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Flow rate measurement of Logan outfall effluents

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FLOW RATE MEASUREMENT

OF LOGAN OUTFALL EFFLUENTS

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INTRODUCTION

Considerable interest and argument has resulted in recent years concerning the necessity and type of treatment required for Logan City's wastes. The sewer outfalls for Logan, Utah, are located on the west side of town. The sewage flows from the outfalls through earth channels in the west fields, passes through a small pond having a surface area of 11 acres, and is then comingled with the flows of Logan River. Eventually, these waters reach the Bear River, pass through Cutler Reservoir, and are ultimately used for irrigation in the Tremonton area or reach Great Salt Lake. The layout of the conveyance channels between the sewer outfalls and the Logan River is shown in Figure 1. Return flows from the irrigated fields enter the channels throughout their course during the summer months, thus diluting the flows.

A research project was initiated in early 1965 to study the biological, chemical, and physical factors involved in the transportation of Logan City effluents between the outfalls and the Logan River. The project was undertaken by the Utah Center for Water Resources Research and placed under the leadership of Dr. John M. Neuhold, Department of Wildlife Resources, and Professor Norman B. Jones, Department of Civil Engineering. Funds were provided through the office of Water Resources Research, U. S. Department of Interior.

A flow measurement network was required as a part of the research project to assist in the evaluation of the biological, chemical, and physical characteristics of the effluents. The selection of sites and the rating of structures was carried out under the direction of Norman B. Jones and Gaylord V. Skogerboe. The location of the flow measurement structures being employed are shown in Figure 1. A Parshall flume is located immediately downstream from both sewer outfalls. The flow measurement structures reported herein are: (1) the control structure located in the Cow Pasture Canal which regulates the water level in the oxidation pond; (2) a box culvert passing under highway U - 69 and located in the natural drainage channel leaving the pond; and (3) a corrugated culvert passing under a gravel road and located in a channel which joins the natural drainage channel from the pond at a point further downstream.

METHOD OF FIELD CALIBRATION

The corrugated culvert and box culvert were rated in the field. A distorted model of the control structure was constructed and tested in the laboratory and the resulting calibrations checked in the field. An evaluation of the discharge required the placing of stilling well upstream from the inlet of both culverts. A stilling well was placed both upstream and downstream from the control structure since submerged flow occurs throughout the entire range of discharges.

The stilling wells consist of a 6-foot length of corrugated metal pipe 15 inches in diameter. Steel pipe one inch in diameter extends

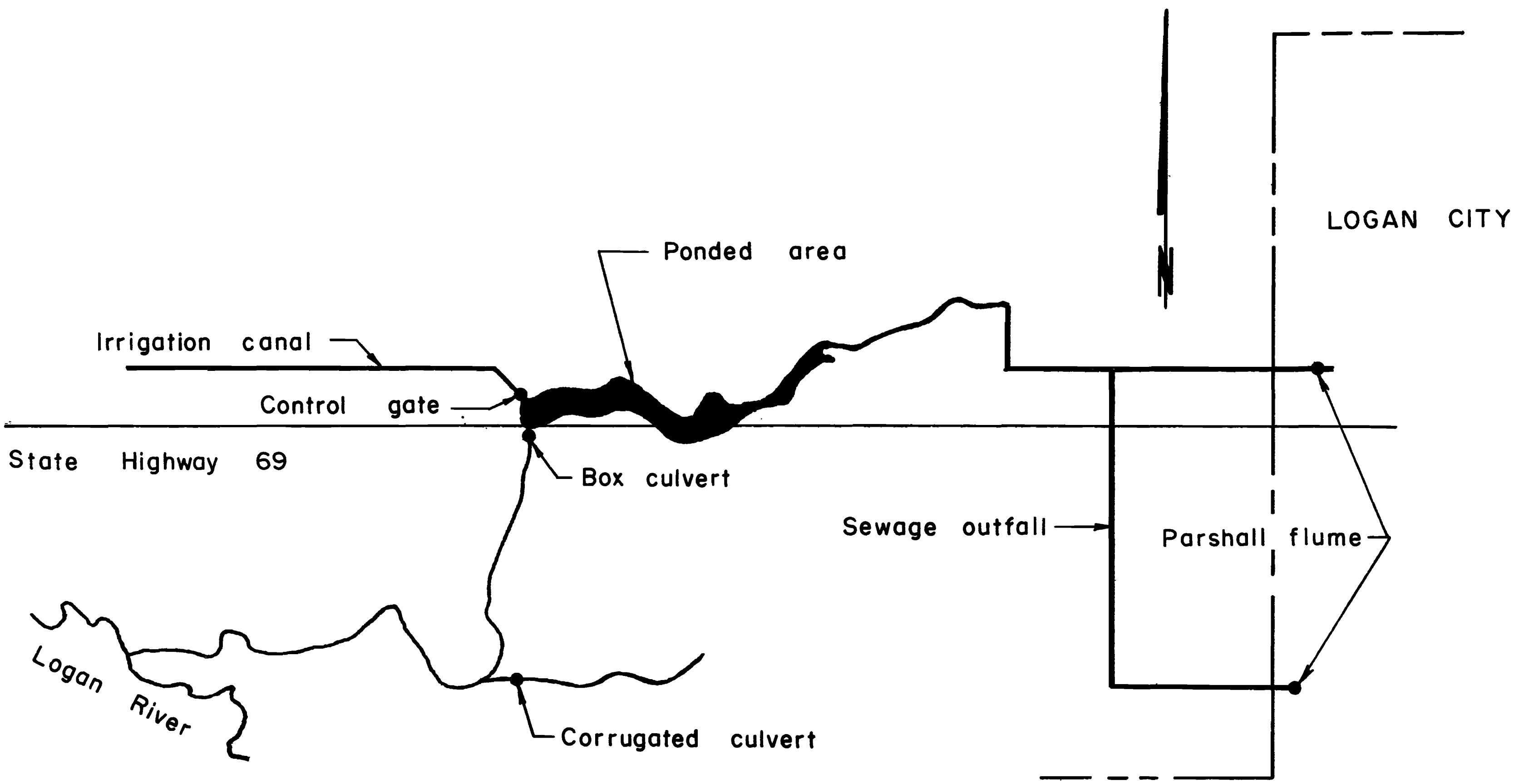


Figure 1. Map of project area showing flow measurement network.

Figure 2. Downstream view of control structure.

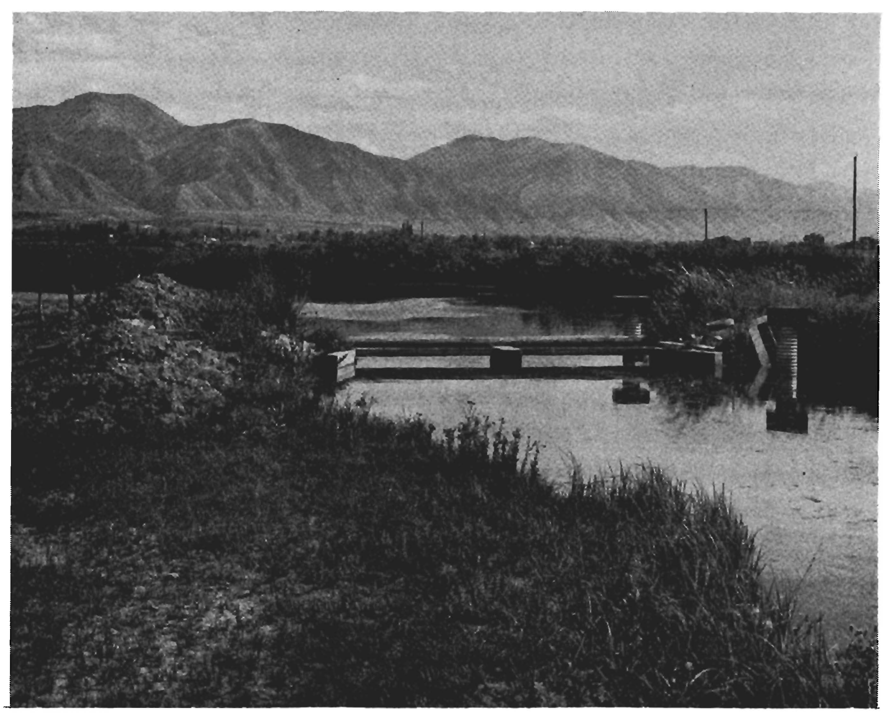


Figure 3. Upstream view of control structure.

Figure 4. Looking at upstream side of corrugated culvert.

