-INCH METERGATE

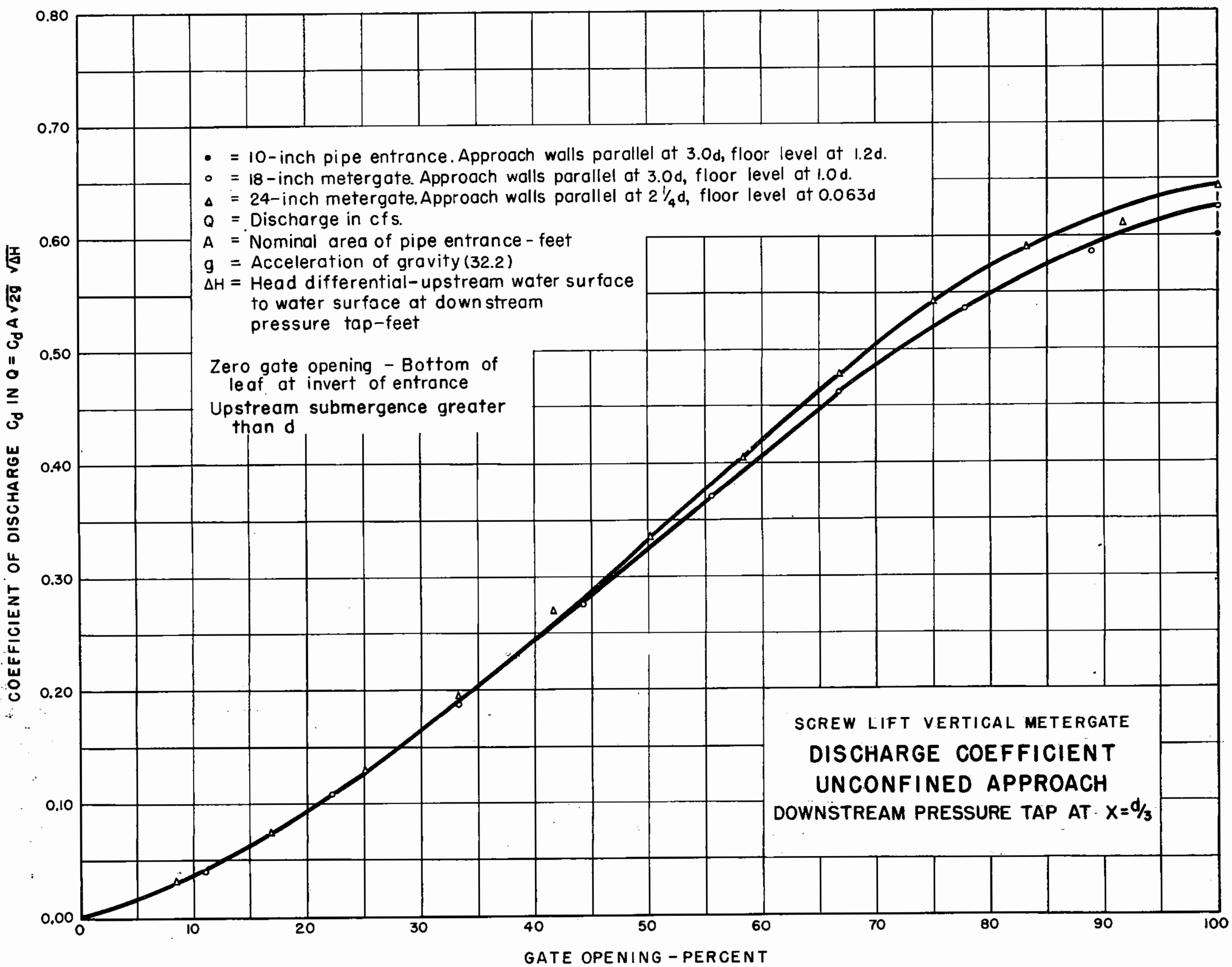
2:1 SLOPING FLOOR AND 8:1 FLARING WALLS

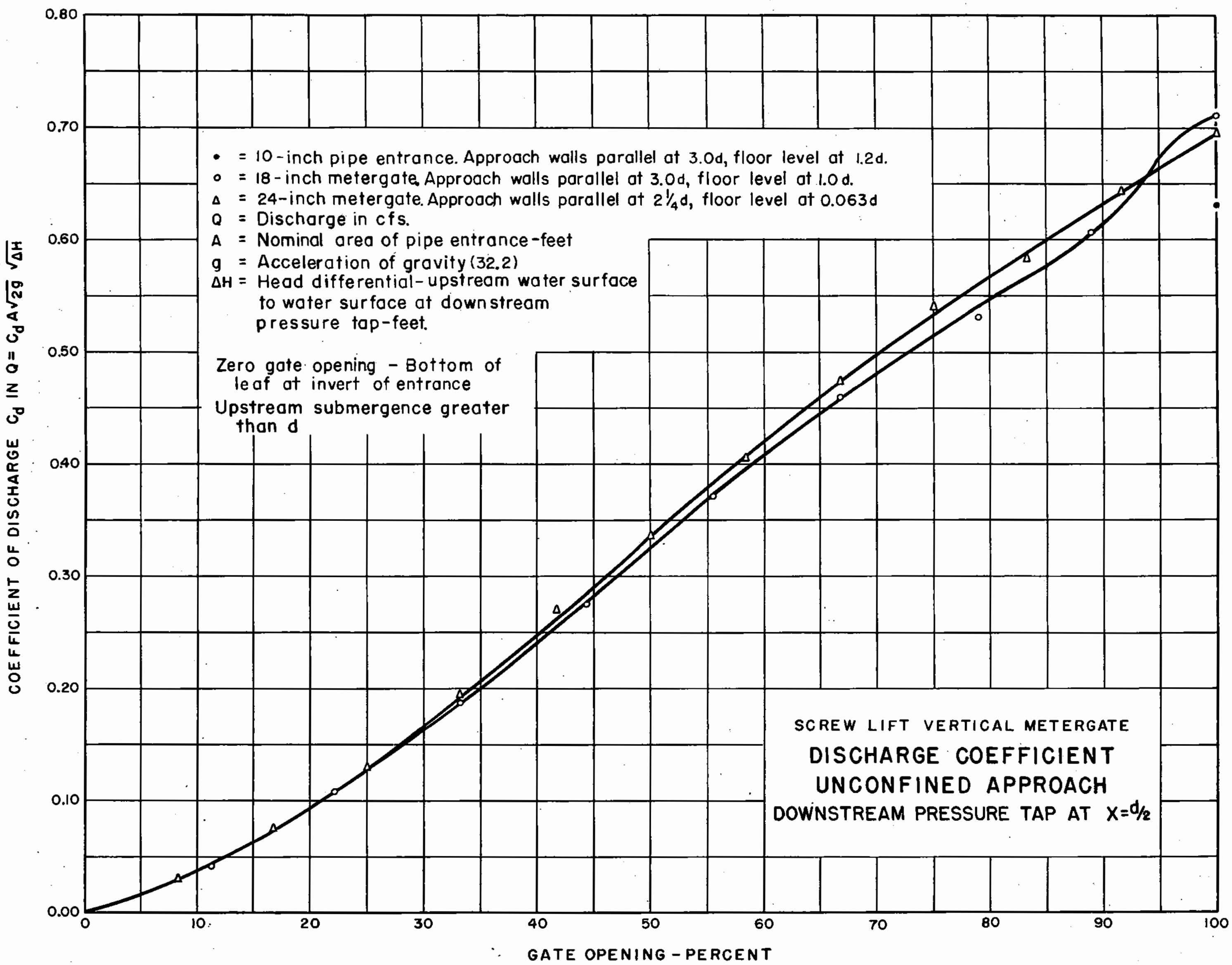


573

FIGURE 20
