FINAL REPORT

PROJECT A-953

HYDRAULIC INVESTIGATIONS OF TAINTER GATES AS FLOW MEASURING DEVICES

BY

PAUL G. MAYER
and
BRUCE R. OLMSTEAD

CONTRACT NO. 12-14-100-8874(41)

24 JUNE 1966 to 24 DECEMBER 1967

Prepared for
UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL AND WATER CONSERVATION RESEARCH DIVISION
ATHENS, GEORGIA

1967

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

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TABLE OF CONTENTS

LIST OF FIGURES

(Continued)

LIST OF FIGURES
(concluded)

LIST OF TABLES

ABSTRACT

This report is the Final Report on an intensive study of the feasibility of Tainter gates as flow measuring devices.

The effective use, control, and management of water resources usually requires both flow-control devices and flow measurements. Hydrologic studies on agricultural watersheds involve flows through drainage channels. An important area of agricultural water is that of irrigation. In both irrigation and drainage, basic information on methods of flow control and the measurement of flow quantities over and through control structures is of utmost economic importance in the design and maintenance of stable channels in erodible soils.

Soil and water conservation activities in the Southern Florida Flatwoods, as elsewhere, have utilized Tainter gates for the purpose of stream flow control. A study of existing control structures in Okeechobee County, Florida, was coupled with hydraulic model studies to enhance the design of Tainter gates, to investigate the use of such gates as flow measuring devices, to adapt remote sensing devices for the recording of pertinent field data, and to develop a computer program which would translate periodic recordings into discharge rates.

Hydraulic models of two typical installations were built and tested. The model results were in accord with available field measurements. A parametric formulation of the pertinent variables was possible and, in general, the extension of model data to prototype field performance promises to yield indirect flow measurements of considerable accuracy.

I. INTRODUCTION

The determination of flow rates is essential to all hydraulic engineering projects. The effective use, control, and management of water resources usually require accurate measurements and records of stream flows.

Hydrologic studies on agricultural watersheds involve flow rates of water through drainage channels. Another critical area of agricultural water use is that of irrigation. Basic information on methods of measuring quantities of flow over and through control structures is further of utmost economic importance in the design and maintenance of erodible channels.

A common method of controlling flow over and through control structures is the use of Tainter gates. Tainter gates are radial type gates, which are horizontally supported between piers and abutments. Such control devices are installed in single-gate control structures as well as in multiple-gate control structures.

Soil and water conservation activities in the Southern Florida Flatwoods, as elsewhere, have utilized Tainter gates for the purpose of stream flow control. In an effort to improve the operation of existing control structures and the management of water resources in the Southern Florida Flatwoods, the Agricultural Research Service, U. S. Department of Agriculture, has contracted with the Georgia Tech Research Institute to carry out a study of the feasibility of utilizing Tainter gates as flow measuring devices.

The contract called for field observations and for the construction and investigation of hydraulic models of control structures No. 1 and No. 3 of the Taylor Creek watershed, Okeechobee County, Florida. The project area is near Lake Okeechobee, as shown in Figure 1. A location sketch of the Taylor Creek watershed and the locations of the control structures in the project area are shown in Figure 2. Structure No. 1 is located on the main stem of Taylor Creek and consists of three Tainter gates, each 15 feet wide and 7 feet high. The gates are supported by concrete piers and abutments and are manually operated. A stilling basin at the downstream side of the control structure is designed to dissipate excessive kinetic energy of the flow issuing from the Tainter gates and to protect the downstream channel of Taylor Creek from scour and erosion. The control structure No. 3 has similar features and its single gate is 10 feet wide and 3 feet high. Control structure No. 3 is located on an upper branch of Taylor Creek.

Some design and operational criteria for structure No. 1 were available. On August 9, 1966, Mr. Roy B. Stone, Jr., Mathematician in Charge, U.S.G.S., Branch of Surface Water, Florida District, wrote to Mr. William H. Speir, reporting difficulty in obtaining a unique rating for structure No. 1 because of the variable backwater conditions from Lake Okeechobee. Mr. Stone presented some field calibration data for overflows only.

Through the courtesy of Mr. David E. Alcorn, State Conservation Engineer for Florida, U.S.D.A., Soil Conservation Service, additional design criteria for structure No. 1 were received by letter, dated August 10, 1966. The letter gave, in part, design discharges as quoted below:

> "For structure No. 1. . . . .
> Design Q = 600 c.f.s. over the gates with all gates closed.
> Design Q = 600 c.f.s. under one gate only. The other two gates closed.
> The structure would accommodate a flow of 1800 c.f.s. with its three gates wide open.
> The channel was designed to convey 600 c.f.s. to the structure at the hydraulic gradient shown on the engineering plans.
> When the channel is full, all gates have to be opened gradually at the same time to prevent distorted flows below the structure that will erode the channel banks and embankments behind the wing walls.
> The gate openings should be about equal at all stages during the time that they are being operated when the channel is flowing at or near the design capacity.
> The apron on this structure is not designed to accommodate full capacity flow through one gate with the other two closed without

causing distorted flows that may cause downstream erosion detrimental to the structure."

According to the terms of the contract, the investigators agreed to:

1. Investigate improvement in the design of the Tainter gates described above;

2. Calibrate such gates for the measurement of discharges;

3. Adapt sensing devices for periodic recordings of gate position and water surface elevations; and

4. Develop a computer program which would translate field data into discharge rates. The computer program was to be written in Fortran.

The study was performed under a Memorandum of Understanding between the Agricultural Research Service and the Georgia Tech Water Resources Center. The liaison officer for the Agricultural Research Service was Mr. John C. Stephens, Director, Southeast Watershed-Hydrology Research Center, Athens, Georgia. The project director was Dr. Paul G. Mayer, Professor of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia.

For reasons of endearment, the control structures No. 1 and No. 3 were named Richard and Herman respectively. These designations were retained in this Final Report.

II. THE HYDRAULIC MODELS

The experimental work was carried out in the Hydraulics Laboratory of the School of Civil Engineering, Georgia Institute of Technology. Much valuable assistance was rendered by Mssrs. Bruce Olmstead and Wouter Gulden, Senior Civil Engineering students, and by Mr. Homer Bates, Principal Laboratory Mechanic.

The study was undertaken by proposing that model studies would yield useful results in terms of the performances of the actual structures. The problem was tackled by assuming tentative answers in the form of hypotheses which were to be tested by deriving suitable relationships, and by checking these by actual experiments in the laboratory. It is difficult to report on the formative period as both speculation and preliminary experiments were of aid in determining the course of action. It is fair to report that some of the hypotheses were ad hoc and were based on antecedently obtained experimental results, others were based on theoretical consideration, and still others were based on mere intuition. The results of some laboratory tests were gathered into mathematical formulations. Further laboratory data were used to test further implications of preliminary results, and to provide more or less strong support for the initial assumptions.

The concept of geometrical similarity suggested that the hydraulic models were to be geometrically similar to the prototype structures in all important respects. Exact geometrical similarity was precluded by the lack of information on all details of the structures and of the adjacent portions of Taylor Creek. A further limitation was the inability in the shop and in the laboratory to reduce such and other details to the scales of the models.

The predictability of prototype performance from the results of hydraulic model studies requires that the models, having satisfied geometrical similarity, have the identical flow pattern encountered in the prototype structures at any given time and at a given mode of operation. The motion patterns are the result of external forces acting on a system. These forces obey Newton's Second Law.

The equation of motion for a constant-density, constant-viscosity fluid (essentially true for water at ordinary temperatures) in the earth's gravity field is given by

$$\rho\vec{g} - \nabla p + \mu\nabla^2\vec{q} = \frac{\partial\vec{q}}{\partial t} + (\vec{\nabla}\cdot\vec{q})\vec{q} \qquad (1)$$

where ρ, mass density

p, pressure intensity

μ, dynamic viscosity

$\vec{q}$, total velocity vector having components u, v, w

t, time

∇, ∇^2, vector operators

g, gravitational acceleration

In a Cartesian co-ordinate system, the above equation has three components and the x-component of the equation of motion is given by

$$-\rho g\frac{\partial h}{\partial x} - \frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) =$$

$$\rho\frac{\partial u}{\partial t} + \rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right) \qquad (2)$$

where h is a position term. This equation may be non-dimensionalized by the use appropriate reference values of length, $L = \frac{x}{x^\circ}$, and velocity $V = \frac{u}{u^\circ}$ in which the superscript "°" denotes dimensionless quantities. The same operations may be carried out for the other component equations. Summarizing the dimensionless equations and representing them in vector notation

$$-\left(\frac{gL}{V^2}\right) \nabla h^\circ - \nabla \rho^\circ + \left(\frac{\mu}{\rho V L}\right) \nabla^2 \vec{q}^\circ =$$

$$\frac{\partial \vec{q}^\circ}{\partial t} + (\Delta \cdot \vec{q}^\circ)\vec{q}^\circ \qquad (3)$$

The equality sign of the above dimensionless formulation demands that the coefficients are also dimensionless. In fact, the coefficients are recognized as the Froude number and as the Reynolds number, respectively. An important physical interpretation of these results rests with the fact that the Froude number also represents the ratio of the inertia force to the gravity force, and the Reynolds number also represents the ratio of the inertia force to the viscous resistance force. In the above mathematical analog as in the hydraulic model analog, the Froude number is therefore an important model law whenever gravity forces are dominant in fluid motion, and the Reynolds number is the important model law whenever viscous behavior dominates the flow patterns.

In order to obtain identical flow patterns in the hydraulic models and in the prototype structures, identical force ratios must prevail. Hence the same Froude number and the same Reynolds number must be present in the models and the prototype structures. Unfortunately, each model law has its own and distinctly different relationship between velocity and length. Based on the above considerations, complete dynamic similarity is obtainable only in a full scale model, or in the absence of either one force ratio in the study of a small scale hydraulic model in the laboratory. The above formulation also does not allow for the effect of the free surface which may assume an influence in the model performance out of proportion to its role in the prototype operation. The aforementioned lack of complete geometrical similarity introduces into the model performance an additional uncertainty regarding the level of turbulence in the motion patterns of the models.

Ultimately, the flow through and over Tainter gates was judged to be predominantly a gravity flow phenomenon, and the Froude model law was employed in the laboratory studies. The results of the studies were expected to be subject to the same and possibly other limitations as outlined above.

The model-prototype relationships were predicated on geometrical and dynamical similarity in general, and on the Froude model law in particular. Both considerations of laboratory space available and laboratory flow capacity determined the approximate model scales. Water was supplied by the laboratory's permanent constant-head recirculatory system. The system capacity allowed for flows in excess of 5 cubic feet per second. For the 3-gated control structure No. 1 (Richard) a 10-foot wide channel was available. For Herman, the 1-gated control structure No. 3, a 3-foot wide channel was used. For both hydraulic models the corrugated surfaces of the Tainter gates were machined from a 20-inch diameter steel pipe. The gate radii thus fixed the model scale of Richard at 1:10.60, and the model scale of Herman at 1:6.15. A schematic view of the laboratory arrangements is shown in Figure 3.

The model scales are represented by the ratio of the length, L_{model}, to the appropriate length in the prototype structure, $L_{prototype}$. This ratio is designated by λ. Table 1 shows the pertinent ratios for the models Richard and Herman.

The Froude model law also determines the area ratios, velocity ratios, and discharge ratios. The area ratios are, obviously, the square of the length ratios. The velocity ratios are obtainable directly from the Froude number, since the gravitational acceleration is invarient. Thus, the velocity ratios are equal to the square-roots of the length ratios. The discharge ratios are obtained from considerations of continuity, that is the volumetric discharge is equal to the velocity times the cross sectional area. The discharge ratios are therefore equal to the area ratios times the appropriate velocity ratios. The model-prototype relationships are summarized in Table 1.

TABLE I

MODEL DATA

Froude Model Law: $(\frac{V^2}{gL})$ Model $= (\frac{V^2}{gL})$ Prototype

	Richard	Herman
Scale, λ	1:10.60	1:6.15
Area, λ^2	1:112.36	1:37.82
Velocity, $\lambda^{1/2}$	1:3.26	1:2.48
Discharge, $\lambda^{5/2}$	1:366.29	1:93.79

RICHARD

Water for Richard was continually pumped to a weir-controlled head tank and released through a 12-inch valve-controlled pipe either into an automated weighing tank or into the entrance bay of the model channel. The model of Taylor Creek in the proximity of Richard was made of plywood. Fiberglass coating provided both water tightness and permanency.