Figure 5. Looking at upstream side of box culvert.

horizontally from the stilling well into the stream. Perforations at the end of the steel pipe allow the flow depth to be measured in the stilling well. The depth of water in the stilling well is recorded on a chart on a continuous recorder (Figure 6) by means of a float located on the water surface and connected to a cable passing over a pulley connected to the drum. The horizontal, or time, component is controlled by a clock connected to the pen. The chart thus provides a time history of flow depth, which is then converted to a time history of flow rate.

The measurement of discharge in the field was made both with a current meter and a combination piezometer and pitot tube instrument (Figures 7 and 8). The piezometer and pitot tube instrument (Figure 8) consists of an aluminum case 6 feet high, 8 inches long, and 2 inches wide with one side being of glass. Open end plastic tubes are connected to each of the piezometers and pitot tubes. The height of water in each tube was read by means of steel tapes placed behind the tubes. To facilitate reading the height of water, a periscope-type box was used (Figure 8). The readings allowed the velocity of flow to be computed at the location of each pitot tube, which in turn allowed velocity profiles to be drawn. The velocity profiles obtained from the combination piezometer and pitot instrument were compared with the velocity profiles obtained with the current meter. After the velocity profiles were determined for various vertical sections, the flow rate was computed in the same manner normally used in stream gaging.

Figure 6. Continuous water level recording setup.

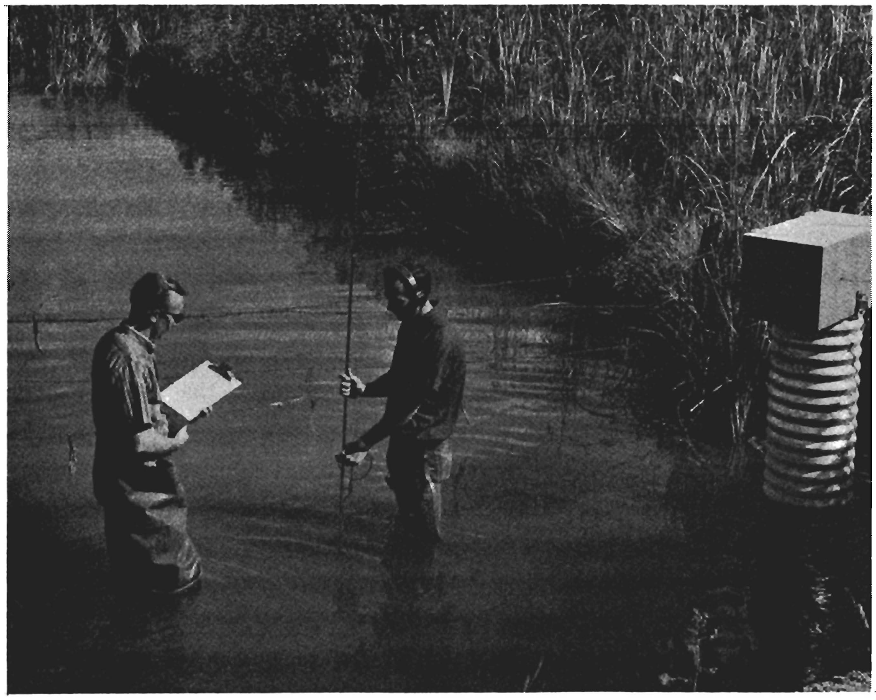


Figure 7. Current meter used for obtaining discharge.

Figure 8. Combination piezometer and pitot tube instrument used for obtaining discharge.

CORRUGATED CULVERT

The location of the 42-inch circular corrugated culvert is indicated on the map in Figure 1. A view of the upstream side of the culvert is shown in Figure 4. Also shown is the stilling well and recording system on the south (right side) of the stream. A more complete and thorough illustration of the physical setup is found in Figure 9 where both the plan view and elevation view are shown.

The corrugated culvert was rated in the field and the resulting calibration curve is found in Figure 11. The discharge is located on the ordinate and the upstream depth, Y_u, is located on the abscissa. The upstream depth is obtained from the continuous recorder. Knowing the upstream depth, Y_u, allows the discharge to be determined from the calibration curve (Figure 11).

BOX CULVERT

The location of the box culvert in the overall physical plan is shown by the map (Figure 1). A view of the upstream side looking toward the east is shown in Figure 5. Shown also on the east side is the stilling well and box containing the recording system. A more thorough and complete view of the box culvert and related setup is found in Figure 10 where both the plan and elevation views are shown. The box culvert is 5 feet wide and 3.5 feet deep.

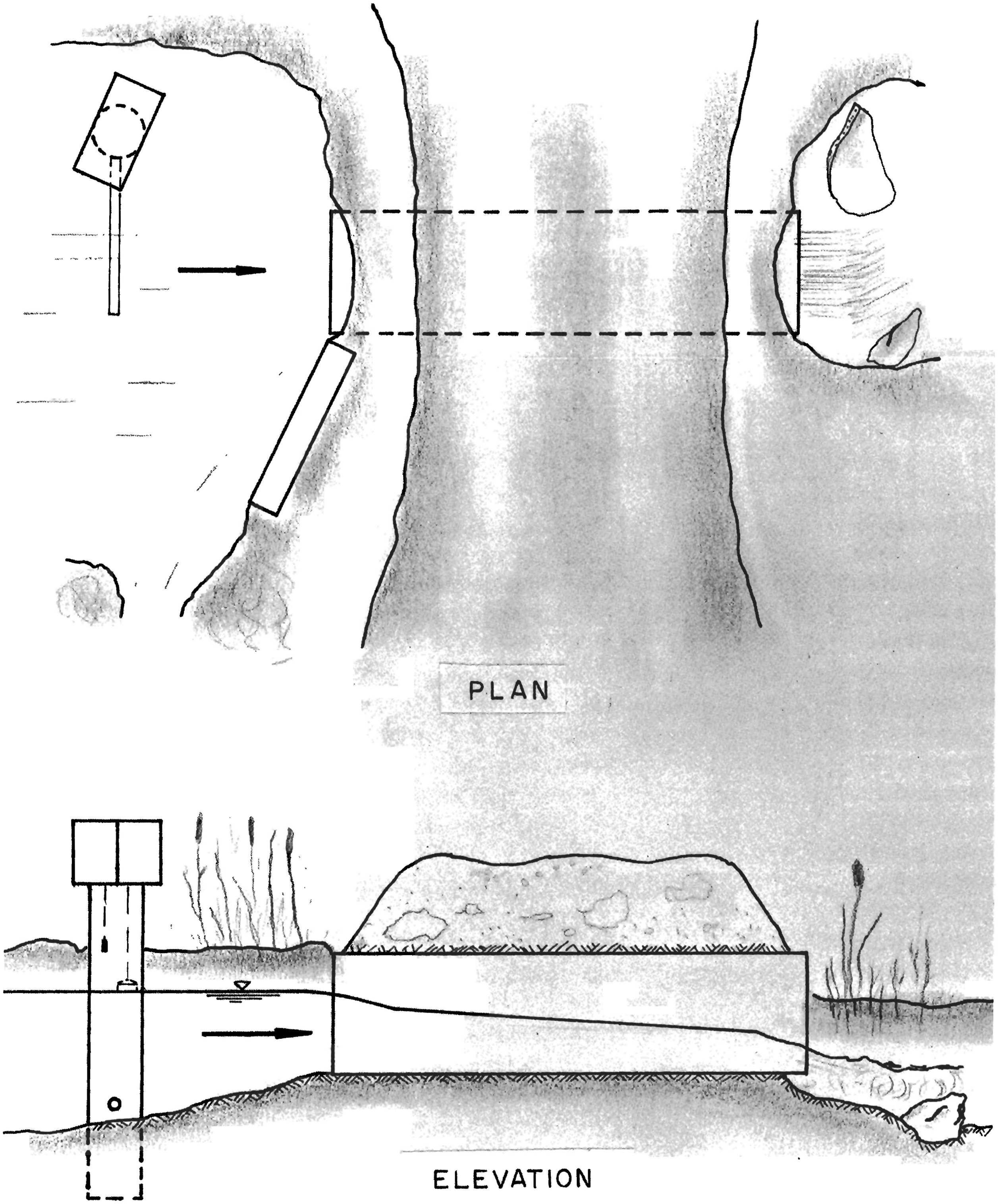


Figure 9. Plan and elevation view of corrugated culvert.