REPORT HYD 471

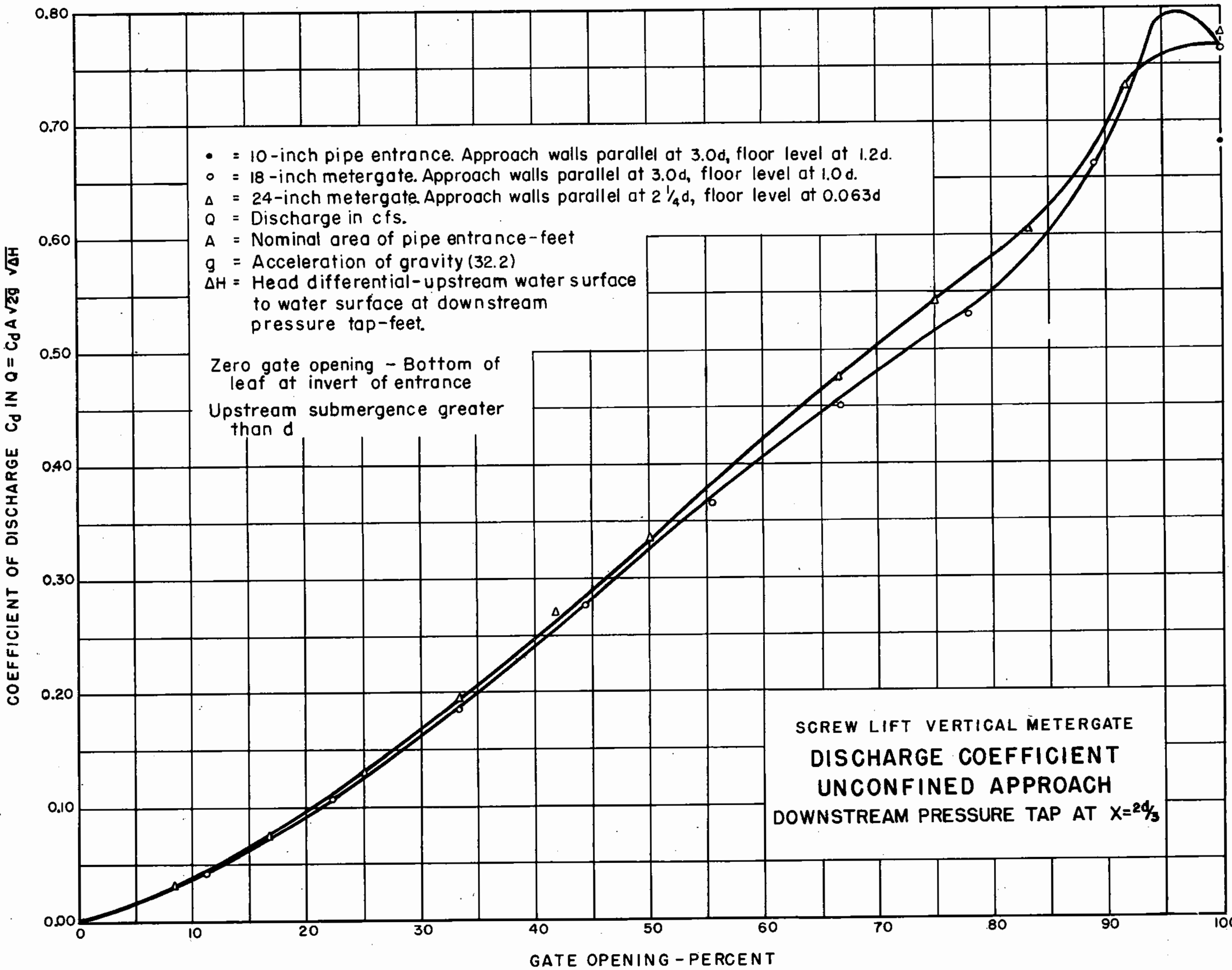
FIGURE 21
REPORT HYD 471





573

FIGURE 22
REPORT HYD. 471



SCREW LIFT VERTICAL METERGATE