Two separate models of Richard were built. The first of the models, Richard I, featured a set of smooth-faced Tainter gates made of plastic. These gates were supported between wooden piers and abutments. The purpose of the smooth-faced gate study was to obtain operational model data which was to be compared with performance characteristics of other smooth-faced Tainter gates tested and reported elsewhere, and with performance characteristics of the corrugated gates of prototype structures in the Taylor Creek watershed project area. Unfortunately, the model, Richard I, was subject to considerable changes in geometry and damage due to swelling and cracking of the wooden gate supports. No data analysis for Richard I was undertaken. Laboratory data are presented in the Appendix.

Richard II featured the corrugated gates. These gates were supported between plastic piers and abutments and were not subject to detrimental deformations during the period of study. All subsequent references to Richard are thus applicable to the second model.

Satisfactory flow conditions into the model entrance bay were accomplished by means of expanded metal screens in conjunction with wooden slats. A floating wave suppressor was effective in eliminating water surface agitation upstream from Richard. The water surface elevations downstream from the gate controls were maintained in the model by means of adjustable weirs. Figure 4 shows details of the model entrance bay during operation.

Details of Richard are shown in Figure 5. A typical model of the Tainter gate is shown in Figure 6. The gates were fabricated in the shop of the Georgia Tech Experiment Station. The corrugations were simulated by cutting appropriate grooves on the surface of a 20-inch diameter steel pipe. Subsequently, sectors were sliced from the pipe and angle iron supports were then welded to the sectors to form the model gates. Figure 7 shows the 3 gates of Richard II during operation of the hydraulic model. A comprehensive view of the model is shown in Figure 8. Water is seen discharging from the weighing tank into the model entrance bay. The effectiveness of the expanded metal screens and the floating wave suppressor can be judged by the quiescent flow conditions upstream from the gate structure. The turbulent flow patterns downstream from the gates resulted from the baffle blocks of the stilling basin. A close-up of the baffle blocks in the model stilling basin is shown in Figure 9.

HERMAN

Herman was the name given to the model of the control structure No. 3. It featured one Tainter gate. In the prototype structure, the gate was manually operated. Details of Herman are shown in Figure 10.

The hydraulic model, Herman, was built into a 36-inch wide channel. It featured the one corrugated Tainter gate which was similar to those of Richard. The gate supports were made of Plexiglass. Portions of Taylor Creek in the proximity of Herman were made of wood, appropriately sealed and connected to the control structure. The baffle blocks and the stilling basin downstream from the gate were also made of wood. The model Tainter gate is shown in Figure 11. Details of the model stilling basin and baffle blocks are shown in Figure 12.

In the laboratory, flow entered Herman through a 12-inch valve controlled pipe from the constant head tank. The flow entered first into a entrance bay. Expanded metal screens and wooden slats together with a floating wave suppressor were used to obtain quiescent flow conditions in the model entrance. The water surface elevations below the control structure were controlled by an adjustable tail gate at the end of the channel. This tail water control mechanism is shown in Figure 13. An overall view of the laboratory installation of Herman is shown in Figure 14. In this figure, the control structure is viewed from the downstream end of the laboratory channel. The flow through Herman was either collected for measurement in the automated weighing tank, or returned to the floor sump of the laboratory's recirculatory system.

III. MODEL TEST PROCEDURES

A. RICHARD

Field operation of the control structure No. 1 was simulated in the laboratory. One series of tests on the model were conducted with all gates closed. In this instance all discharges through the control structure were represented by flows over the Tainter gates only. Discharges over the closed Tainter gates were not affected by downstream flow conditions or by water surface elevations downstream from the structure. Overflows were measured in the model for various stages in the upstream reach of Taylor Creek. The water surface elevations were measured by means of a point gage. The flow quantities were determined by means of the weighing tank. Repeated measurements were made to assure proper determinations of the pertinent quantities.

Other series of tests on Richard involved discharges from under the Tainter gates only, and combined overflows and underflows. These tests were conducted for various gate positions and combinations of gate openings. For every rate of discharge, gate settings were systematically selected in a fashion of o-o-n, o-n-o, n-o-n, and n-n-n, where n represented gate openings in one-half-foot intervals and n = 1, 2, 3, etc. The symbol o represented a closed gate.

The prototype control structure No. 1 is located sufficiently close to Lake Okeechobee so that Taylor Creek below the structure is in effect in the backwater of the lake. Lake Okeechobee is subject to considerable wind set-up and hence the water surface elevations below the structure would likewise be subject to fluctuations. The range of conditions of downstream water surface elevations which were investigated in the model was limited by the assumption of a non-scouring mean velocity for sandy soils such as the one found in the Florida Flatwoods. Thus the maximum permissible velocities were assumed to be

1.5 feet per second for the prototype. To reflect the backwater of Lake Okeechobee, additional conditions were investigated, in which the tailwater settings corresponded to velocities of approximately 1.0 feet per second and 0.5 feet per second. These manipulations were accomplished by raising the exit weirs in the model.

The maximum water depth upstream from the control structure was specified as 9.74 feet. The design discharge was 1800 cubic-feet per second. The model of Taylor Creek featured a bottom width of about 47.5 feet and 1:1 side slopes.

A systematic investigation of the performance characteristics of Richard was then carried out. For given conditions of gate openings, the flow rates were varied, and for each condition of gate position and flow rate the tailwater elevation was manipulated, as indicated above, to simulate the effects of Lake Okeechobee on the performance of the control structure.

Measurements of discharge through Richard were made by means of the automated weighing tank. Upstream and downstream water surface elevations were measured by means of a carriage mounted point gage. Gate positions were set by means of calibrated spacer blocks. All measurements were made repeatedly and under steady state conditions.

HERMAN

Field operations of the prototype control structure No. 3 were simulated in the model for flow over the closed Tainter gate only, for flow under the partially open gate only, and for combined overflow and underflow. Model data of discharge and water surface elevations were obtained for various flows up to the prototype design discharge of 250 cubic feet per second.

A characteristic feature of Herman is a 4.3 foot drop from the gate sill to the creek bottom elevation downstream from the structure. Thus flows over the closed Tainter gate are obviously free of interference from flow conditions and water surface elevations downstream from the control structure.

The control structure No. 3 is located sufficiently far upstream from structure No. 1 so that the water surface elevations in Taylor Creek immediately downstream from Herman are uniquely determined from uniform flow conditions. Field data available for Taylor Creek give the channel slope equal to 0.00018, Manning's n equal to 0.035, and the channel dimensions as a bottom width of 10 feet and side slopes of 1:2. The computed variations of uniform flow depth with discharge are shown in Figure 15.

A series of preliminary tests were carried out on Herman to establish an upper limit of downstream water surface elevations below which the flow through the control structure could be considered independent of backwater effects. For that purpose, flows through the ungated structure were studied. For every discharge, the upstream water surface was carefully measured as the tailwater was raised. Whenever the upstream water surface elevation began to be raised because of backwater effects, that tailwater elevation was recorded and disignated as limiting depth.

Another series of preliminary tests on Herman were carried out with gate openings equal to 1.0 feet (prototype) in order to establish limiting depths under these conditions.

These preliminary tests were analyzed and the results are shown in Figure 16. Accordingly, discharges through the control structure No. 3 were controlled by the structure at all flows up to the design discharge of 250 cubic feet per second, and were independent of the downstream water surface elevations.

A systematic investigation of Herman was then carried out in which the Tainter gate positions were systematically raised by one-half-foot intervals. Measurements of discharge were made by means of the automated weighing tank. Upstream water surface elevations were measured by means of a point gage. Gate positions were set by means of calibrated spacer blocks.

IV. MODEL DATA ANALYSIS AND RESULTS

The pertinent flow conditions in the models Richard and Herman which corresponded to prototype performances were:

a. Overflow only

b. Underflow only

c. Combined overflow and underflow

In order to extract basic design information from this study, the model was analyzed in various ways. In as much as a mathematical formulation is only an analogue of a physical phenomenon, attempts were made to establish interrelationships that exist between pertinent variables. The application of the notion of dimensions of physical quantities was essential to the derivation of formulae and equations. Dimensional analysis yielded a surprising amount of information. The method itself was only a tool in the study and did not in itself yield numerical answers. Dimensional analysis, however, gave insight into the physics of the problems of this study as it is based on dimensional homogeneity of the fundamental units of mass, length, and time, in terms of which all other physical quantites may be described. The method also served as a mnemonical aid to the investigator as to the proper assembly of a mathematical analogue.

The following variables were judged to bear importantly on the problem of the use of tainter gates as flow measuring devices.

Q, discharge, in cubic feet per second

H, difference in headwater and tailwater elevations, in feet

h, head on gate during overflow, in feet

G_o, gate opening, in feet

L, length of gate, in feet

g, gravitational acceleration in feet per second per second

θ, lower gate-lip angle as measured from the vertical

These variables are indicated on the definition sketch in Figure 17. The lengths of the gates were also independent variables inasmuch as Richard was operated with some of the gates closed, and Herman was of a different model scale.

Analysis of Overflow Conditions

In the analysis of overflow conditions, it was obvious that the closed Tainter gates acted as weirs, both in Richard and in Herman. It was therefore assumed that the experimental data would obey a weir formula of the form

$$Q = C\ L\ h^{a} \tag{4}$$

where C and a were numerical constants. Table 2 and Table 3 show laboratory results for Richard and for Herman, respectively.

TABLE 2

Richard Overflow

Run	h_A	h_B	h_C	Q_m
1	3.24	3.24	3.24	958.44
2	2.75	2.75	2.75	731.64
3	2.44	2.44	2.44	599.94
4	2.00	2.00	2.00	438.98
5	1.70	1.70	1.70	341.31
6	1.28	1.28	1.28	222.42
7	1.04	1.04	1.04	163.89

TABLE 2.

Richard Overflow
(Continued)

Run	h_A	h_G	h_C	Q_m
8	0.79	0.79	0.79	115.23
9	0.47	0.47	0.47	58.53
271	2.39	2.39	2.39	553.12
280	2.84	2.84	2.84	731.27

Subscripts A, B, and C refer to Tainter gates as seen from upstream, left to right.

TABLE 3.

Herman Overflow

Run	h	Q_m
1	3.65	249.0
2	3.36	222.8
3	3.09	196.0
4	2.77	165.0
5	2.53	142.0
6	2.15	109.70
7	1.80	83.2
8	1.25	46.7
9	1.13	39.0
10	0.89	27.6
11	0.62	15.7

Although the two model gates in Richard and Herman were similar, there were significant structural differences in details of the control structures.

These differences were found in the flow approaches to the structures and, primarily, in the configurations of the respective stilling basins.

Flow over the Tainter gates was, of course, independent of downstream conditions in both structures as long as the top of the Tainter remained unsubmerged by the tailwater. The experimental data showed excellent correlation for all ranges of flow for both models. A minor exception was the region of low overflow of Richard. Richard was of course the smaller of the two models and hence may have been subject to the limitations of scale effects such as surface tension and levels of turbulence intensity.

RICHARD

Data for Richard II was from runs 1-9, 271 and 280. Within a mean error of 0.7% and a standard deviation from the mean of 2.6%, the experimental data obeyed the law

$$Q/L = \left(3.25 + \frac{0.2}{h^{2.5}} \right) h^{1.6} \qquad (5)$$

The correction on the coefficient evidently applies only to small values of the head on the gates. This may be, in fact, a result of scale effects and hence unnecessary when applied to the prototype gates.

HERMAN

Data for Herman was from runs 1-11. Within a mean error of -1.3% and a standard deviation from the mean of 1.8%, the experimental data obeyed the law

$$Q/L = 3.25\ h^{1.6} \qquad (6)$$

Figures 18 and 19 show the data correlations for Richard and for Herman. Field verification of the overflow performance was available for Richard. The prototype data was supplied by Mr. R. B. Stone, Jr., Mathematician in Charge, U.S.G.S., Florida District.