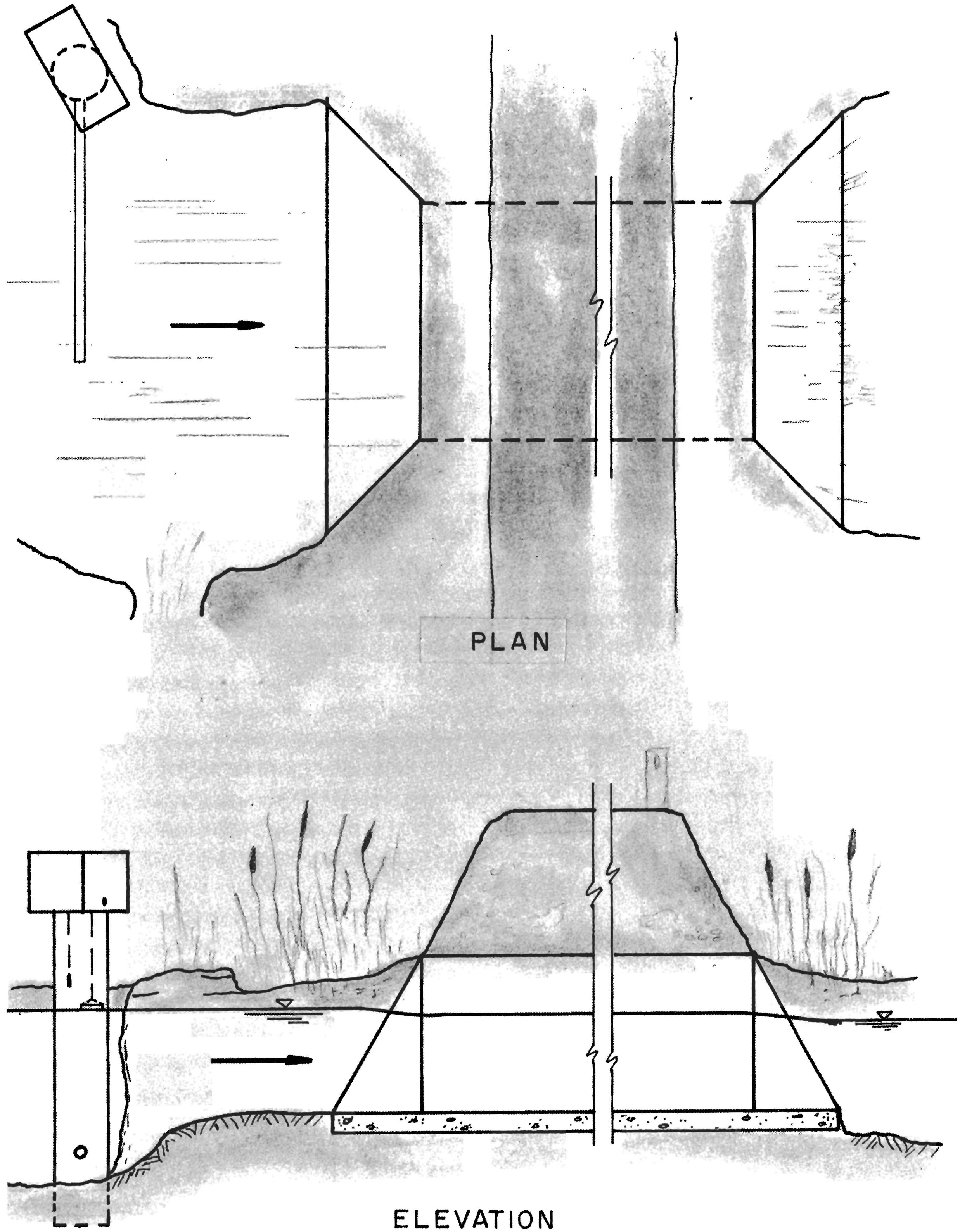


Figure 10. Plan and elevation view of box culvert.

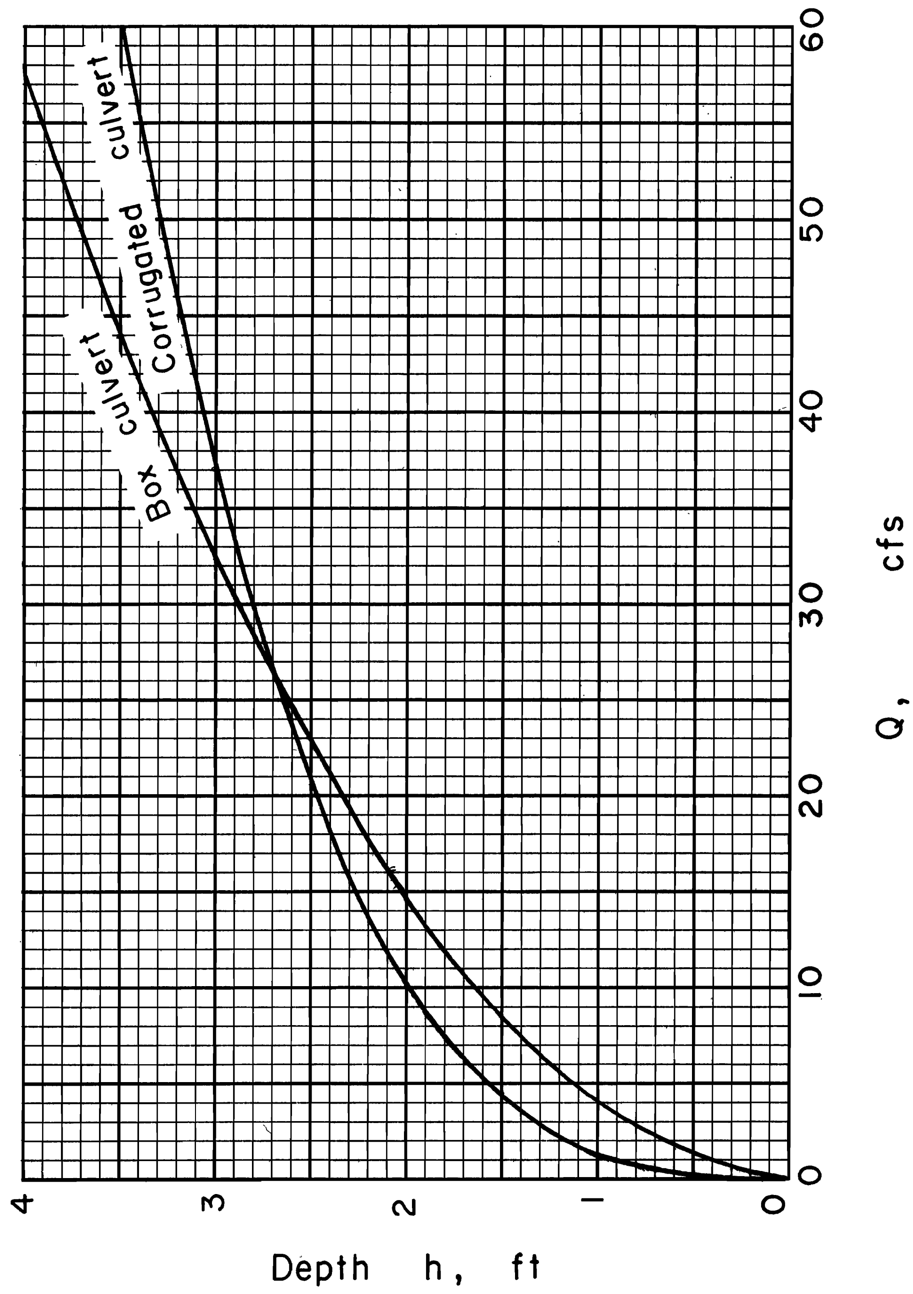


Figure 11. Calibration curves for the corrugated and box culverts.

The box culvert was also rated in the field. The calibration curve developed for the box culvert is found in Figure 11. This calibration curve is similar in nature to the one for the corrugated culvert and is used in the same manner. Obtaining the upstream depth of flow, Y_u, from the continuous recorder chart allows the discharge to be determined from the calibration curve in Figure 11.