DISCHARGE COEFFICIENT
UNCONFINED APPROACH
DOWNSTREAM PRESSURE TAP AT X=2d/3

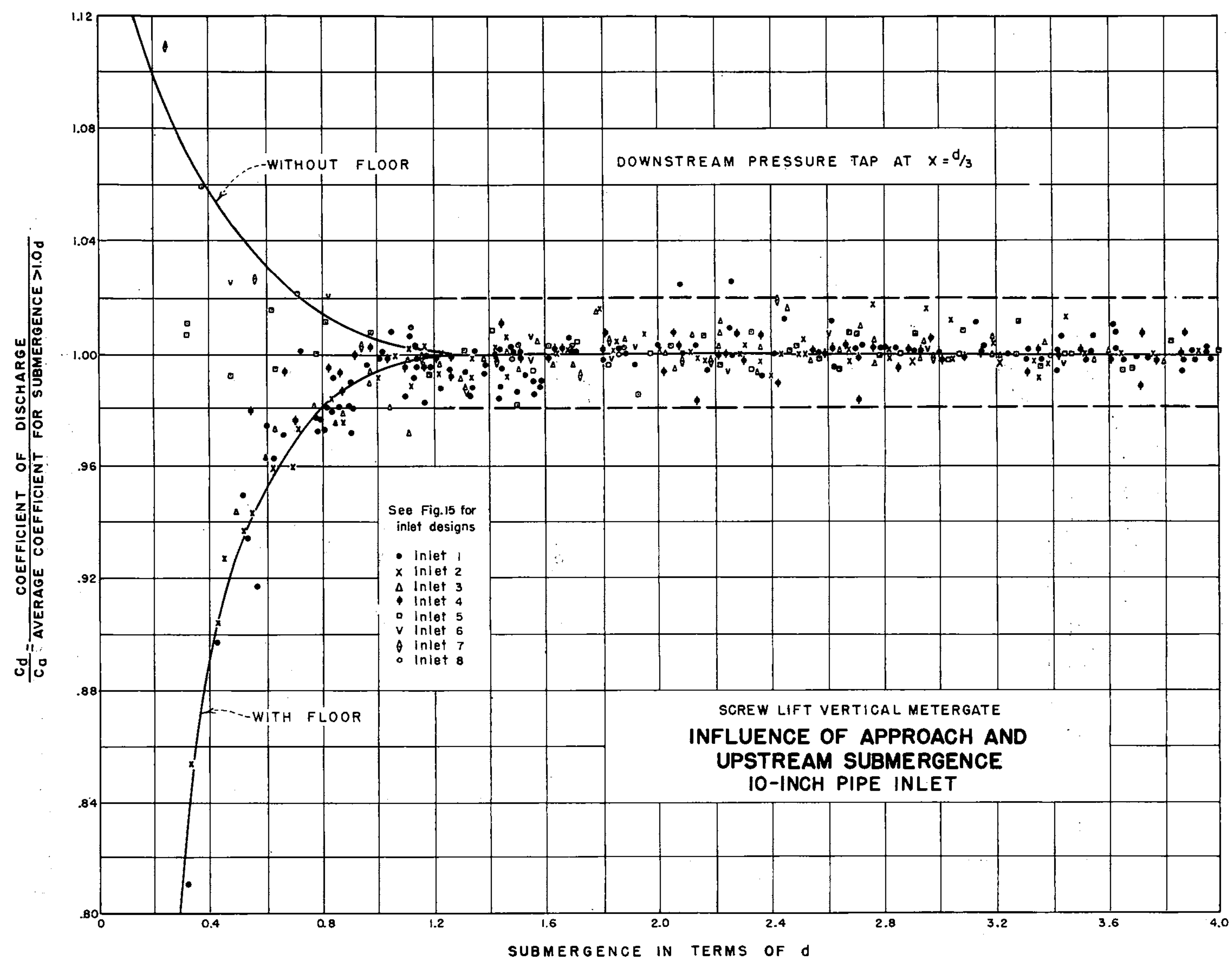
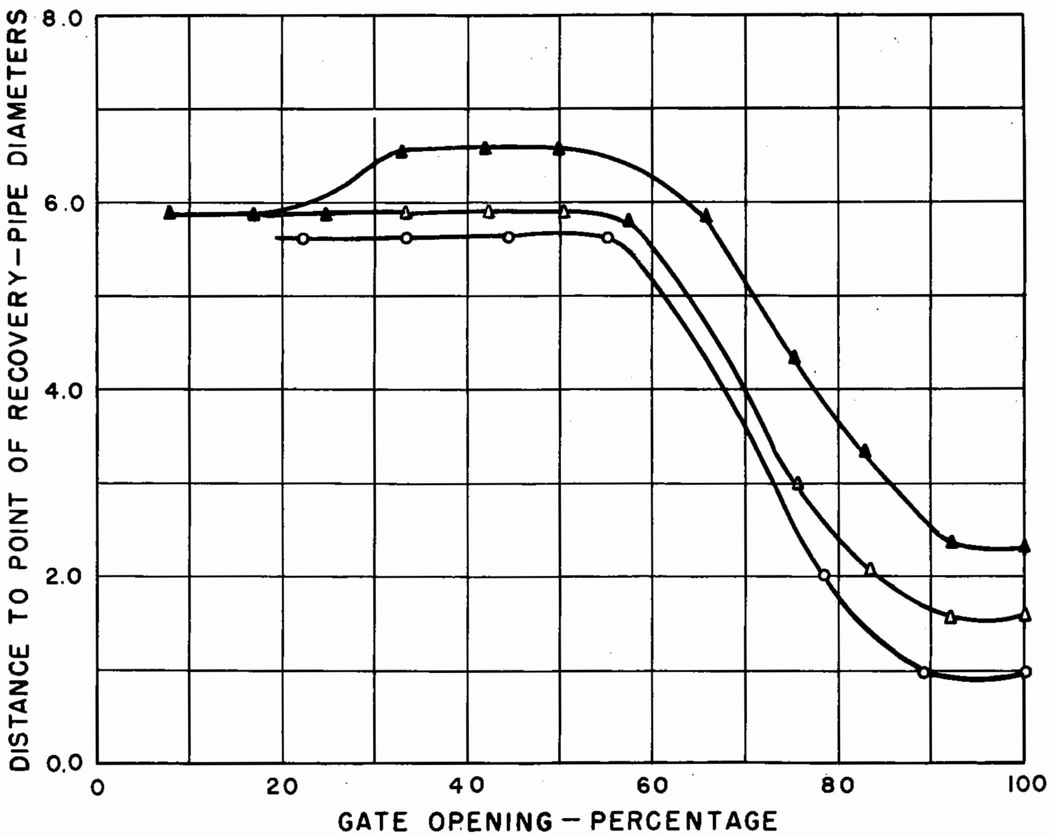