The correlation of the field data and the model data indicated that the performance of the model of Richard was indeed subject to scale effects. Thus, for the extrapolation overflow prototype performance for Richard, the same equation appeared suitable as was applicable for Herman. Without the data subject to scale effects, an error analysis for Richard showed a mean error of 2.1% and a standard deviation from the mean of 2.2%.

Mr. Stone indicated some difficulty in obtaining unique ratings for the Prototype Richard because of variable backwater conditions from Lake Okeechobee. Nevertheless, a remarkably good correlation was possible between model and prototype performances. Figure 20 shows both field data and values computed from equation 6.

<u>Analysis of Underflow Conditions</u>

Underflow conditions were theoretically viewed from energy considerations. Based on the Bernoulli equation, the efflux velocity from an infinitely wide slot is proportional to the square root of the difference in water surface elevations. For large differences, the efflux velocity is closely approximated by the velocity at the center of the jet issuing from the gate opening.

For flow conditions resulting from relatively small or medium differences in water surface elevations, as was the case in these studies, the variation of velocities across the jet had to be considered. Thus, along a stream line,

$$V = \sqrt{2g\left(\frac{V_o^2}{2g} + \bar{h} - z\right)} \tag{7}$$

where V_o is the approach velocity

$\bar{h}$ is the head to the center of the jet

z is the variable elevation measured from the center line

Assuming an elemental discharge to be represented by

$$\frac{dQ}{L} = dq = V\,dz \tag{8}$$

then,

$$q = \frac{2}{3}\sqrt{2g}\left[\left(\frac{V_o^2}{2g} + \bar{h} + \frac{G_o}{2}\right)^{3/2} - \left(\frac{V_o^2}{2g} + \bar{h} - \frac{G_o}{2}\right)^{3/2}\right] \tag{9}$$

For the conditions of this study, the approach velocities occuring in Taylor Creek are rather small and, therefore, the velocity heads are negligible. Allowing further that the discharge per unit width of gate can be represented by

$$q = C_D\,\bar{h}^{3/2} \tag{10}$$

where C_D is the coefficient of discharge, then

$$C_D = \frac{2}{3}\sqrt{2g}\,\frac{1}{\bar{h}^{3/2}}\left[\left(\bar{h} + \frac{G_o}{2}\right)^{3/2} - \left(\bar{h} - \frac{G_o}{2}\right)^{3/2}\right]$$

Expanding the terms $(\bar{h} + \frac{G_o}{2})^{3/2}$ and $(\bar{h} - \frac{G_o}{2})^{3/2}$ yield

$$\left(\bar{h} + \frac{G_o}{2}\right)^{3/2} = \bar{h}^{3/2} + \frac{3}{4} G_o\,\bar{h}^{1/2} + \frac{3}{16} G_o^2\,\bar{h}^{-1/2} - \frac{9}{96} G_o^3\,\bar{h}^{-3/2} + \ldots \tag{11}$$

and

$$\left(\bar{h} - \frac{G_o}{2}\right)^{3/2} = \bar{h}^{3/2} - \frac{3}{4} G_o \bar{h}^{1/2} + \frac{3}{16} G_o^2 \bar{h}^{-1/2} + \frac{9}{96} G_o^3 \bar{h}^{-3/2} + \quad (12)$$

thus,

$$C_D = \frac{2}{3} \sqrt{2g} \quad \frac{1}{\bar{h}}^{3/2} \left[\frac{3}{2} G_o \bar{h}^{1/2}\right] \quad (13)$$

or

$$C_D = \sqrt{2g} \quad \frac{G_o}{\bar{h}} \quad (14)$$

The coefficient of discharge is therefore shown to vary with the ratio of the gate opening, G_o, and the head to the center of the jet. Since there is also a jet contraction, and since the coefficient of contraction was not known, it was conjectured that

$$\frac{H}{G_o} = A \left(\frac{C_D^2}{g}\right)^{-0.5} \quad (15)$$

where A was a function of H and Θ.

Thus, for underflow conditions, the relationship was expressed by

$$\frac{C_D^2}{g} = \phi \left[\frac{H}{G_o}, \Theta\right] \quad (16)$$

In the laboratory study, many particular sets of these chosen variables were measured.

Subsequently, mathematical and graphical techniques were employed in order to arrive at formulae that reproduced within acceptable limits the laboratory measurements.

Whereas dimensional analysis represented the physical interpretation of the problem and defined properties which the mathematical analogue must contain, the final formulation of the relationships between the variables represented primarily mathematical problems in which approximate interpolation formulae yielded the best fit through known data points. Any extrapolation of prototype performance from the hydraulic model studies postulated that both the conditions of geometrical similarity and dynamical similarity between models and prototype structures were satisfied.

RICHARD .

The experimental results for Richard are shown in Figures 21 and 22. Figure 21 represents operating conditions with gates A, B, and C open and all gates at equal G_o. The data are presented in Table 4. Figure 22 represents operating conditions with gates A and C closed and only gate B open. The data of Figure 22 are presented in Table 5. From the large number of tests the relationship

$$\frac{H}{G_o} = \left(0.679 + 0.694\theta\right) \left(\frac{g}{C_D^2}\right)^{0.5} \tag{17}$$

was obtained.

TABLE 4.

Richard Underflow (All Gates)

Run	ΔH	Gate A	Gate B	Gate C	Q_m
13	0.47	0.50	0.50	0.50	107.18
24	1.59	0.50	0.50	0.50	219.12
37	2.14	0.50	0.50	0.50	219.12

TABLE 4.

Richard Underflow (All Gates)

Run	ΔH	Gate A	Gate B	Gate C	Q_m
45	0.63	1.00	1.00	1.00	219.12
46	0.54	1.00	1.00	1.00	219.12
52	0.23	1.50	1.50	1.50	219.12
57	0.16	2.00	2.00	2.00	219.12
61	0.13	2.50	2.50	2.50	219.12
102	1.39	1.00	1.00	1.00	329.97
103	1.13	1.00	1.00	1.00	329.97
108	0.56	1.50	1.50	1.50	329.97
113	0.33	2.00	2.00	2.00	329.97
135	1.37	1.00	1.00	1.00	329.97
140	0.64	1.50	1.50	1.50	329.97
145	0.37	2.00	2.00	2.00	329.97
150	0.26	2.50	2.50	2.50	329.97
155	0.18	3.00	3.00	3.00	329.97
188	2.01	1.00	1.00	1.00	438.98
189	2.47	1.00	1.00	1.00	438.98
213	2.40	1.00	1.00	1.00	438.98
218	1.13	1.50	1.50	1.50	438.98
223	0.65	2.00	2.00	2.00	438.98
228	0.41	2.50	2.50	2.50	438.98
229	0.46	2.50	2.50	2.50	438.98
234	0.29	3.00	3.00	3.00	438.98
235	0.32	3.00	3.00	3.00	438.98
256	0.51	2.50	2.50	2.50	438.98
257	0.39	3.00	3.00	3.00	438.98
261	0.99	2.00	2.00	2.00	553.12
262	0.42	3.00	3.00	3.00	553.12
268	0.59	3.00	3.00	3.00	553.12
273	1.04	2.00	2.00	2.00	553.12
274	0.48	3.00	3.00	3.00	553.12
278	1.70	2.00	2.00	2.00	731.27
279	0.73	3.00	3.00	3.00	731.27
283	0.85	3.00	3.00	3.00	731.27
289	0.87	3.00	3.00	3.00	731.27
294	1.35	3.00	3.00	3.00	916.01
299	1.28	3.00	3.00	3.00	916.01
304	1.83	3.00	3.00	3.00	1101.84

TABLE 5.

Richard Underflow (Gate B Only)

Run	ΔH	Gate B	Q_{MEAS}
50	2.10	1.50	219.12
56	1.25	2.00	219.12
63	0.81	2.50	219.12
65	0.59	3.00	219.12
318	0.55	1.50	109.01
319	0.33	2.00	109.01
320	1.02	2.00	189.13
321	0.71	2.50	189.13
322	0.48	2.50	160.96
323	0.71	2.00	160.96
324	1.05	1.00	99.87
325	0.51	1.50	99.87
326	0.31	2.00	99.87
327	0.22	2.50	99.87
328	0.71	1.00	79.38
329	0.66	1.00	79.38
330	0.35	1.50	77.55
331	0.40	1.50	100.60
332	0.34	1.50	100.60

The data of Table 4 fitted equation 17 with a mean error of 1.36% and a standard deviation from the mean of 5.51%. The data of Table 5 fitted equation 17 with a mean error of - 1.95% and a standard deviation from the mean of 6.41%.

HERMAN

The experimental results for Herman are shown in Figure 23. The underflow data are presented in Table 6. As was previously demonstrated, the discharge through Herman was independent of downstream water surface elevations. Some 24 different combinations of upstream water surface elevations and gate positions, other than closed, were tested and the data analyzed. The experimental results were best represented by

$$\frac{H}{G_o} = \left(1.582\,\theta^2 - 0.848\,\theta + 0.812\right)\left(\frac{g}{C_D^2}\right)^{0.5} \qquad (18)$$

The data fitted the equation 18 with a mean error of 0.99% and a standard deviation from the mean of 4.68%.

TABLE 6.

Herman Underflow

Run	H(*)	G_o	$Q_{meas.}$
12	2.46	0.5	47.09
21	2.04	1.5	95.30
30	4.05	1.5	142.72
31	2.84	2.0	142.72
41	4.40	2.0	189.70
42	3.47	2.5	189.70
47	4.66	2.0	189.70
48	3.57	2.5	189.70
53	4.72	2.5	231.88
74	4.66	3.0	259.17
95	3.37	1.0	93.80
96	1.87	1.0	64.91
97	2.29	1.0	73.35
98	2.69	1.0	81.52
99	3.38	1.0	93.99
100	4.03	1.0	104.59
101	4.23	1.0	107.40
102	3.03	1.0	87.97
110	2.15	0.5	42.25
111	3.81	2.0	171.89
116	4.75	3.5	229.86
109	3.75	0.5	57.73
103	4.74	2.5	227.89
114	3.84	2.5	208.48

(*) H is upstream water depth

Analysis of Combined Overflow and Underflow

Flow conditions through the control structures Richard and Herman are frequently such that both overflow and underflow from partially open Tainter gates will take place. These conditions were reproduced in the laboratory. Since the possible combinations of flow rate, upstream water depth, downstream water surface elevation, and gate positions are very large, the laboratory investigation of Richard and Herman was restricted to a systematic variation of the variables. From this systematic approach it was hoped that general performance characteristics could be extrapolated.

It was reasoned that the independently established relationships for underflow and for overflow could be combined to predict the performance characteristic for each control structure.

RICHARD

Accordingly, the total discharge from combined underflow and overflow for Richard would be

$$Q/L = 3.25\ h^{1.6} + C_D\ H^{1.5} \qquad (19)$$

where C_D is determined by equation 17. Table 7 summarizes tests in which underflow came from the center gate B only. Gates A and C were closed. Overflows occured at gates A and C at times and at all three gates at other times. The computed results fitted the measured results quite accurately. The mean error was 0.06% and the standard deviation from the mean was 3.07%. Table 8 summarizes test results for combined flows with all gates partially opened.

TABLE 7

Richard Combined Flows (Underflow Gate B Only)

Run	ΔH	h_A	h_B	h_C	Gate A	Gate B	Gate C	Q_m
36	3.94	1.01	0.41	1.01	0.00	0.50	0.00	219.12
47	3.42	0.49	0	0.49	0.00	1.00	0.00	219.12
48	3.33	0.39	0	0.39	0.00	1.00	0.00	219.12
91	4.93	1.45	0.86	1.45	0.00	0.50	0.00	329.97
92	4.96	1.48	0.89	1.48	0.00	0.50	0.00	329.97
100	4.48	1.01	0	1.01	0.00	1.00	0.00	329.97
129	2.45	1.61	1.02	1.61	0.00	0.50	0.00	329.97
134	2.31	1.47	0.28	1.47	0.00	1.00	0.00	329.97
139	2.02	1.19	0	1.19	0.00	1.50	0.00	329.97
144	1.77	0.93	0	0.93	0.00	2.00	0.00	329.97
149	1.52	0.68	0	0.68	0.00	2.50	0.00	329.97
154	1.30	0.47	0	0.47	0.00	3.00	0.00	329.97
179	5.07	1.87	1.27	1.87	0.00	0.50	0.00	438.98
186	4.78	1.58	0.39	1.58	0.00	1.00	0.00	438.98
187	4.87	1.66	0.47	1.66	0.00	1.00	0.00	438.98
207	3.40	1.96	1.36	1.96	0.00	0.50	0.00	438.98
212	3.26	1.82	0.63	1.82	0.00	1.00	0.00	438.98
217	3.03	1.59	0	1.59	0.00	1.50	0.00	438.98
222	2.71	1.27	0	1.27	0.00	2.00	0.00	438.98
227	2.40	0.95	0	0.95	0.00	2.50	0.00	438.98
233	2.14	0.70	0	0.70	0.00	3.00	0.00	438.98

TABLE 8.