CONTROL STRUCTURE

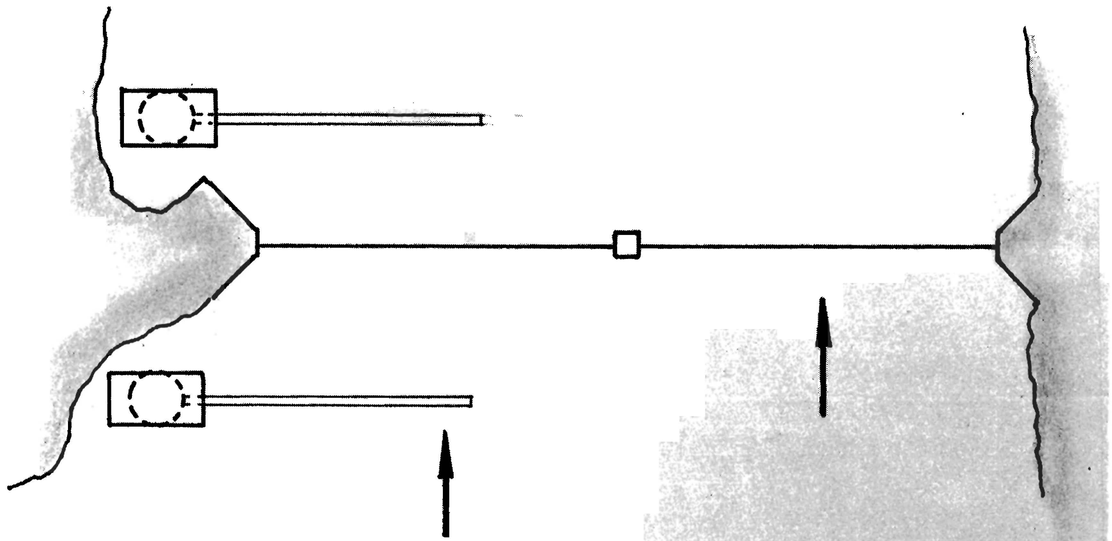
The control structure is located west of Logan at the west end of the oxidation pond and at the entrance of the Cow Pasture Canal (Figure 1). Figure 2 shows the upstream side of the structure looking down the Cow Pasture Canal. Figure 3 gives a view of the downstream side of the structure looking upstream into the oxidation pond. Also shown in both Figures 2 and 3 are the stilling wells and boxes containing the continuous recording equipment.

The control structure itself is about 20 feet wide and is divided into two bays of approximately equal size. The ends of the bays are slotted to hold standard 2-inch flashboards. Varying the height and number of flashboards controls the water level in the oxidation pond. Figure 12 shows a plan and elevation view of the control structure layout.

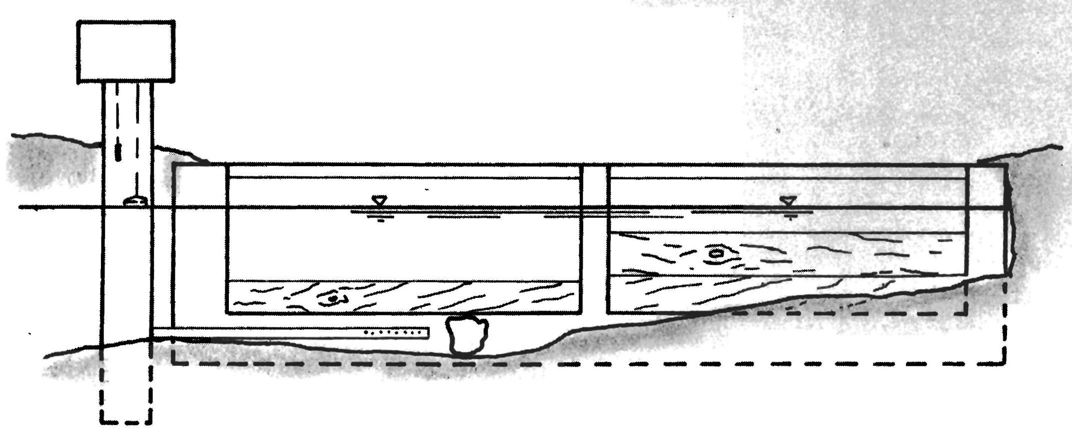
The control structure was rated in the field for the combinations of flashboards used during the summer. Because a great amount of time would be required before field conditions would provide the wide range of flow rates and variety of flashboard combinations that might possibly be encountered, it was felt that adequate calibration curves could only be obtained by constructing a model of the control structure.

The Fluid Mechanics Laboratory at Utah State University was selected for the model study. The flume used in the Fluid Mechanics Laboratory was 5 feet wide and 5 feet deep, and based on the size of this flume, a scale ratio for the model of 1:7 was selected. The 1:7 length ratio would require a flow rate ratio, Q_r, of 129.63 ($Q_r = L_r^{5/2}$). Flow rates through the prototype control structure as high as 40 cfs were expected, but this still results in a rather small discharge for the model. Since the flow rates available in the laboratory were greatly in excess of the flow rate required for a geometrically similar model, it was decided to distort the model. Since the depth of the flume was greater than the depth of the prototype control structure, it was possible to use the true vertical scale, while constructing the width and length of the structure 1/7 of the size of the prototype structure.

Stilling wells similar to those for the prototype structure were placed in the model. The depth of water in the stilling wells was measured by means of a point gage accurate to 0.001 feet.



PLAN



ELEVATION

Figure 12. Plan and elevation view of the control structure.

The flow passed through the model and discharged into weighing tanks where the water was weighed over a period of time to obtain the flow rate. The water was then discharged from the weighing tanks into a sump, where it was recirculated.

The flashboards used in the model were 8 inches high, and four were used in each bay. All possible combinations of flashboards were tested. An adjustable tailgate located downstream from the model was used to give different water levels for any given flow rate. For each constant flow rate used, the combinations of flashboards were varied, and for each flashboard pattern, the tailgate level was varied to provide all possible flow conditions.

In analyzing the data, an effort was made to develop a solution relating all the flashboard combinations but this proved impossible because of nonsymmetry in the control structure. As a result, a number of calibration curves had to be prepared to encompass the various flashboards. Hence, care must be taken to note the configuration of flashboards in each bay to insure that the proper rating curves are used. Another stipulation placed on the use of these calibration curves is that flashboards of 8 inch height be used in the prototype structure, although it is possible to estimate the discharge by interpolation for other flashboard heights. The measurements collected in the field were compared with the curves developed from the model study. The field measurements verified the prototype calibration curves developed from the model study with the result that no corrections were required.

The difference in the upstream and downstream flow depths, ΔY, is plotted as the abscissa for the calibration curves, while the upstream depth, Y_u, is plotted as the ordinate, and the flow rate, Q, is plotted as the varying parameter. Also found on the calibration curve is a small drawing indicating the flashboard combinations for which the curves are valid. Hence, to obtain the discharge through the control structure, the upstream and downstream flow depths are obtained from the continuous recorder charts and ΔY is computed. The proper calibration curves for the particular flashboard combination being used are located, and the values of Y_u and ΔY are used to obtain a point on the graph from which the discharge may be interpolated.

Following, in Figures 13 through 25, are the calibration curves for the control structure in the field for almost all possible flashboard combinations. The drawings found on the calibration curves illustrate the configuration of flashboards used. The bay on the left side is designated the south bay, S, and the bay on the right side is designated the north bay, N. The subscripted number indicates the number of flashboards present in that bay, thus S_0N_3 indicates no flashboards in the south bay and three in the north bay, and S_3N_1 signifies three flashboards in the south bay and one in the north.