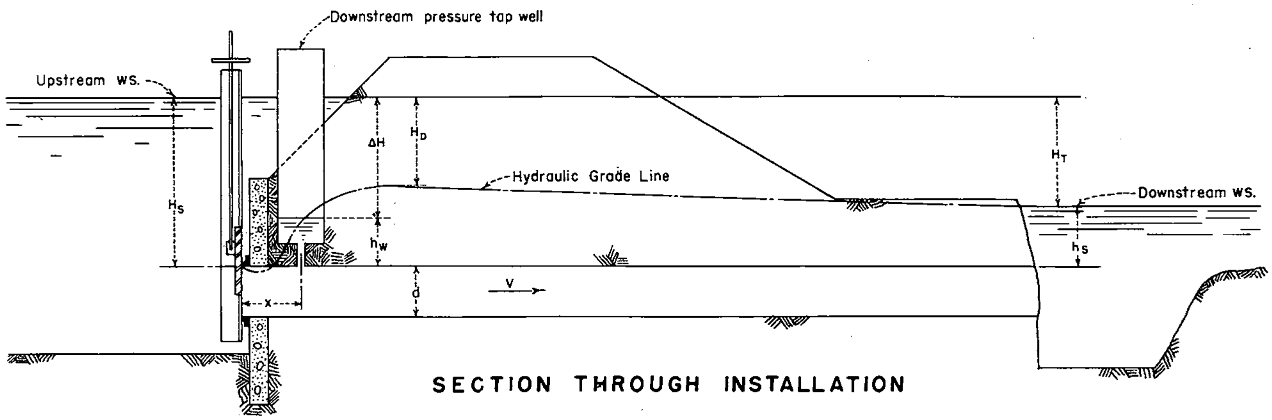
FIGURE 24
REPORT HYD 471



▲ 24-inch metergate with 2:1 sloping floor 0.17d below entrance and 8:1 flaring walls at d/4 from entrance.
△ 24-inch metergate with level floor 0.63d below entrance and parallel walls at 2 1/4 d from entrance.
o 18-inch metergate with level floor 1.0 d below entrance and parallel walls at 3 d from entrance.
Upstream submergence greater than d.

SCREW LIFT VERTICAL METERGATE

LENGTH OF PIPE REQUIRED FOR PRESSURE RECOVERY



SECTION THROUGH INSTALLATION

DETERMINATION OF METERGATE INSTALLATION

GIVEN

1. Upstream water surface El. 100.0.
2. Downstream water surface El. 99.0.
3. Turnout discharge, Q, = 8 cfs.
4. Depth of water in downstream measuring well, h_w, should be 6 inches above crown of pipe.
5. Length of metergate pipe, 50 feet.
6. Submergence of metergate inlet, H_S, should be equal to or greater than d above the crown of the pipe.

FIND

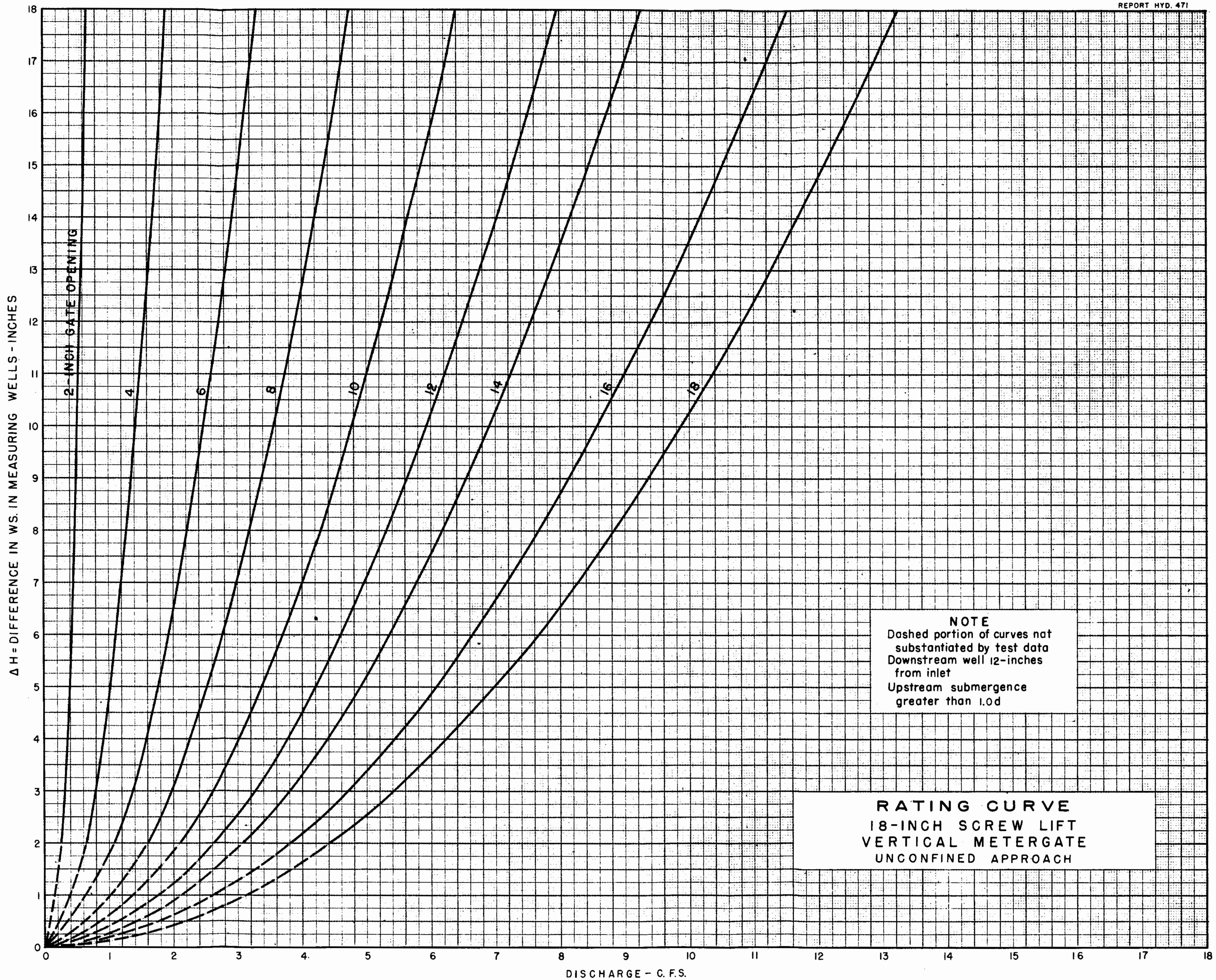
1. SIZE OF METERGATE (One of two methods may be used)
   a. Where downstream scour may be a problem.
      Select exit velocity that will not cause objectionable scour, say 4 feet per sec.
      From $A = \frac{Q}{V} = \frac{8}{4} = 2.00$, $d = 19\frac{1}{8}$ inches.
      Requires 20-inch metergate.
   b. Where scour downstream is not a problem.
      Assume metergate to be operated at openings up to 75 percent. (The influences of entrance design, upstream submergence and downstream pressure tap location are minor for these openings.) (Figures 13 and 16).
      For 75 percent gate opening coefficient of discharge, $C_d \approx 0.5$, and maximum $\Delta H \approx 1.85\ H_D$ (Figures 17, 18 and 19) $\Delta H \approx 1.85\ (1.0) \approx 1.85$ ft.
      From $Q = C_d A\sqrt{2g\Delta H}$
      Area of pipe, $A = \frac{8}{0.5\ (8.02)\ (1.36)} = 1.47$ sq. ft.
      $d = 16\frac{3}{8}$ inches.
      Requires 18-inch metergate, d = 18 inches.
   c. Check capacity of gate using 18 inch metergate.
      $H_D = H_T - H_f$ (H_f is friction loss from pressure recovery point to pipe exit).
      $H_f = f\frac{l}{d}\frac{V^2}{2g}$
      Where f is coefficient of friction, l is length of pipe, d is pipe diameter and v is velocity in pipe.
      From $V = \frac{Q}{A} = \frac{8}{1.767} = 4.53$
      Assume f for concrete or steel pipe as 0.025.
      $H_f = \frac{0.025\ (26.3)\ 20.5}{64.4} = 0.21$ feet.
      $H_D = 1.0 - 0.21 = 0.79$ feet.
      In order to have a measurable water surface in the downstream well for all gate openings and downstream tap positons the installation should be designed for maximum ΔH.
      From figures 17, 18 and 19, $\frac{\Delta H}{H_D}$ (maximum) ≈ 1.85
      $\Delta H \approx 1.85 H_D \approx 1.85(0.79) \approx 1.46$
      Using this adjusted value of ΔH, turnout capacity at 75 percent gate opening, $Q \approx 0.5(1.767)\ (8.02)\ (1.21) \approx 8.57$ cfs.
      18-inch metergate is adequate.