Richard Combined Flows

Run	ΔH	h_A	h_B	h_C	Gate A	Gate B	Gate C	Q_m
93	4.41	0.34	0.34	0.34	0.50	0.50	0.50	329.97
94	4.26	0.19	0.19	0.19	0.50	0.50	0.50	329.97
130	2.32	0.89	0.89	0.89	0.50	0.50	0.50	329.97
180	4.72	0.92	0.92	0.92	0.50	0.50	0.50	438.98
208	3.43	1.40	1.40	1.40	0.50	0.50	0.50	438.98
252	0.53	1.91	1.91	1.91	0.50	0.50	0.50	438.98
253	0.64	1.42	1.42	1.42	1.00	1.00	1.00	438.98
254	0.70	0.88	0.88	0.88	1.50	1.50	1.50	438.98
255	0.69	0.28	0.28	0.28	2.00	2.00	2.00	438.98
260	2.97	0.65	0.65	0.65	1.00	1.00	1.00	553.12
266	0.89	1.68	1.68	1.68	1.00	1.00	1.00	553.12
267	0.95	0.55	0.55	0.55	2.00	2.00	2.00	553.12
272	1.79	1.19	1.19	1.19	1.00	1.00	1.00	553.12
277	3.33	1.32	1.32	1.32	1.00	1.00	1.00	731.27
281	2.06	1.72	1.72	1.72	1.00	1.00	1.00	731.27
282	1.76	0.23	0.23	0.23	2.00	2.00	2.00	731.27
287	1.41	1.95	1.95	1.95	1.00	1.00	1.00	731.27
288	1.45	0.80	0.80	0.80	2.00	2.00	2.00	731.27
292	2.29	0.77	0.77	0.77	2.00	2.00	2.00	916.01
293	2.47	2.15	2.15	2.15	1.00	1.00	1.00	916.01
297	1.69	2.37	2.37	2.37	1.00	1.00	1.00	916.01
298	1.73	1.22	1.22	1.22	2.00	2.00	2.00	916.01
305	2.27	1.48	1.48	1.48	2.00	2.00	2.00	1101.84
306	2.25	2.66	2.66	2.66	1.00	1.00	1.00	1101.84

For every test with all gates partially opened (Table 8) , G_o was the same for every gate during a particular test run, although the gate openings were varied from test to test. The mean error based on this sample of data was 8.01% and the standard deviation from the mean was 4.96%. Factors other than those previously considered affected the hydraulic model performance, and certain operating conditions invalidated to some degree the chosen mathematical model. Foremost perhaps was the effect of relatively large overflows which caused a back pressure and a rise of the water surface elevation beneath the nappe over and above that of the measured downstream water surface elevation. This rise would in turn diminish the head available for underflow from the gates with the result that there was always a smaller measured combined discharge when compared with the discharge prediction based on measured differences in upstream and downstream water surface elevations.

HERMAN

The combined overflow and underflow through Herman was analyzed in the same fashion. Thus,

$$Q/L = 3.25 \; h^{1.6} + C_D \; H^{1.5} \qquad (20)$$

where C_D is determined from equation 18. The experimental results are summarized in Table 9. The data fitted equation 20 with a mean error of 1.42% and a standard deviation of 7.38%.

TABLE 9

Herman Combined Flows

Run	G_o	H*	h	Q_m
14	0.5	4.70	1.04	95.30
28	0.5	5.4	1.74	142.72
29	1.0	5.01	0.74	142.72
38	0.5	5.98	2.32	189.70
39	1.0	5.79	1.52	189.70
40	1.5	5.50	0.60	189.70
49	0.5	6.43	2.77	231.88
50	1.0	6.27	2.00	231.88
51	1.5	6.08	1.18	231.88
52	2.0	5.77	0.36	231.88
69	0.5	6.77	3.11	259.17
70	1.0	6.64	2.37	259.17
71	1.5	6.45	1.55	259.17
72	2.0	6.23	0.82	259.17
43	0.5	6.08	2.42	189.70
44	1.0	5.91	1.64	189.70
45	1.0	5.87	1.60	189.70
46	1.5	5.55	0.65	189.70
55	0.5	6.50	2.84	231.88
56	1.0	6.38	2.11	231.88
57	1.5	6.16	1.26	231.88

* Upstream water depth

V. COMPUTER PROGRAMS

Laboratory Data

All laboratory data was put on IBM cards to facilitate evaluation of experimental results by means of an electronic digital computer. The facility available was the Burroughs B 5500 of the Rich Electronic Computer Center, Georgia Institute of Technology. The language used was ALGOL.

The computational results are reflected in the graphical presentations and in the mathematical discharge relationships obtained for the control structures Richard and Herman as given in Chapter IV. Special programs were written to facilitate the tabulation of laboratory data. These data printouts are attached to this Final Report as Appendixes A,B, and C. The IBM data cards are stored in the project file at the School of Civil Engineering, Georgia Institute of Technology.

Field Measurements

Ultimately, the field implementation of the laboratory results requires field measurements of water surface elevations and of gate positions. Suitable devices are to record these measurements. The field records are then to be utilized in computer programs to evaluate the discharges through the control structures under prevailing conditions.

For water surface determinations upstream and downstream for Richard, and upstream only for Herman, stage recorders are to be installed and referenced to the sill of the gates. The recorders selected were digital punch tape recorders, Fisher and Porter Model 1542. Three recorders and three clocks were purchased under this contract and delivered to the contracting agency. No other auxilliary equipment was supplied.

The manner of installation and the manner of operation of these recorders should follow the practices of the USGS, Surface Water Branch. The recorder locations should be at distances of approximately 50 feet upstream from the Tainter gates to avoid regions of effective drawdown of the water surface, and about the same distance downstream from the gate to avoid surface disturbances in the stilling basins below the structures.

A typical digital recorder is shown in Figure 24. The coded discs rotate to reflect water surface elevations. At specified time intervals, these discs are locked in place and the centrally located tape is punched. Figure 25 shows the back side of the recorder. A spiked pully normally supports a suitably punctured tape which connects the float and the counter weight. Figure 26 shows a section of typical recording tape. The particular sample is for recordings at one-hour intervals.

The measurements for gate openings are the vertical distance between the gate sill and the lower gate lip. These openings are related to the geometry of the gates and the gate positions. A procedure for the determination of the gate openings in terms of rotational displacement of the gates has been developed. The rotational or angular displacements can be measured by means of the same recorders as described above. A typical installation scheme is suggested in Figure 27.

In the suggested scheme, a linkage system translates the rotational motion of the gate into movement of the coded discs of the recorders, and hence into a record of the angular displacement of the gate. It is essential that the linkage arms A and B (see Figure 27) are of the same length; the length itself is arbitrary. The center of the gate trunnion and the center of the recorder pulley must be located vertically above each other. In addition, the link connecting arms A and B must be of the same length as the distance between the gate trunnion and the center of the pulley. In order that the three-arm linkage forms a parallelogram at all positions and that the rotational movement of arm A is identical to that of arm B, these arms must be rigidly connected to the trunnion and to the pulley respectively at one end and pin-connected to each other at the other ends.

Prototype Structure Discharge Calculations

The utilization of the punched field tapes requires a suitable translator or translating device in order that discharge calculations may be carried out. The translated data may be stored on IBM cards or on magnetic tapes. The computer programs presented here assume the use of magnetic tapes. Suitable modifications of the program would likewise accomodate cards.

Specific computational requirements are to be satisfied for Richard and for Herman, respectively. In general, these requirements are presented in standard IBM notation flow charts. The flow chart for Richard is given in Figure 28. The flow chart for Herman is given in Figure 29.

The computer programs were to be written in FORTRAN. Despite considerable effort, the programs for the discharge calculations could not be written in FORTRAN because of the incompatibility of that language with the ALGOL oriented equipment at Georgia Tech. Communication in FORTRAN with the B 5500 met with insurmountable difficulites and the programs were finally written in ALGOL. A subsequent translation into a more suitable machine language will depend on the computer used and on its machine-oriented language.

RICHARD

The program written for Richard assumes that field data from each recorder has been transferred to labelled, unblocked magnetic tapes. A total of five tape "reels" would represent data for one recording "set". These data would be "fed" to the machine in the following manner:

FILE IDENTIFIER	Record contains:
TAPE1	Water surface elevation upstream from gates, referenced to the gate sill
TAPE2	Water surface elevation downstream from gates, referenced to the gate sill
TAPE3	Angular displacement of Gate A
TAPE4	Angular displacement of Gate B
TAPE5	Angular displacement of Gate C

It is also required that the time of the first record of the "set" and the time interval be put into the machine via card reader. This data is to be punched (right-justified) in the following manner:

COLUMNS	Data
1 - 10	Year (for example 1967)
11 - 20	Day, numbered 1 through 365
21 - 30	Hour, numbered 0 through 24

COLUMNS (continued)	Data
31 - 40	Minutes, numbered 0 through 60
41 - 50	Punch interval, in minutes

With this information, the time of each field record and the discharge through the structure are computed until there is no more data on any of the five tape reels. This is designated as and END OF FILE condition and the EOF action label exits the program from the machine. The program for Richard is listed below.

```
BEGIN
    FILE IN CDS (2,10);
    FILE ØUT PBD 15 (2,15);
    FILE IN TAPE1 2(2,2);
    FILE IN TAPE2 2(2,2);
    FILE IN TAPE3 2(2,2);
    FILE IN TAPE4 2(2,2);
    FILE IN TAPE5 2(2,2);
    REAL WSU, WSD, THETA, THETAO, H, CD, Q;
    INTEGER I, J, K, DAY, HR, MIN, YR, INT;
    REAL ARRAY GATE, HGATE, PHI [0:3];
    LABEL EØF;
    DEFINE  FØRJ = FØR J ← 1 STEP 1 UNTIL #,
            FØRK = FØR K ← 1 STEP 1 UNTIL #;
    FORMAT  FMT01 (5I10),
            FMT02 (X51, "FIELD DATA, RICHARD"),
            FMT03 (X1, "TIME", X2, "DAY", X1, "YEAR", X7, "WSU",
                   X7, "WSD", X4, "GATE A", X4, "GATE B", X4,
                   "GATE C", X9, "Q"/),
            FMT04 (I2, ":", I2, 2I5, 6R10.2);
    WRITE (PBD [NØ]);
    READ (CDS, FMT01, YR, DAY, HR, MIN, INT);
    THETAO ← 4 x ARCTAN(1)/180 x 52.1;
    WHILE TRUE DØ
```

```
  BEGIN
      IF HR = 24 THEN
  BEGIN
      WRITE (PBD [PAGE] );
      DAY ← DAY + 1;
      HR ← DAY MØD 24;
      IF (YR MØD 4 ≠ 0 AND DAY = 366) THEN
BEGIN
     YR ← YR + 1;
     DAY ← 1;
END;
     IF (YR MØD 4 = 0 AND DAY = 367) THEN
BEGIN
     YR ← YR + 1;
     DAY ← 1;
END;
     WRITE (PBD, FMT02);
     WRITE (PBD, FMT03);
END;
     READ (TAPE1, *, WSU) [EØF];
     READ (TAPE2, *, WSD) [EØF];
     READ (TAPE3, *, PHI [1]) [EØF];
     READ (TAPE4, *, PHI [2]) [EØF];
     READ (TAPE5, *, PHI [3]) [EØF];
     H ← WSU - WSD;
     FORJ 3 DØ
```

```
BEGIN
     THETA ← THETAO + PHI [J];
     GATE [J] ← 7 - 8.75 x SIN(THETA);
     IF GATE [J] ≠ 0 THEN
     CD ← 5.68 x (.679 +.694 x THETA)/(H/GATE [J])
     ELSE
     CD ← 0;
     HGATE [J] ← WSU - 1.192 x GATE [J] - 7;
     IF HGATE [J] > 0 THEN
     Q ← Q + 48.75 x HGATE [J] * 1.6;
     Q ← Q + 15 x Cd x H x SQRT (H);
END;
     WRITE (PBD,FMT04, HR, MIN, DAY, YR, WSU, WSD, FORK3 DØ
            GATE [K], Q);
     MIN ← MIN + INT;
     IF MIN ≥ 60 THEN
BEGIN
     HR ← HR + 1;
     MIN ← MIN MØD 60;
END;
     Q ←0;
END;
EØF: END.
```

The printed output of this program will be the time of the record, for example 0:23, 339, 1967 (which was the time, day, and year at which this report was written), the upstream water surface elevation, the downstream water surface elevation, the position of each of the three gates, and the total discharge through the structure.