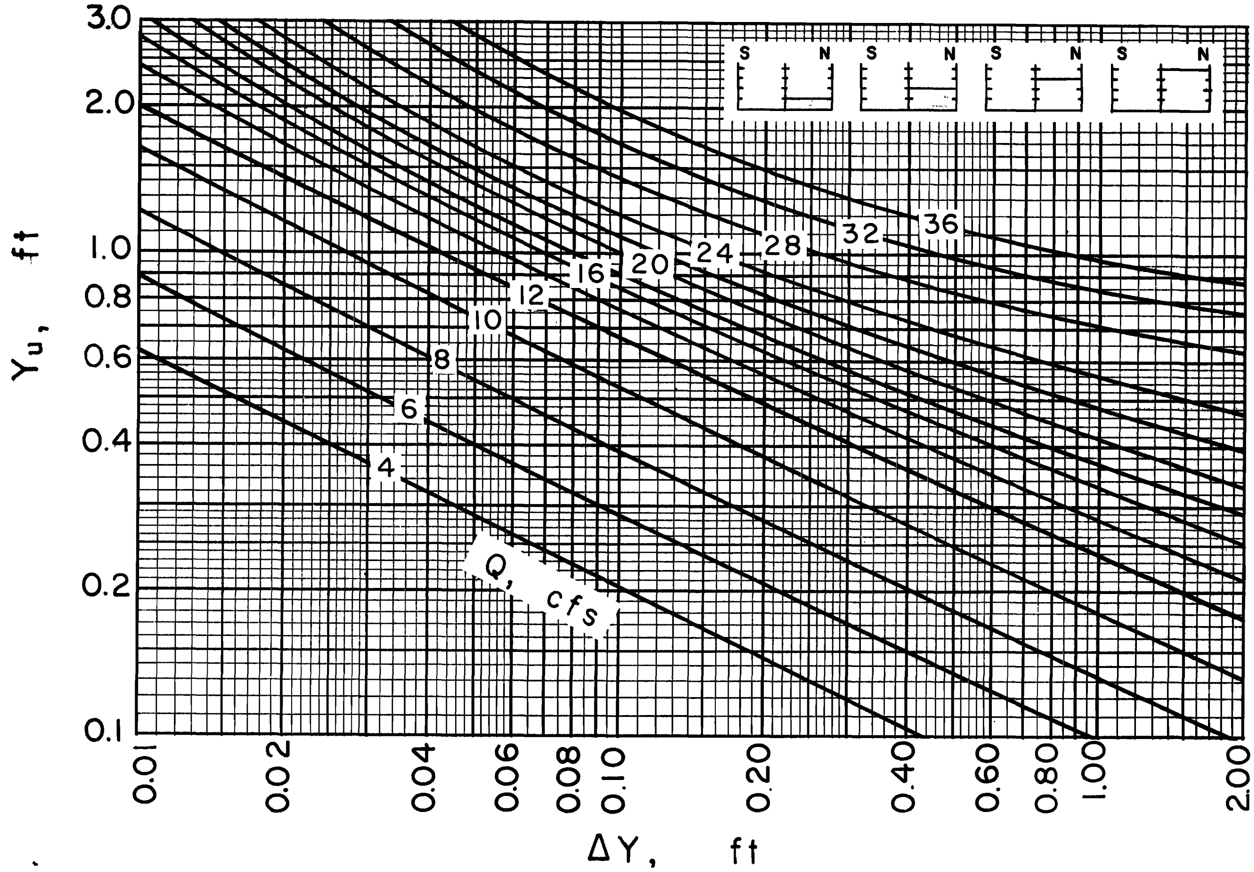


Fig. 13. Calibration curves for S_0N_1, S_0N_2, S_0N_3, and S_0N_4 configurations.

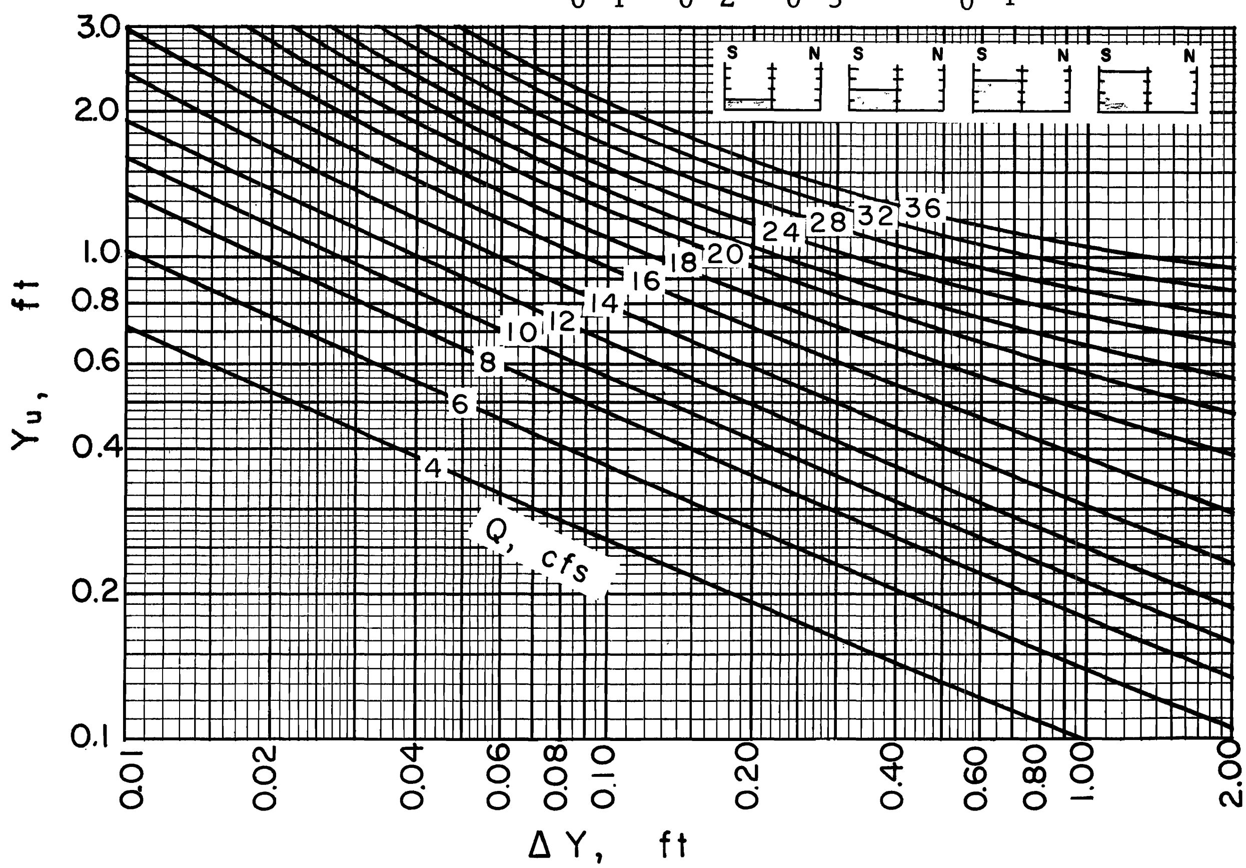


Fig. 14. Calibration curves for N_0S_1, N_0S_2, N_0S_3, and N_0S_4 configurations.

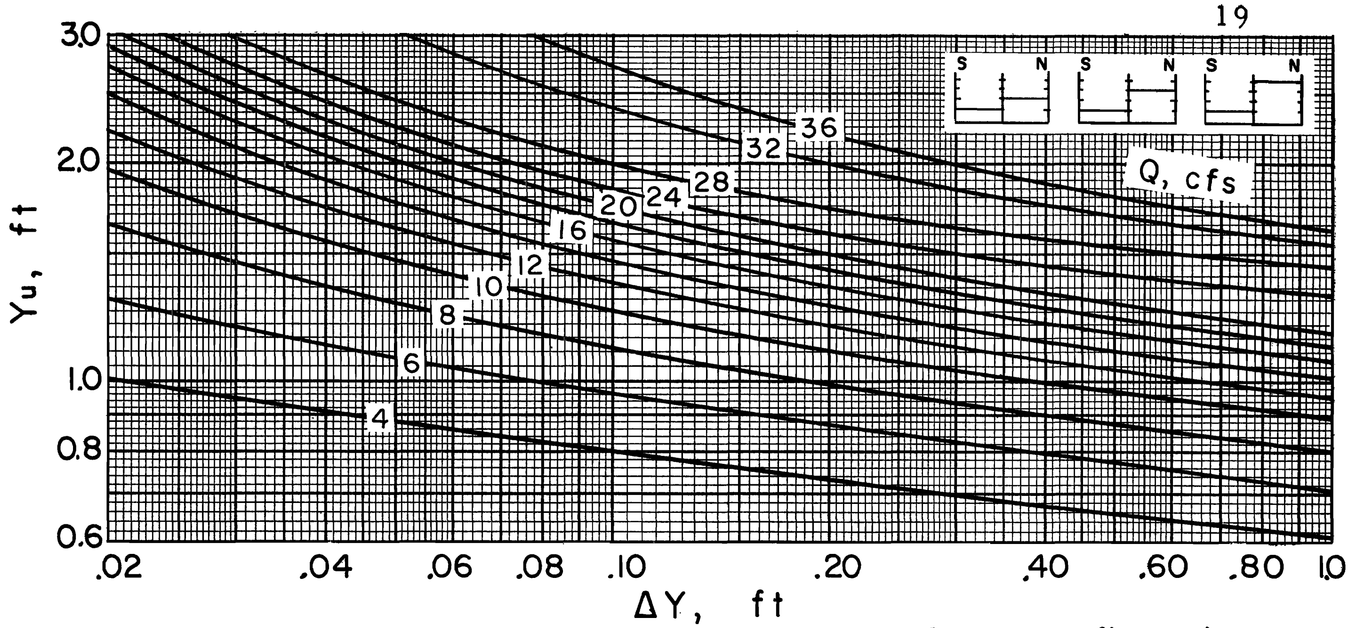


Fig. 15. Calibration curves for S_1N_2, S_1N_3, and S_1N_4 configurations.