2. ELEVATION AT WHICH METERGATE SHOULD BE PLACED.
   a. To meet upstream submergence requirement, H_S, of 1.0d, crown of pipe entrance should be set at El = 100.0 - d = 98.5.
   d. To meet requirement of water surface 6 inches above crown of pipe in downstream well, elevation of crown of entrance would be set at El. 100.0 $- \Delta H - h_w = 100.0 - 1.46 - 0.50 = 98.04$, say El. 98.0.
   Depth requirement for measurable water surface in downstream well is governing factor and gate should be set with crown of entrance not higher than El. 98.0.

3. MAXIMUM CAPACITY OF METERGATE (Full open)
   C_d for full gate opening with downstream pressure tap at $x = 2d/3$ (12 inches from entrance on 18-inch gate) is about 0.75 (Figure 13).
   $\frac{\Delta H}{H_d}$ for $x = 2d/3 \approx 1.1$ (Figure 17)
   $\Delta H = 1.1\ (0.79) \approx 0.87$
   From $Q = CA\sqrt{2g\Delta H}$
   $\approx 0.75\ (1.767)\ (8.02)\ 0.93$
   ≈ 9.9 cfs.

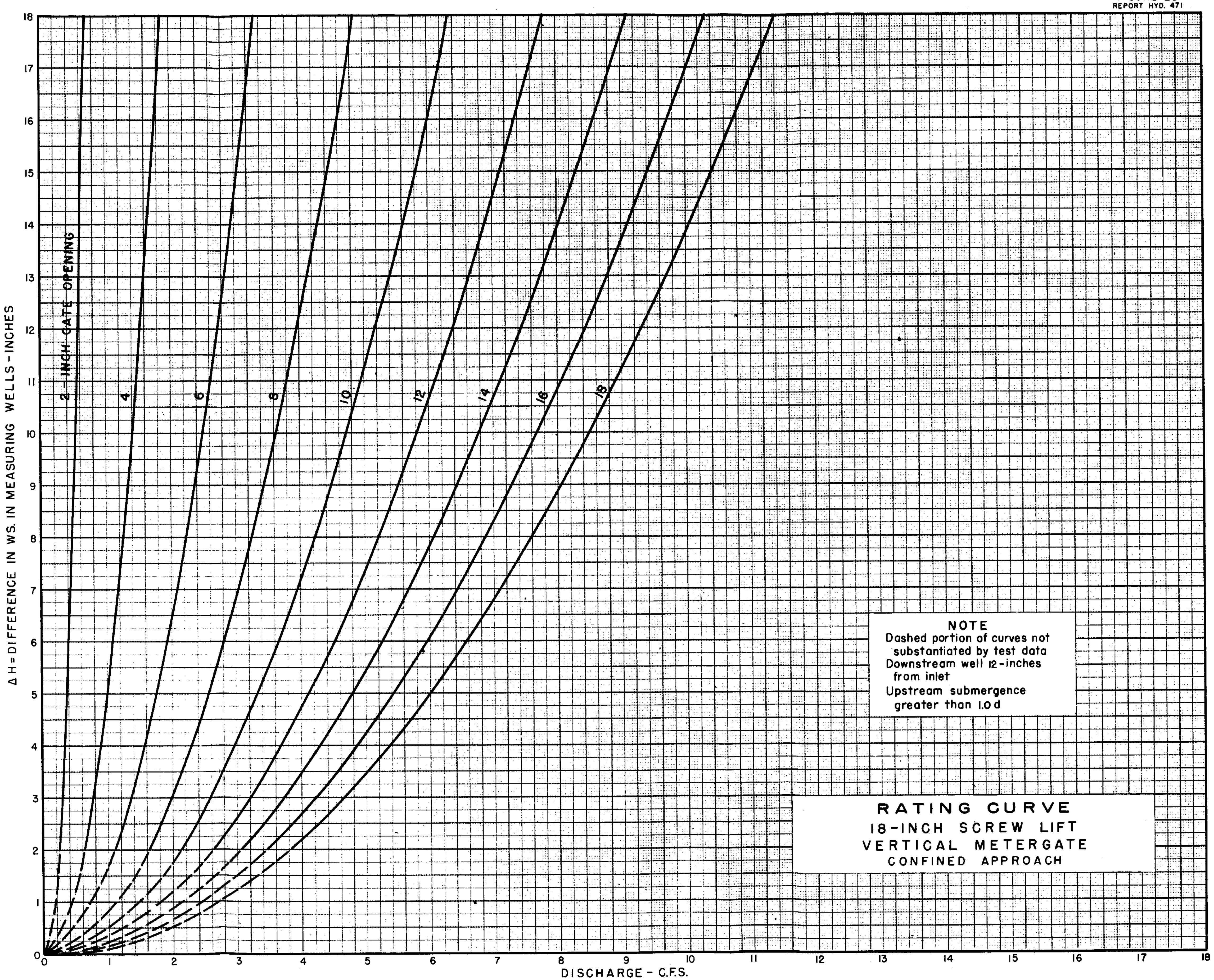
SCREW LIFT VERTICAL METERGATE

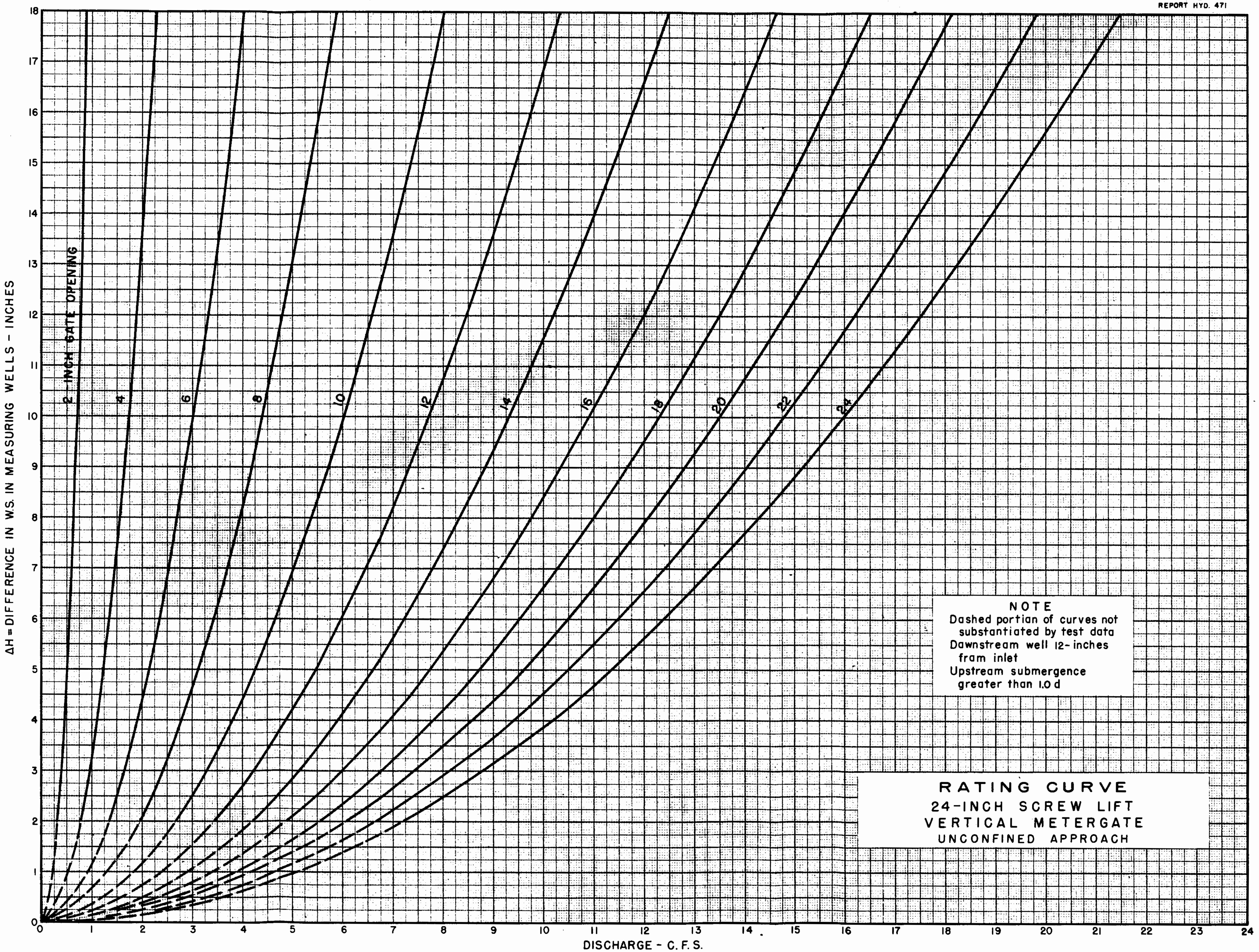
INSTALLATION CRITERIA AND EXAMPLE

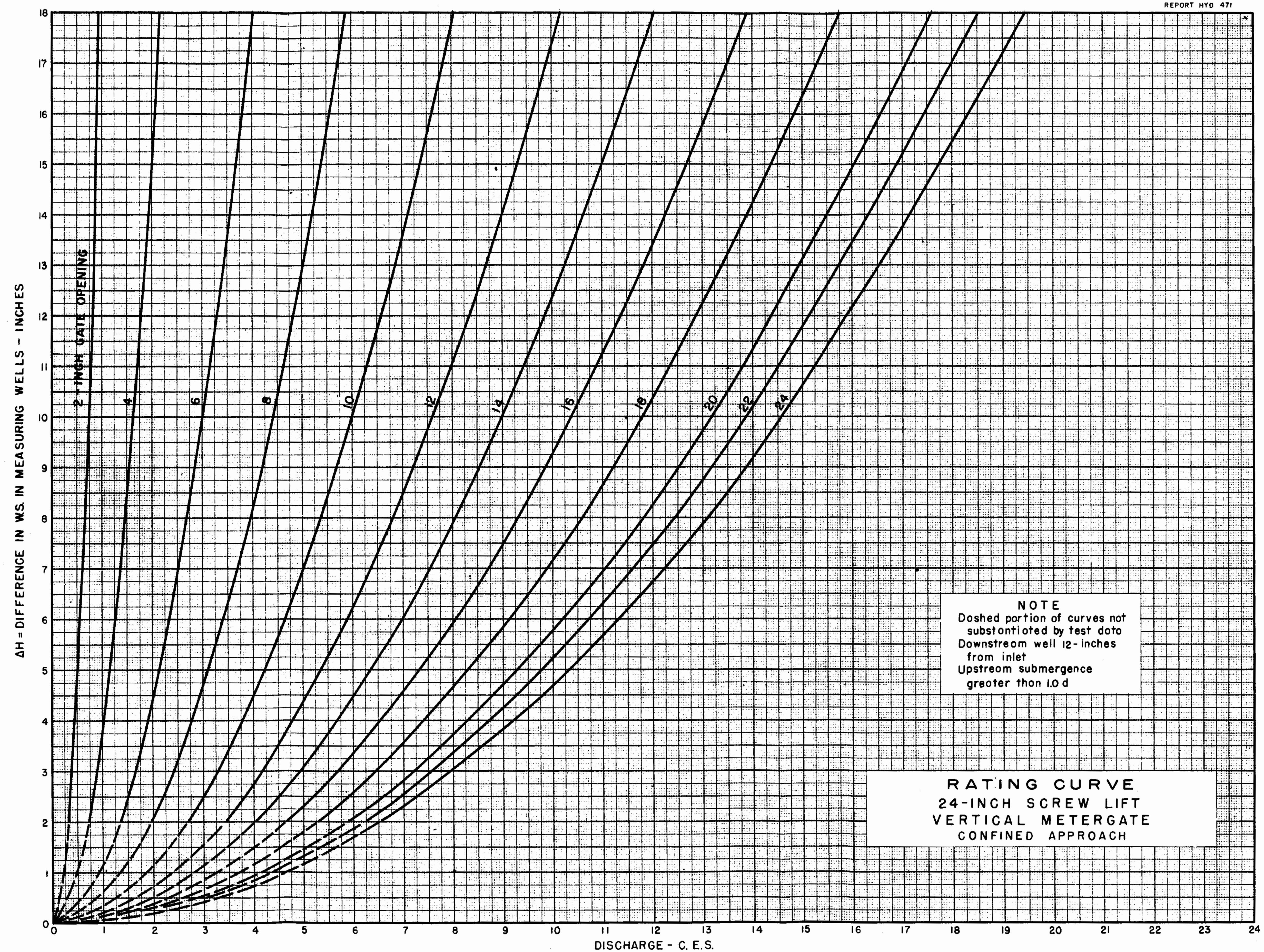


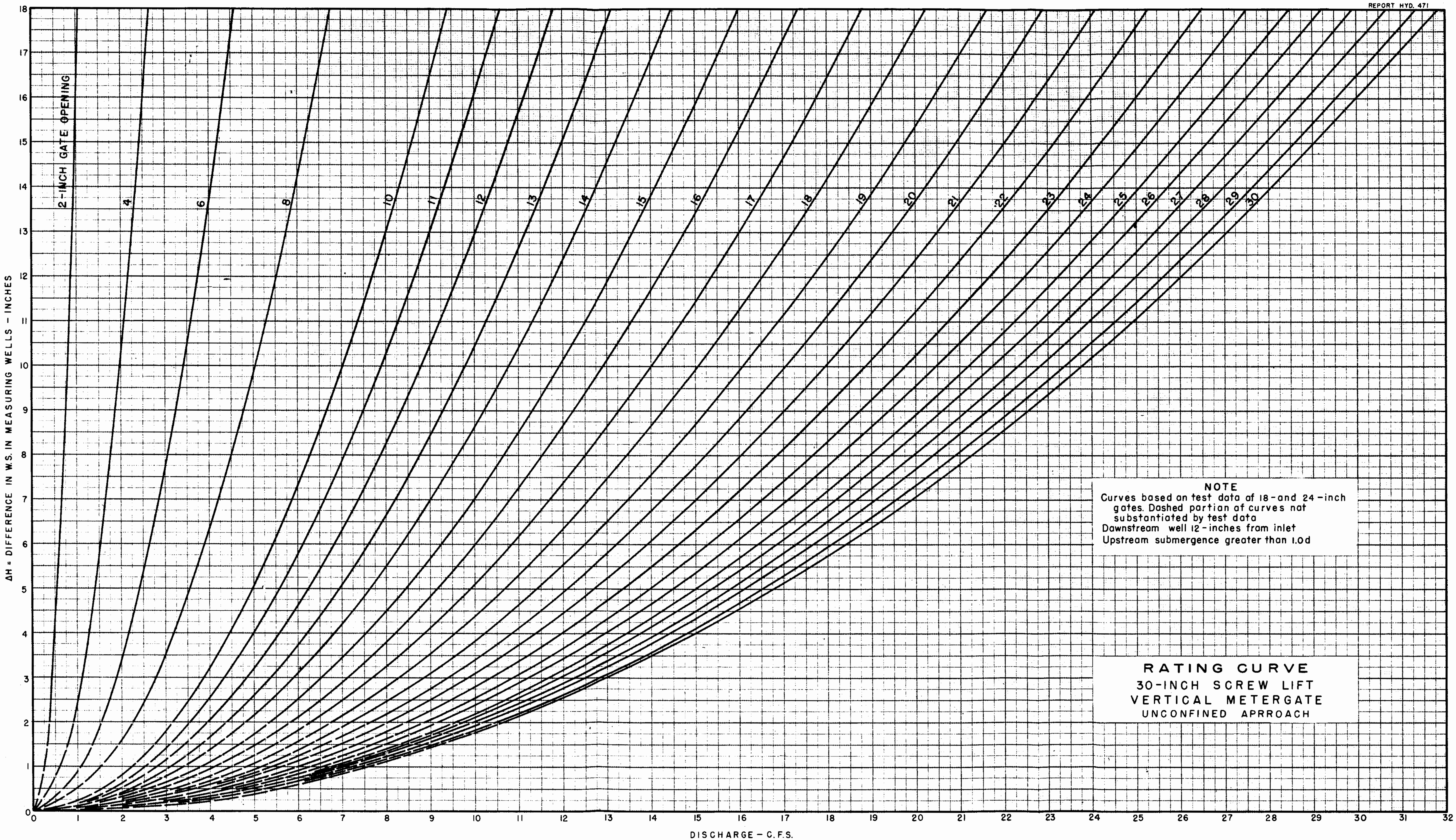
RATING CURVE
18-INCH SCREW LIFT
VERTICAL METERGATE
UNCONFINED APPROACH