HERMAN

The program for Herman is very similar. Again, field records are to be transferred to labelled, unblocked magnetic tapes prior to input into the machine. Water surface elevations must be read into the computer via TAPE1, and gate position is read via TAPE2. The beginning time and the punch time interval must be given in the identical manner as described for Richard. Computation of discharges proceed until terminated by the END OF FILE action label.

The printout for this program is analogous to that of Richard. There is no special designation for the single gate, and there is no record of the downstream water surface elevation. The program is listed below.

```
BEGIN
     FILE IN CDS (2,10);
     FILE ØUT PBD 15 (2,15);
     FILE IN TAPE1 2(2,2);
     FILE IN TAPE2 2(2,2);
     REAL WSU, THETA, THETAO, H, HGATE, CD, Q, GATE, PHI;
     INTEGER I, J, K, DAY, HR, MIN, YR, INT;
     LABEL EØF;
     FØRMAT FMTO1 (5I10),
          FMTO2 (X51, "FIELD DATA, HERMAN"/)
          FMTO3 (X1, "TIME", X2 "DAY", X1, "YEAR", X17, "WSU",
               X16, "GATE", X19, "Q"/),
          FMTO4 (I2, ":", I2, 4R20.2);
     WRITE (PBD [NØ]);
     READ (CDS, FMTO1, YR, DAY, HR, MIN, INT);
     THETAO ← 4 x ARCTAN (1) /180 x 51.4;
     WHILE TRUE DØ
BEGIN
     IF HR = 24 THEN
BEGIN
     WRITE (PBD [PAGE]);
     DAY ← DAY + 1;
     HR ← DAY MØD 24;
     IF (YR MØD 4 ≠ 0 AND DAY = 366) THEN
BEGIN
     YR ← YR + 1;
```

```
        DAY ← 1;
END;
        IF (YR MØD 4 = 0 AND DAY = 367) THEN
BEGIN
        YR ← YR + 1;
        DAY ← 1;
END;
        WRITE (PBD,FMT02);
        WRITE (PBD,FMT03);
END;
        READ (TAPE1, *, WSU) [EØF];
        READ (TAPE2, *, PHI) [EØF];
        H ← WSU;
        THETA ← THETA0 + PHI;
        GATE ← 3 - 5 x SIN(THETA);
        IF GATE ≠ 0 THEN
        CD ← 5.68 x (1.582 x THETA x THETA - 0.848 x THETA + 0.812)/
             (H/GATE)
        ELSE
        CD ← 0;
        HGATE ← WSU - 7.38 + 4.92 x THETA;
        IF HGATE > 0 THEN
        Q ← Q + 32.50 x HGATE * 1.6;
        Q ← Q + 10 x CD x H x SQRT(H);
```

```
END;
     WRITE (PBD, FMT04, HR, MIN, DAY, YR, WSU, WSD, GATE, Q);
     MIN ← MIN + INT;
     IF MIN ≥ 60 THEN
BEGIN
     HR ← HR + 1;
     MIN ← MØD 60;
END;
     Q ← 0;
END;
EØF: END.
```

VI. CONCLUSIONS AND RECOMMENDATIONS

The feasibility of using Tainter gates as flow measuring devices was investigated theoretically and experimentally. The study demonstrated that Tainter gates are suitable devices for the measurement of discharge.

The methods of analysis described in this study can be extended to similar Tainter gate installations. The discharge characteristics were based on general considerations of energy and momentum, and on the notions of similitude and dimensional analysis. The specific relationships obtained for the control structures No. 1 and No. 3 of the Taylor Creek watershed, Richard and Herman, were based on the results of hydraulic model studies. A suggested adaptation of Fisher and Porter digital stage recorders to the operation of the prototype structures, and the development of computer programs should permit the conversions of digital field data into records of discharge through the control structures. The final application of the recording scheme and the field installation of the recording devices was left to the engineers of the contracting agency.

The laboratory observations and the test results of the model studies indicated that certain operating conditions may either be detrimental to the structures or will result in less favorable predictability of the discharges.

For the three-gated structure No. 1, Richard, best hydraulic performances were obtained when either all Tainter gates were closed such that all flow past the control structures was over the top of the gates, or when all gates were opened partially with identical gate openings. Quite satisfactory results were obtained when the center gate only was opened. When either one or both of the outer gates (gates A and C) were opened while the center gate remained closed, relatively high velocities resulted near the banks of the hydraulic model. In Taylor Creek with its erodible sand bed, these flow patterns would be quite undesirable.

The energy dissipators in the stilling basin of structure No. 1 also failed to function effectively when relatively large differences in water surface elevations were present in conjunction with low stages in Taylor Creek below the control structure. The lack of effective energy dissipation was characterized by considerable waviness of the water surface. Like excessive velocities near the banks and the channel floor, wave action would similarly be detrimental to the maintenance of a stable channel in Taylor Creek. These conditions were designated Condition I under remarks column of the data summary in the appendices. The condition is shown in Figure 30.

In terms of predictability of performance, the control structure No. 1 yielded best results when the discharges resulted from overflows alone, and from underflows alone. When both overflow and underflow conditions existed, better predictability in terms of the mathematical formulations was obtained when the larger portions of the total flow resulted from underflow. Large overflows created a back pressure and thus reduced the effective head available for underflows.

For the one-gated control structure No. 3, Herman, the hydraulic performances were satisfactory. Within the design range of discharges, the flows from the structure were independent from conditions of water surface elevations below the structure. The energy dissipator appeared to function well at all test conditions. Best results in terms of predictability were obtained for overflows alone and for underflows alone. During conditions of combined overflows and underflows, the effective head available for underflows was impeded by a back pressure created by the jet from the top of the gate. Relatively large overflows affected the underflows adversely. For better predictability, a larger portion of the total flow should result from underflow.

It is recommended, therefore, that for control structure No. 1 flows are either all underflow or all overflow. For combined flows, it is preferable to have a predominance of underflow. For conditions involving underflows, it is recommended that all gates have the same gate openings or underflow is allowed through the center gate only. For control structure No. 3 it is recommended that flows are either all underflows or all overflows. For combined flows, it is recommended that there is a predominance of underflow for better predictability.

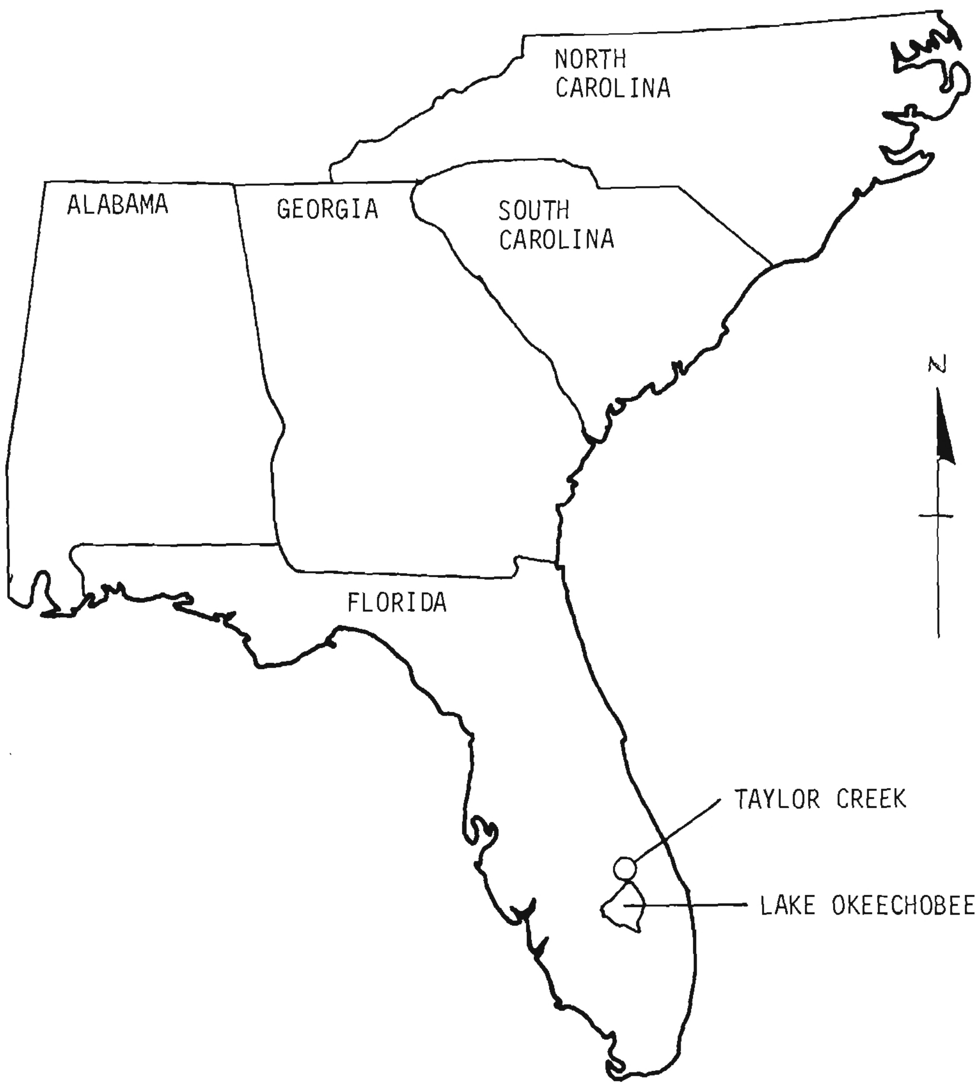

Figure 1. Location of Taylor Creek Watershed.