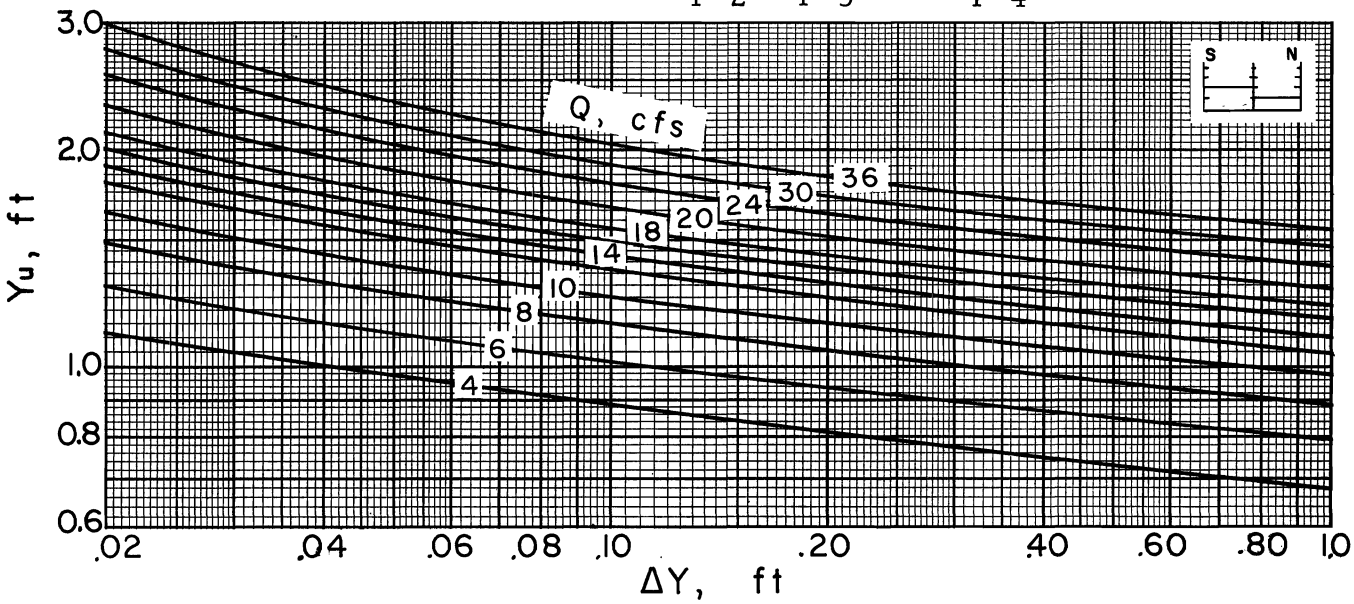


Fig. 16. Calibration curves for S_2N_1 flashboard configuration.

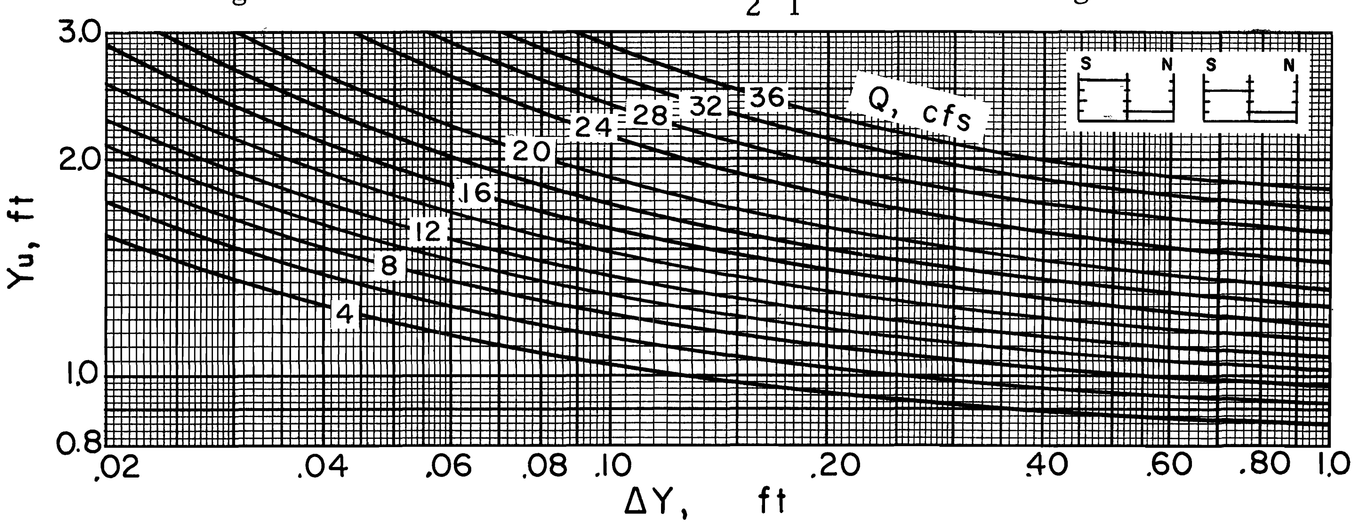


Fig. 17. Calibration curves for S_3N_1 and S_4N_1 configurations.

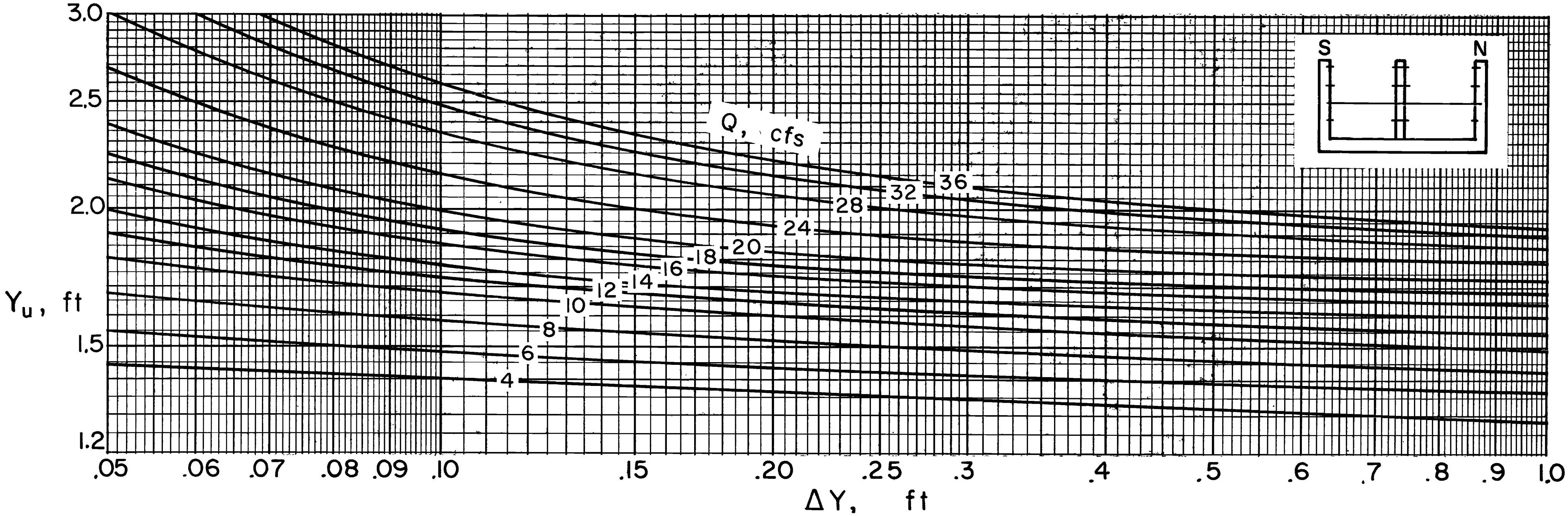


Fig. 18. Calibration curves for S_2N_2 flashboard configuration.