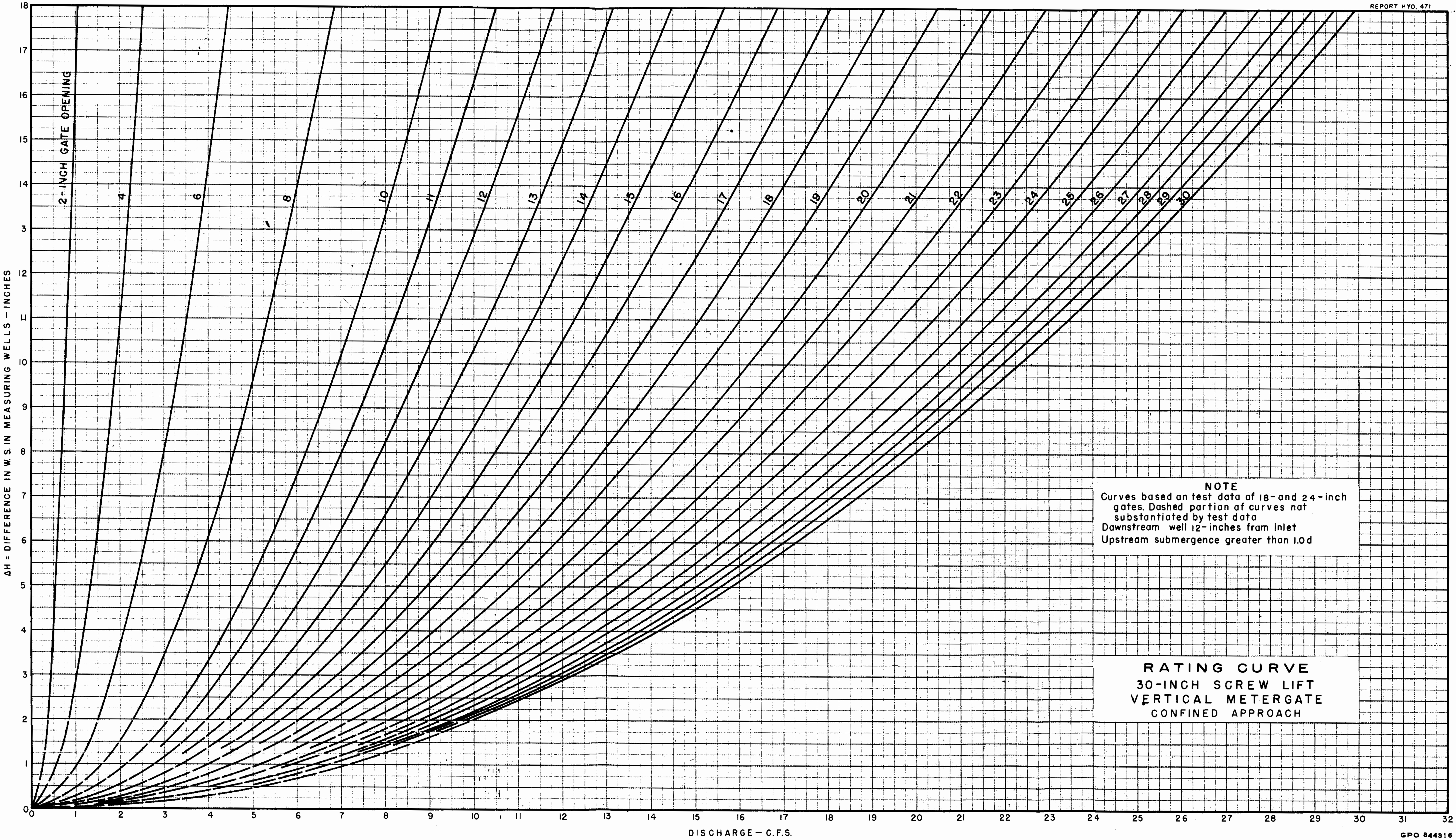
FIGURE 28
REPORT HYD. 471




ΔH = DIFFERENCE IN W.S. IN MEASURING WELLS - INCHES
DISCHARGE - C.F.S.
2-INCH GATE OPENING
4
6
8
10
12
14
16
18
20
22
24
NOTE
Dashed portion of curves not substantiated by test data
Downstream well 12-inches from inlet
Upstream submergence greater than 1.0 d
RATING CURVE
24-INCH SCREW LIFT
VERTICAL METERGATE
UNCONFINED APPROACH


ΔH = DIFFERENCE IN W.S. IN MEASURING WELLS - INCHES
DISCHARGE - C. F. S.
2-INCH GATE OPENING
4
6
8
10
12
14
16
18
20
22
24
NOTE
Dashed portion of curves not substantiated by test data
Downstream well 12-inches from inlet
Upstream submergence greater than 1.0 d
RATING CURVE
24-INCH SCREW LIFT
VERTICAL METERGATE
CONFINED APPROACH


2-INCH GATE OPENING
4
6
8
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
ΔH = DIFFERENCE IN W.S. IN MEASURING WELLS - INCHES
DISCHARGE - C.F.S.
NOTE
Curves based on test data of 18-and 24-inch gates. Dashed portion of curves not substantiated by test data
Downstream well 12-inches from inlet
Upstream submergence greater than 1.0d
RATING CURVE
30-INCH SCREW LIFT
VERTICAL METERGATE
UNCONFINED APPROACH



RATING CURVE
30-INCH SCREW LIFT
VERTICAL METERGATE
CONFINED APPROACH

GPO 844316