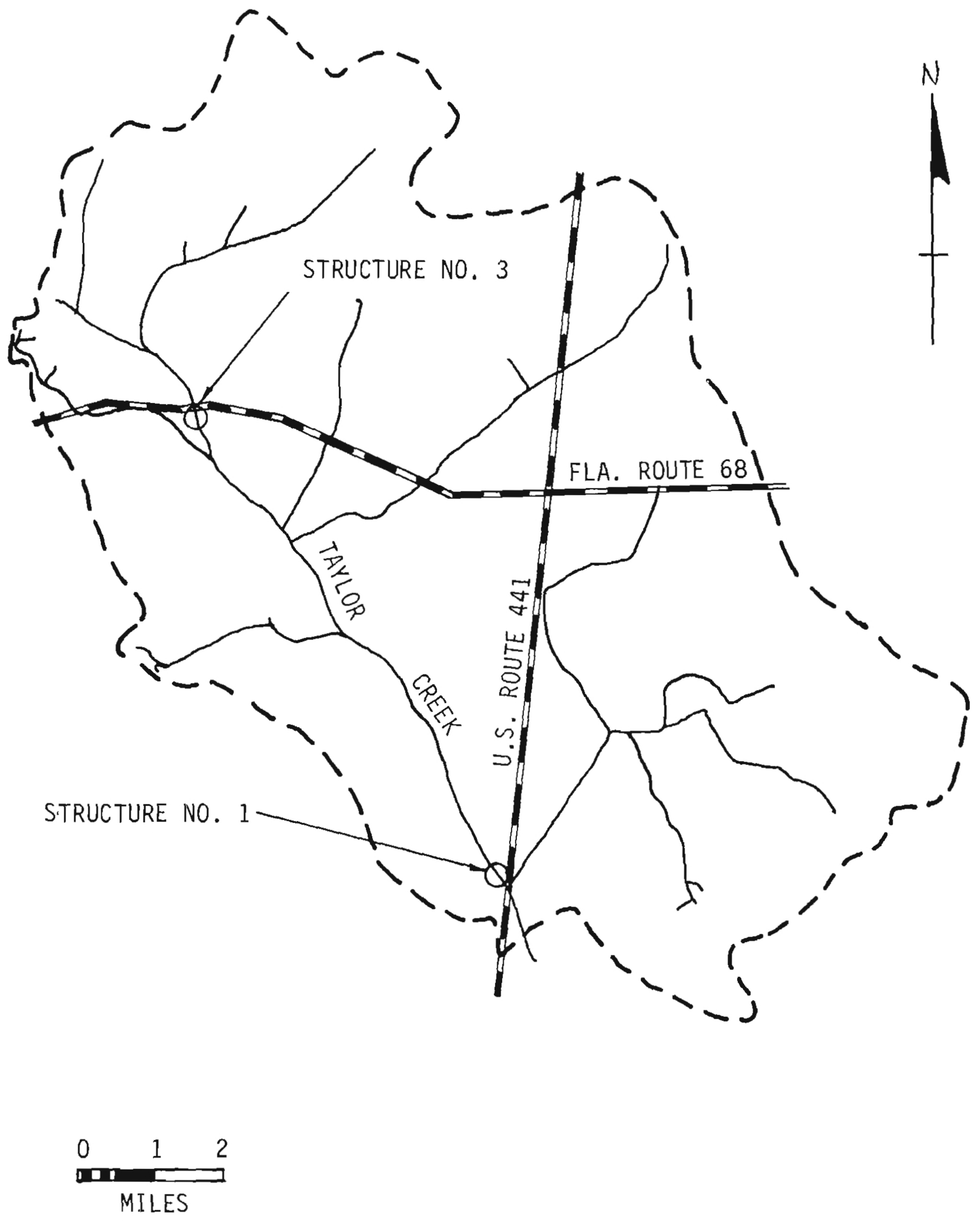

Figure 2. Taylor Creek Watershed, Okeechobee County, Florida.

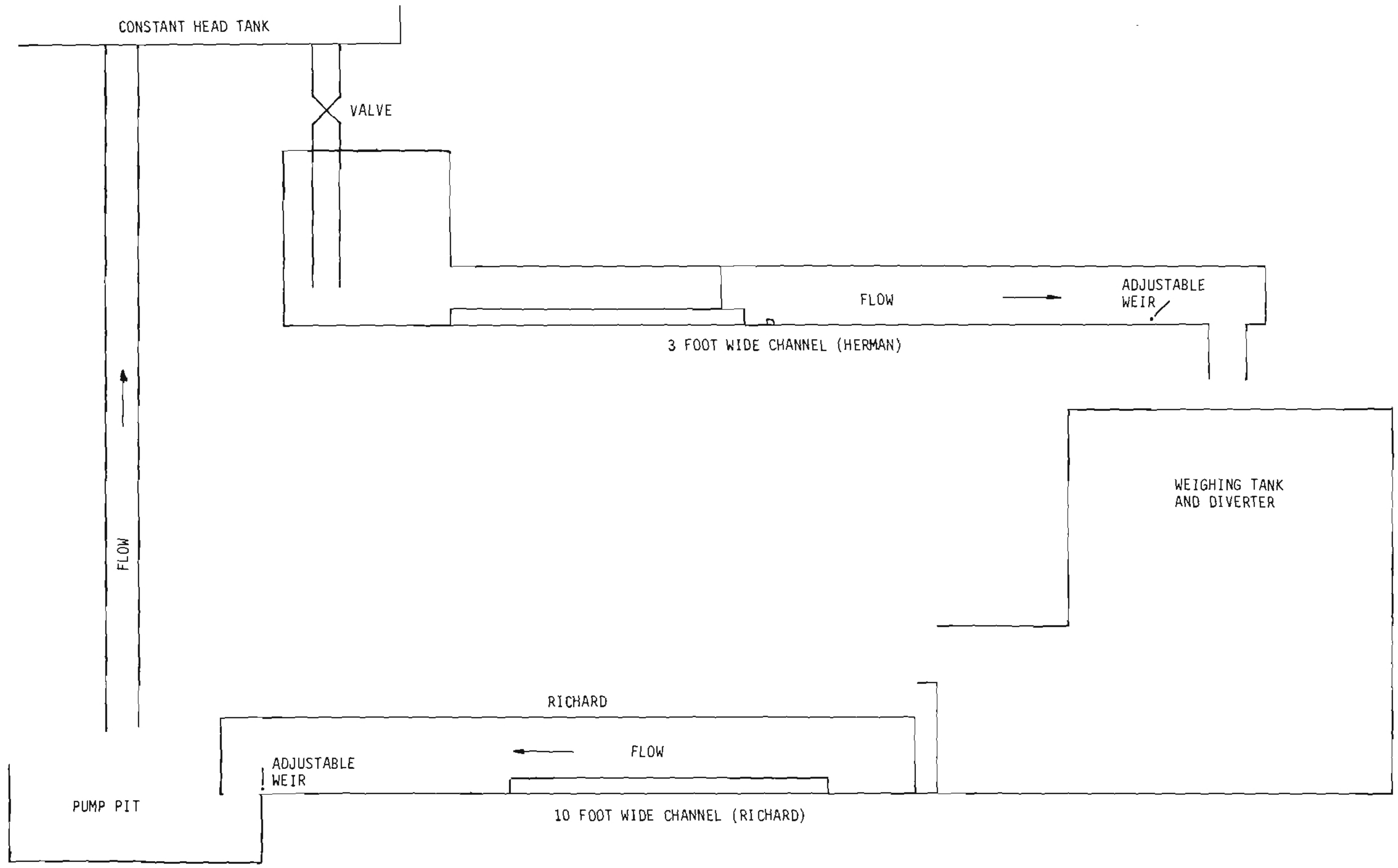

Figure 3. Schematic Diagram of Recirculatory System, Hydraulics Laboratory.

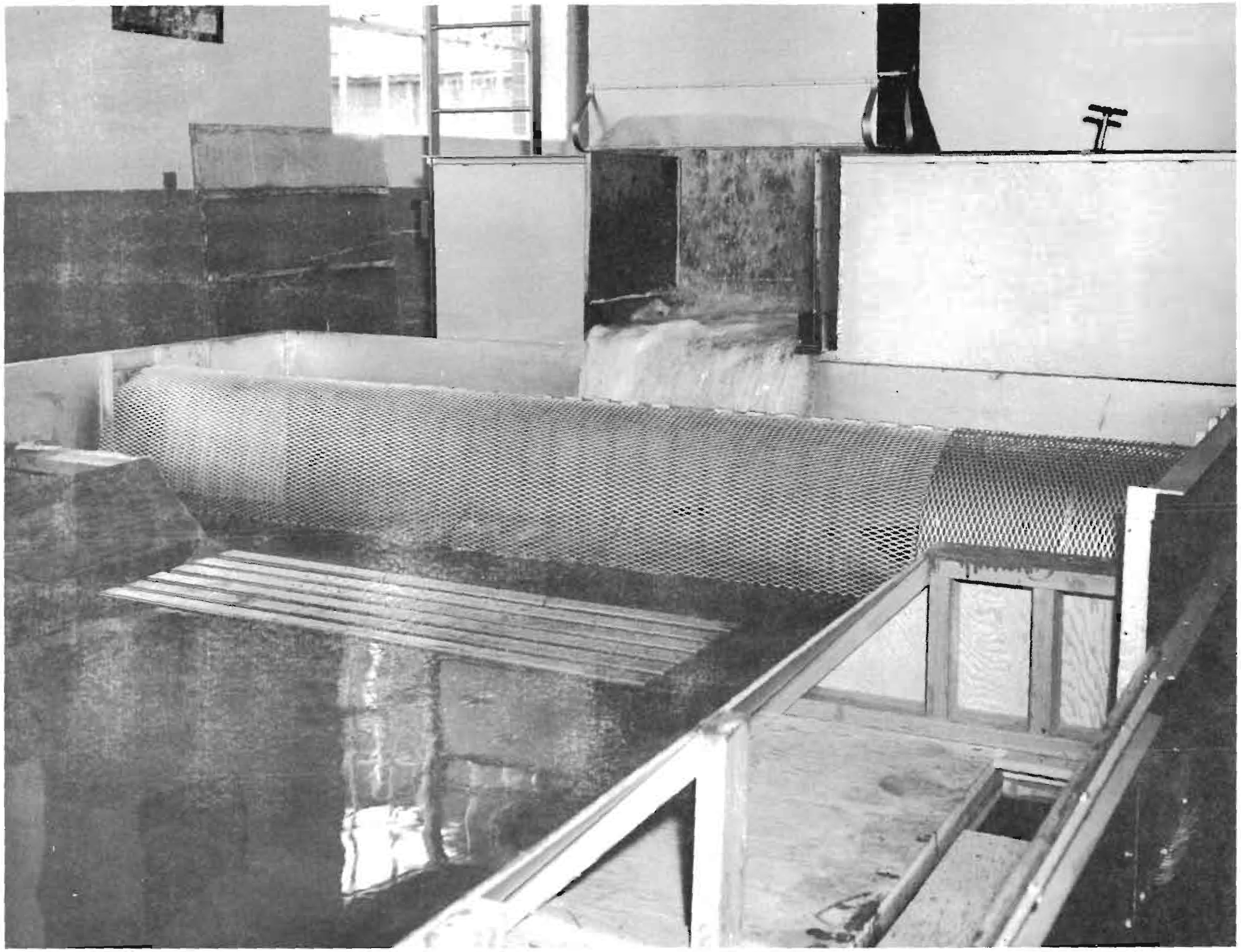

Figure 4. Model Entrance Bay, Richard.

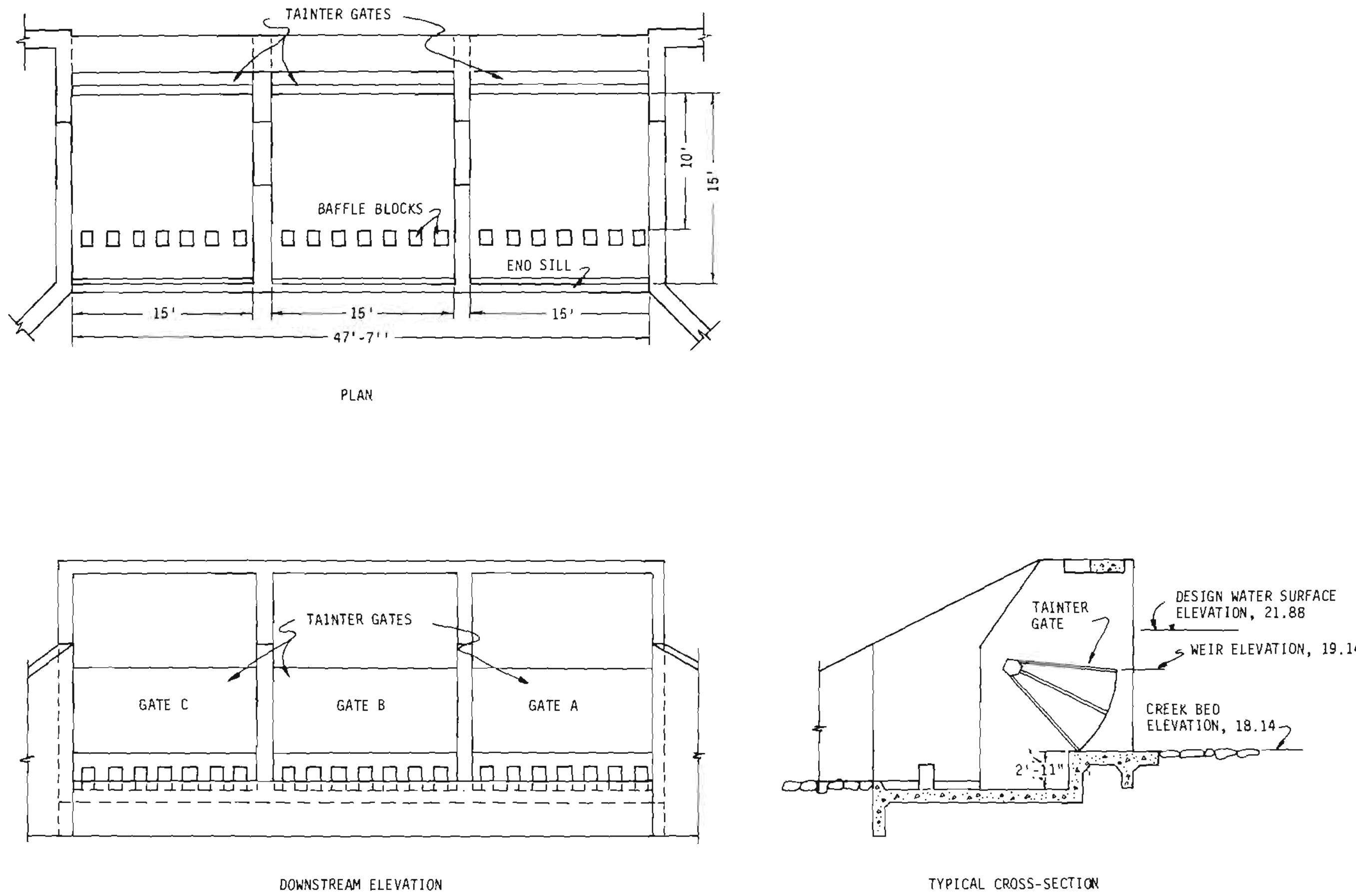

Figure 5. Details of Richard.