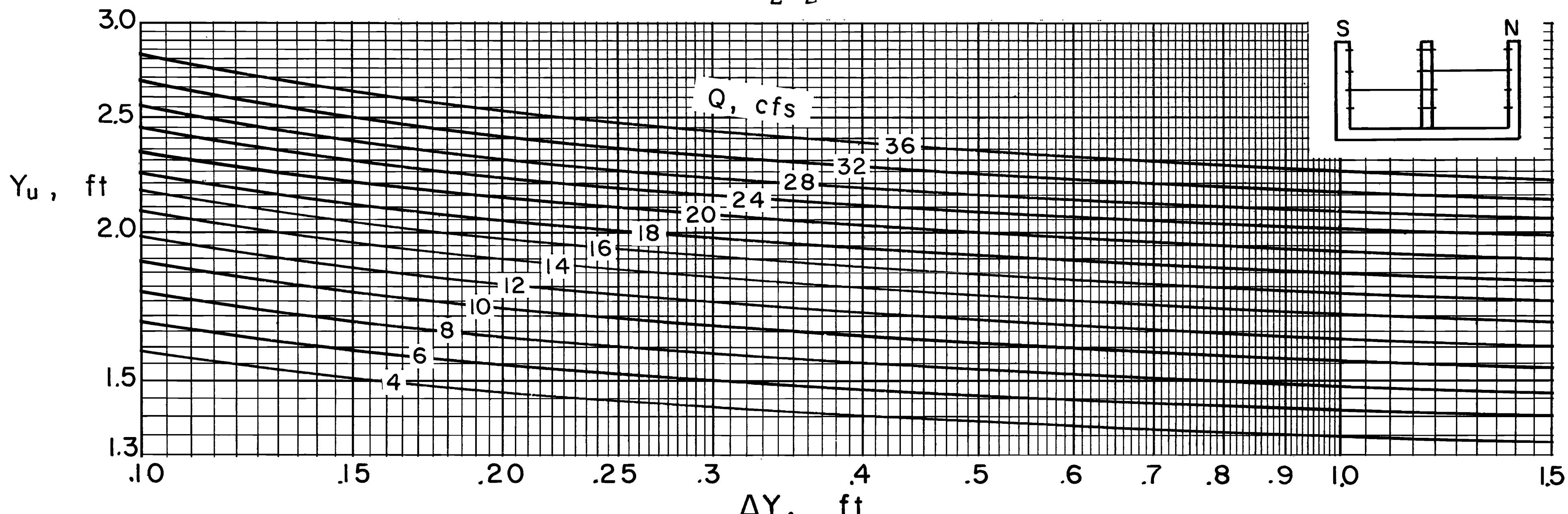


Fig. 19. Calibration curves for S_2N_3 flashboard configuratior

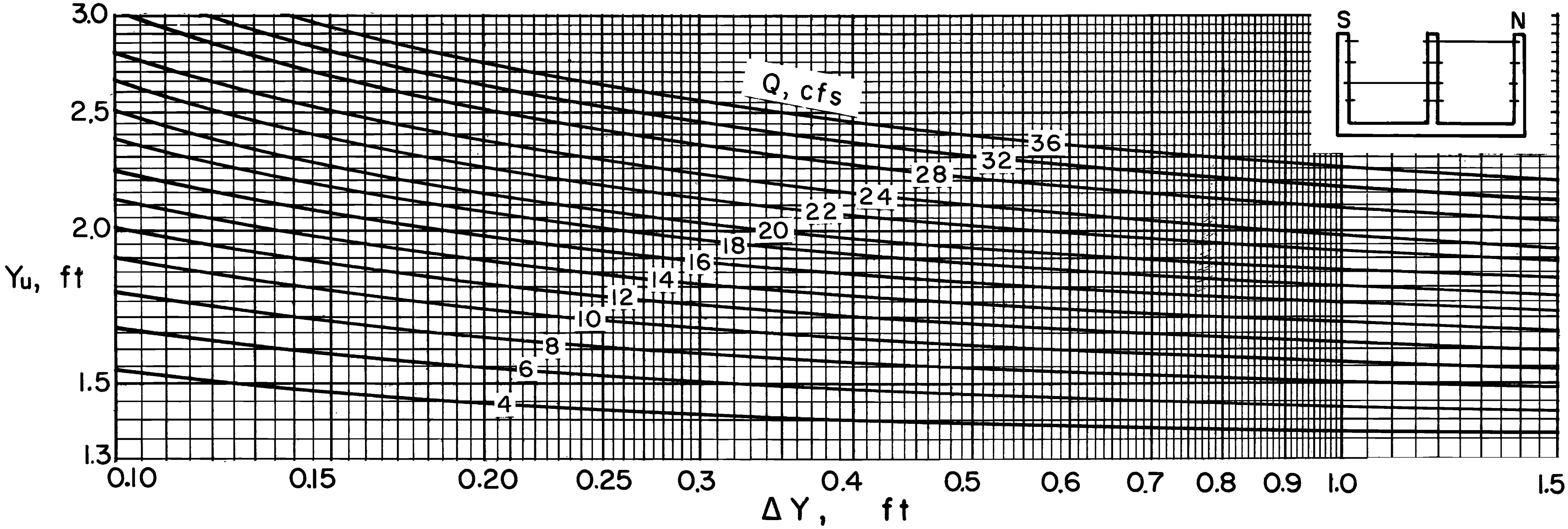


Fig. 20. Calibration curves for S_2N_4 flashboard configuration.

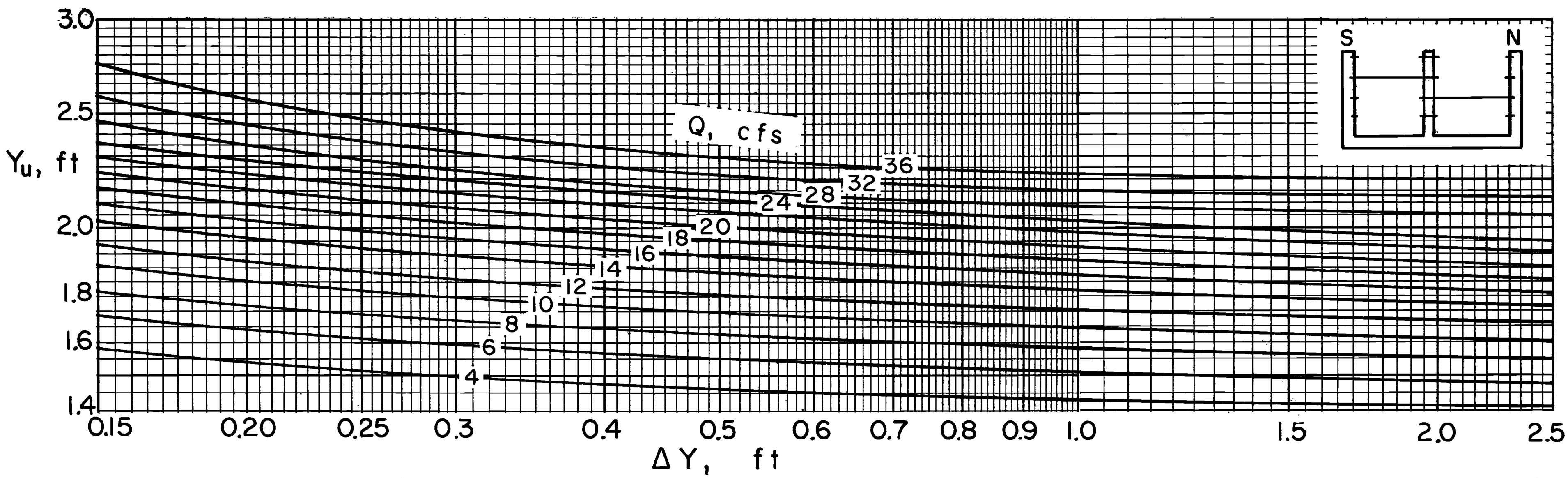


Fig. 21. Calibration curves for S_3N_2 flashboard configuration.