Figure 6. Typical Model Tainter Gate, Richard II.

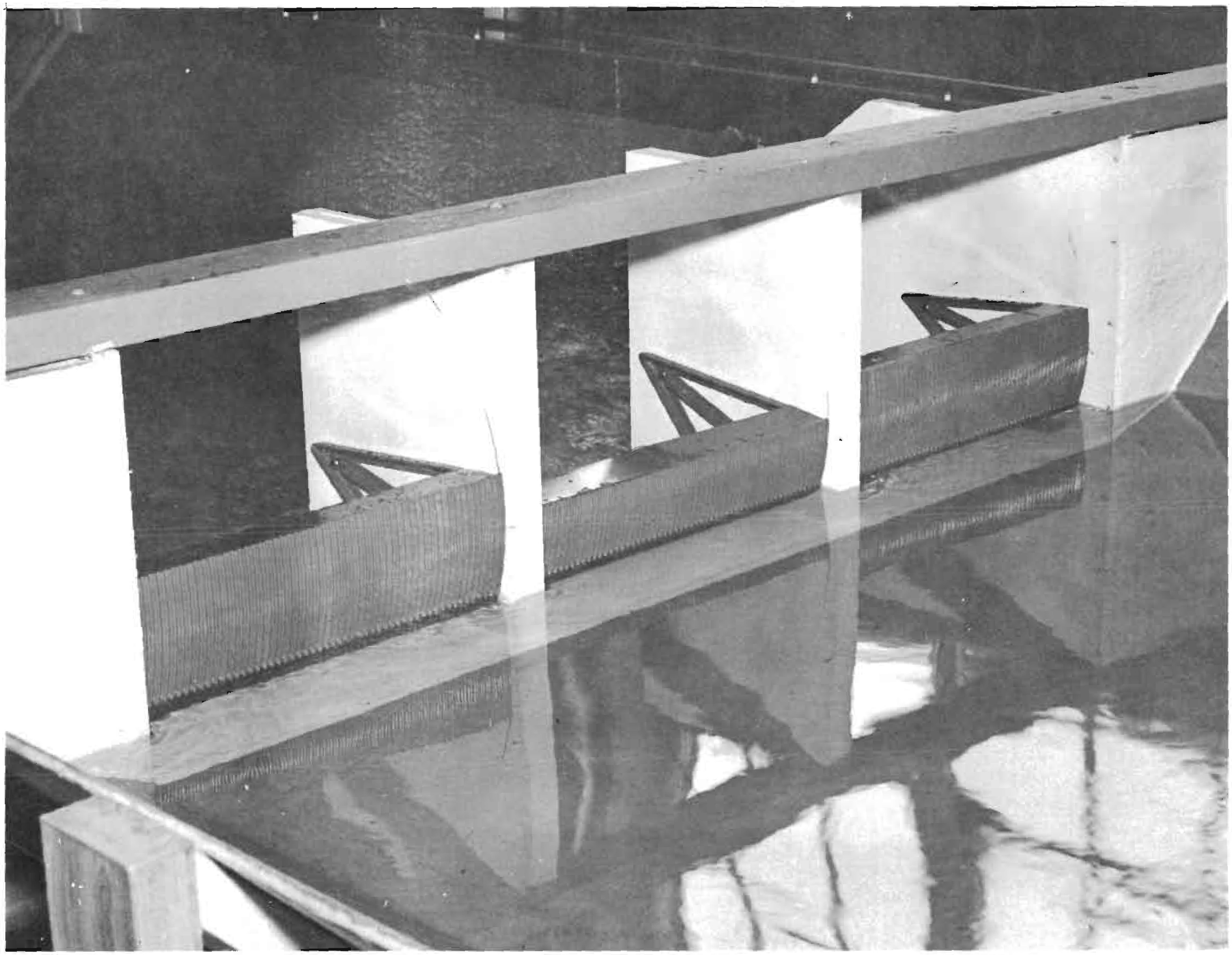

Figure 7. Model Tainter Gates in Operation.

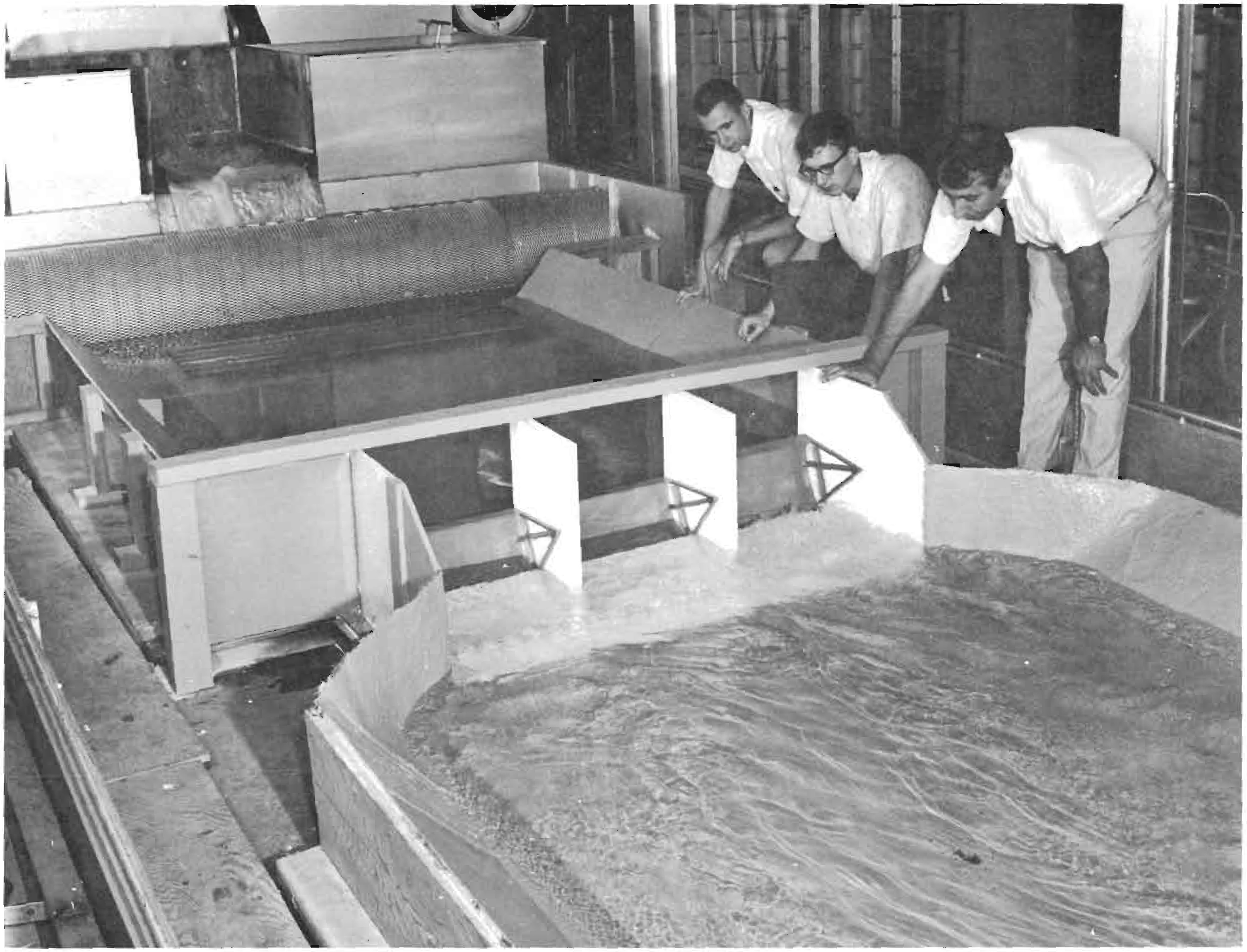

Figure 8. Comprehensive View of Richard.

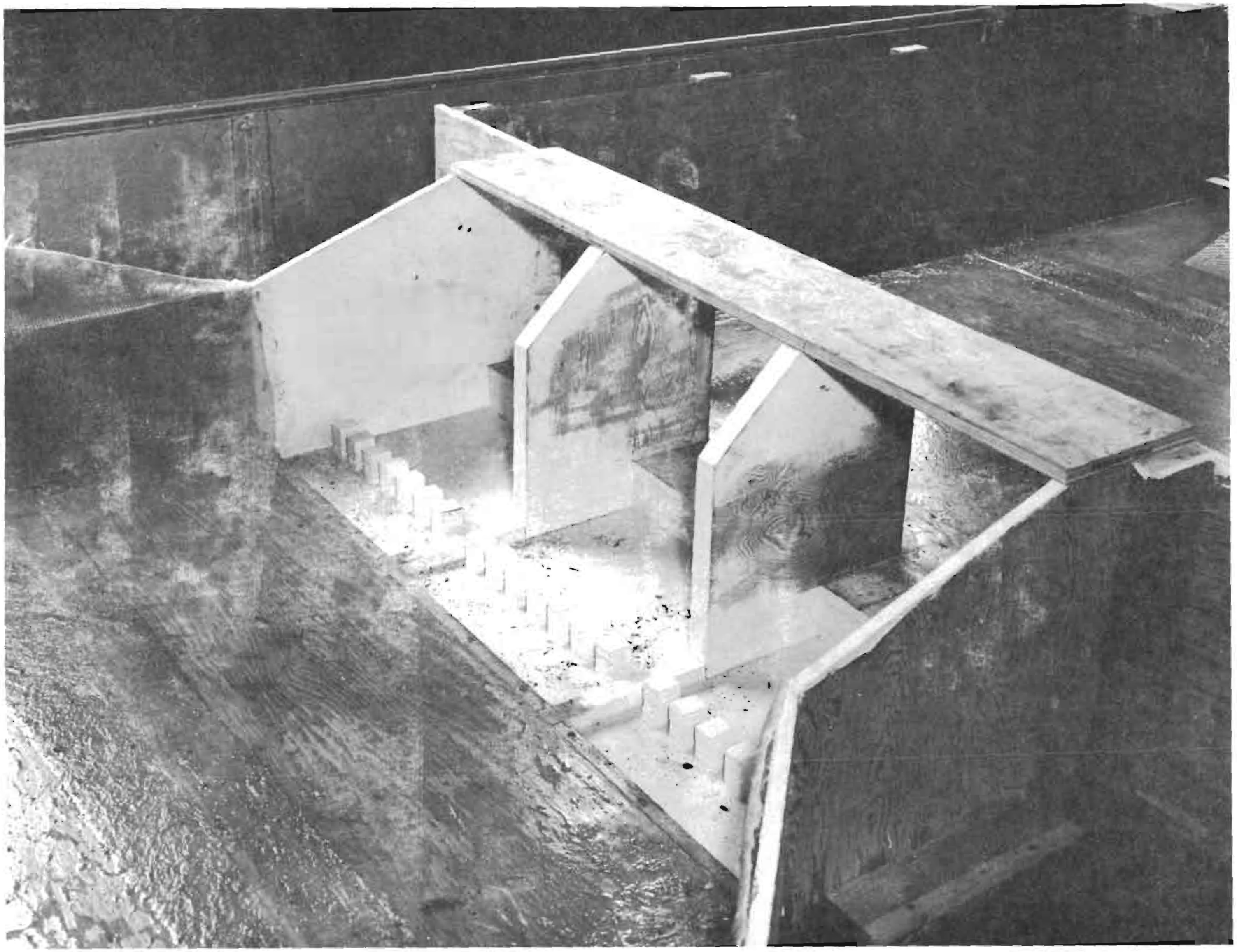

Figure 9. Close-up View of Stilling Basin, Richard.