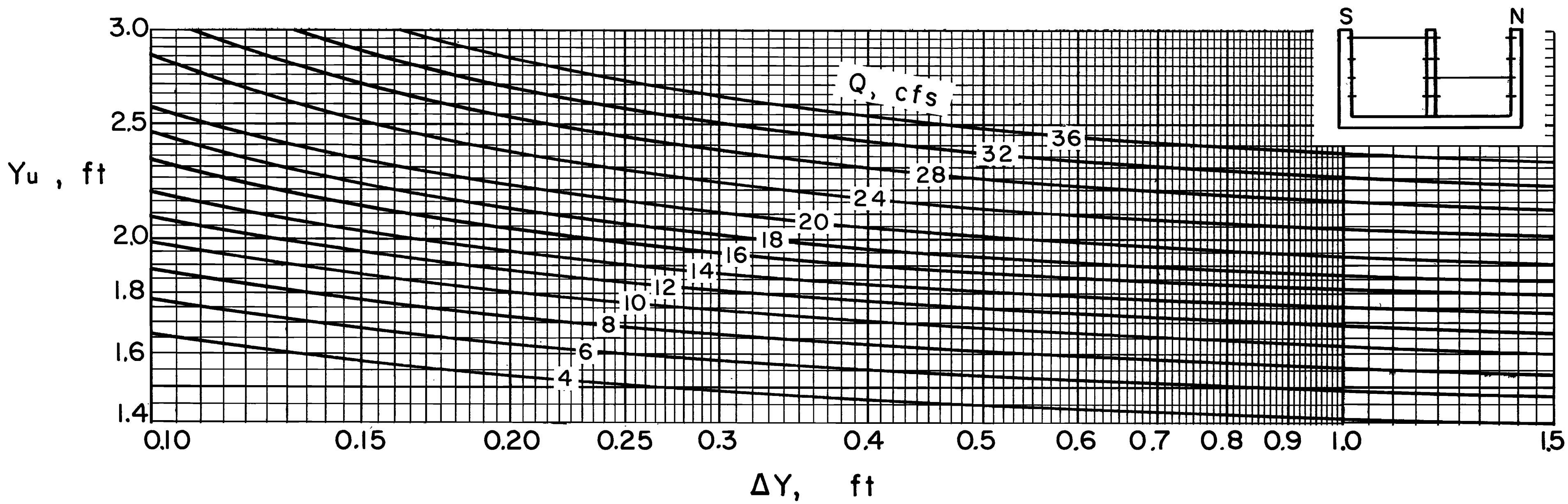


Fig. 22. Calibration curves for S_4N_2 flashboard configuration.

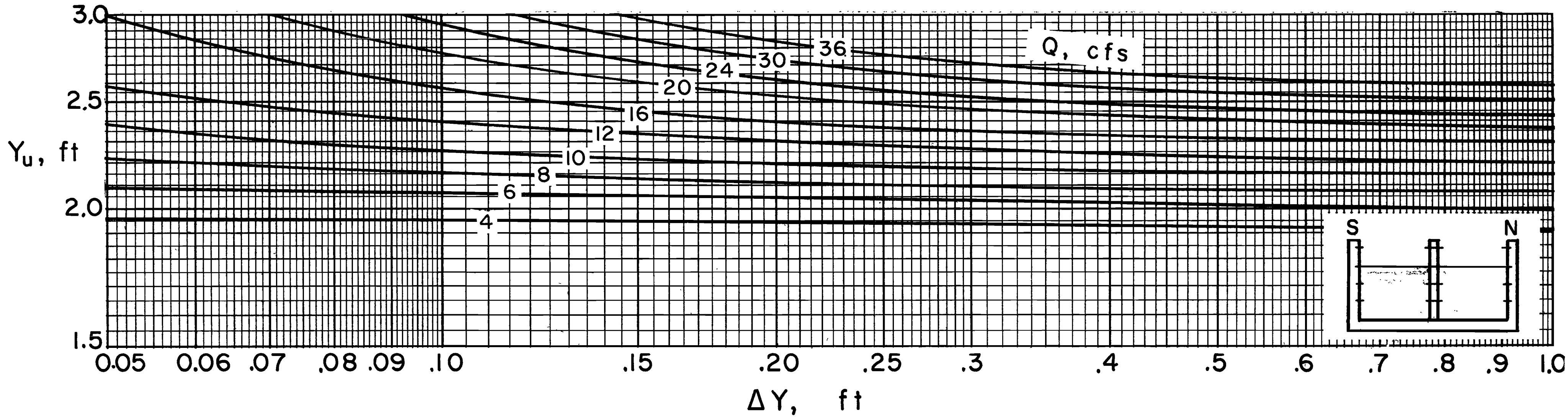


Fig. 23. Calibration curves for S_3N_3 flashboard configuration

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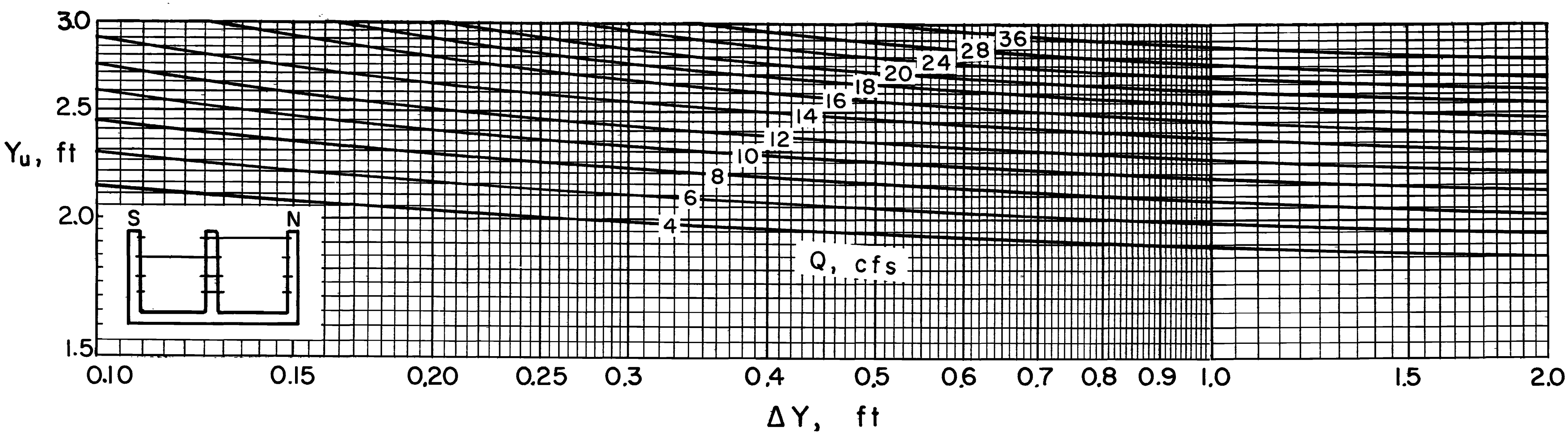

Fig. 24. Calibration curves for S_3N_4 flashboard configuration.

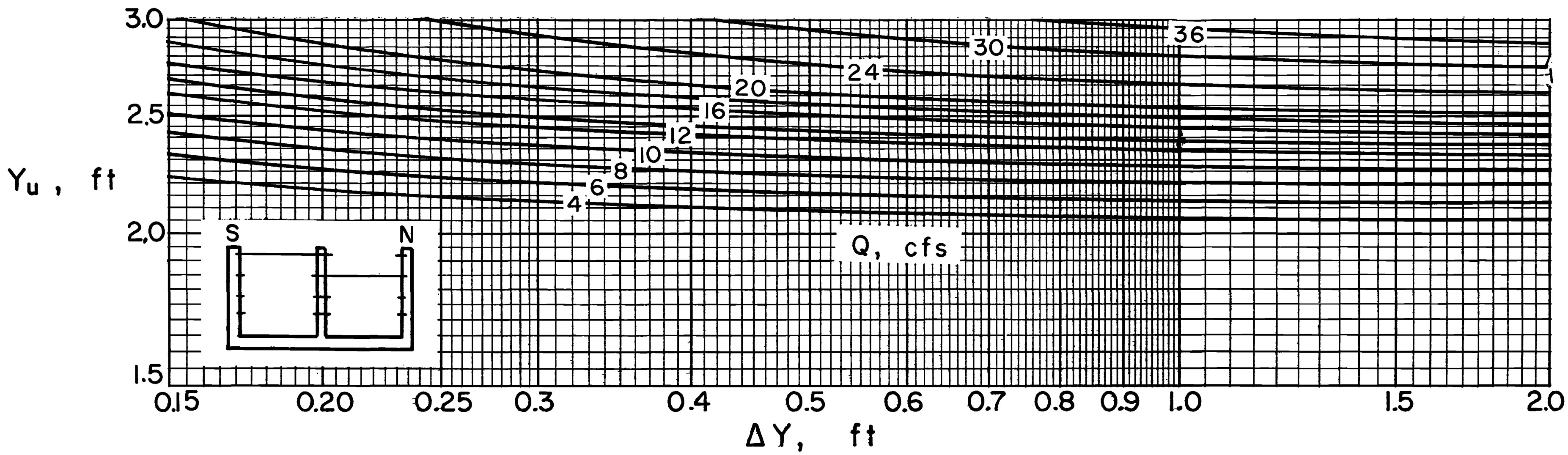

Fig. 25. Calibration curves for S_4N_3 flashboard configuration.