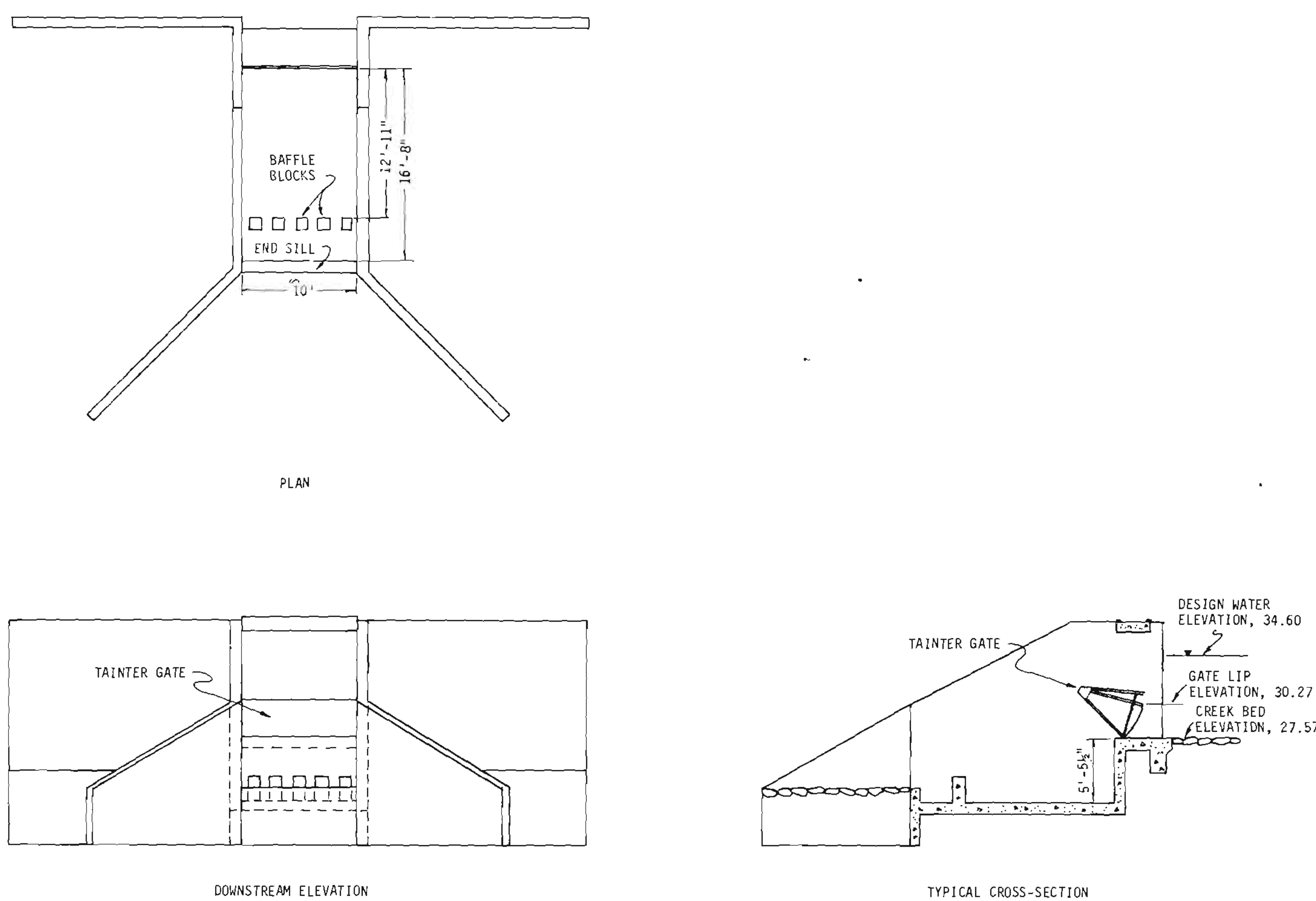

Figure 10. Details of Herman.

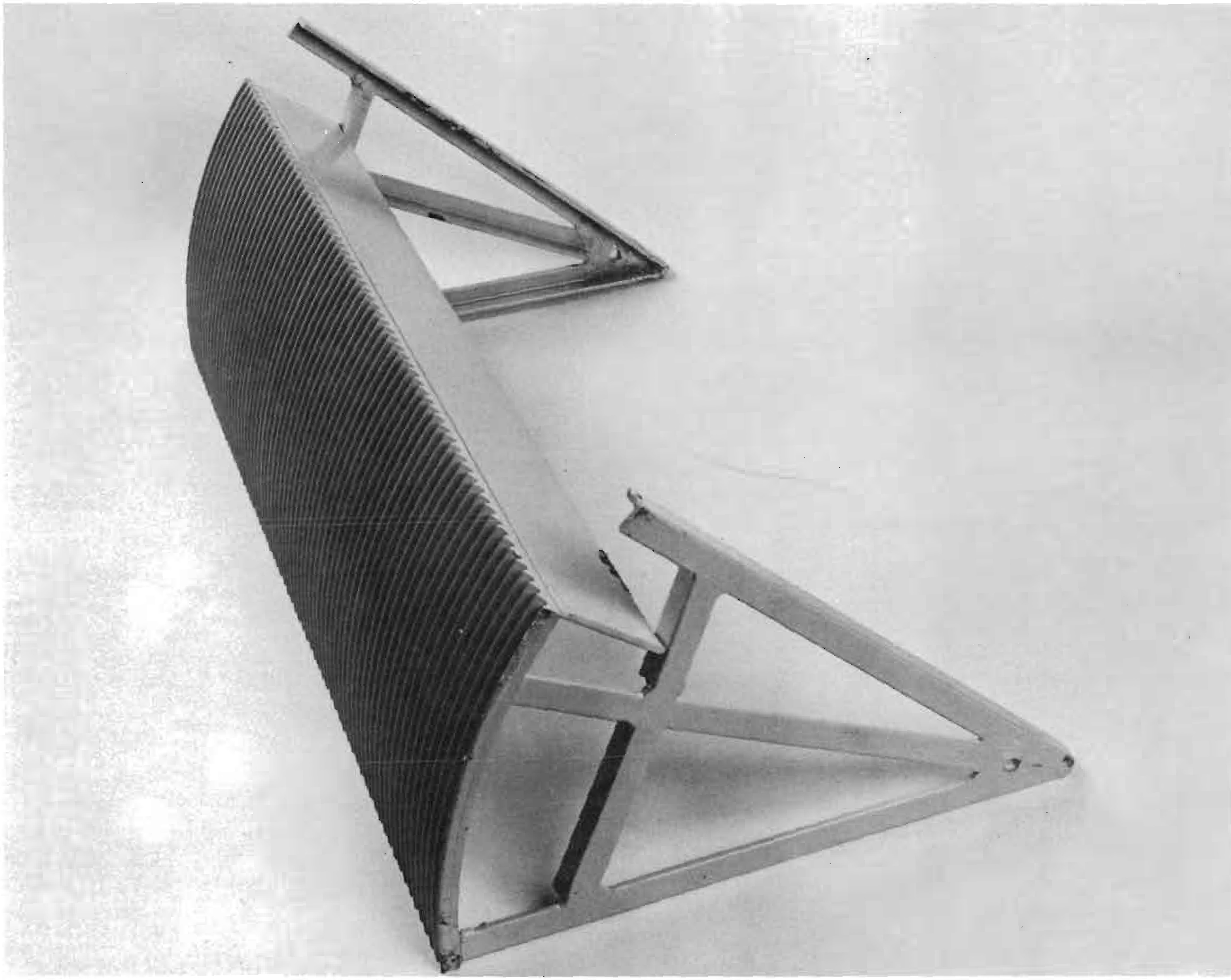

Figure 11. Model of Tainter Gate, Herman.

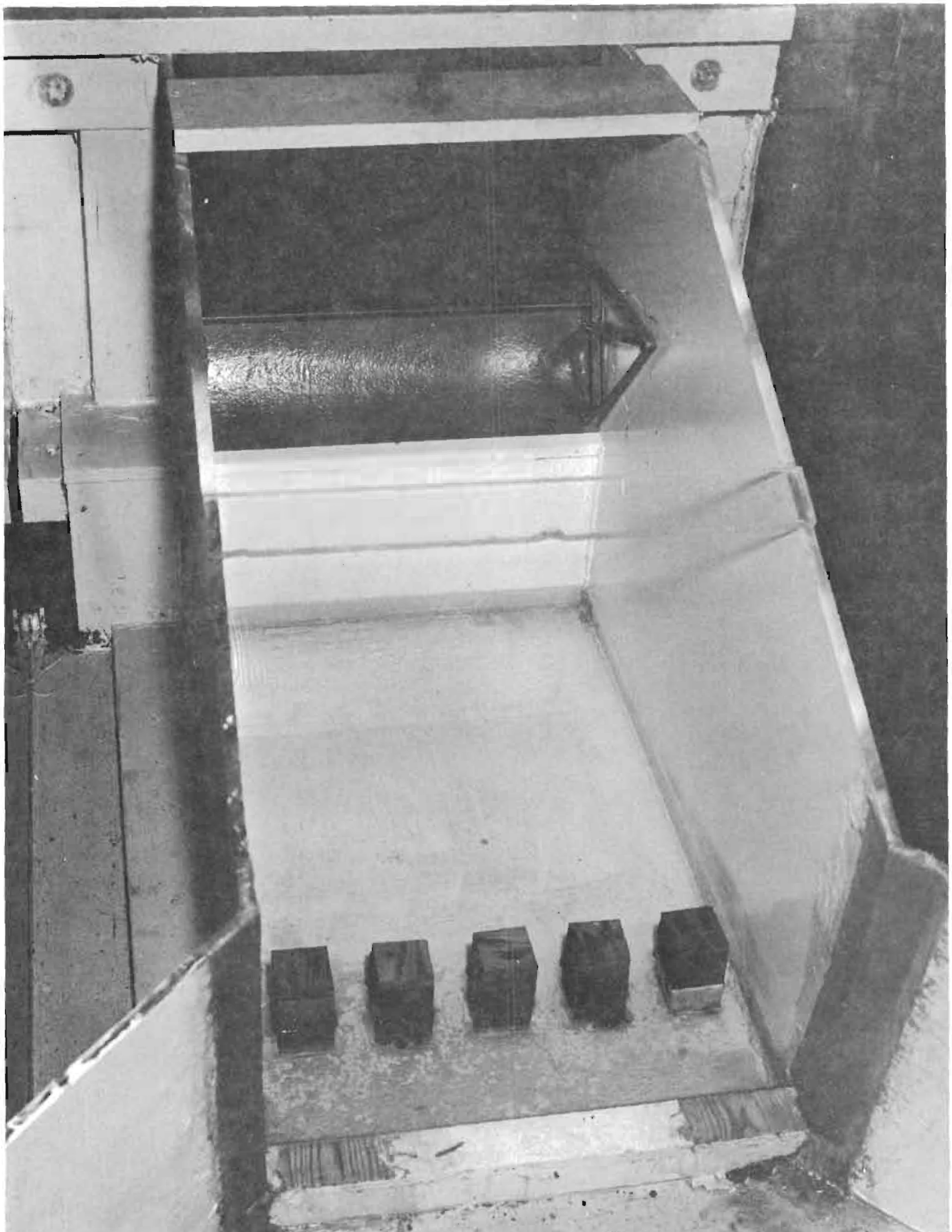

Figure 12. Details of Stilling Basin, Herman.

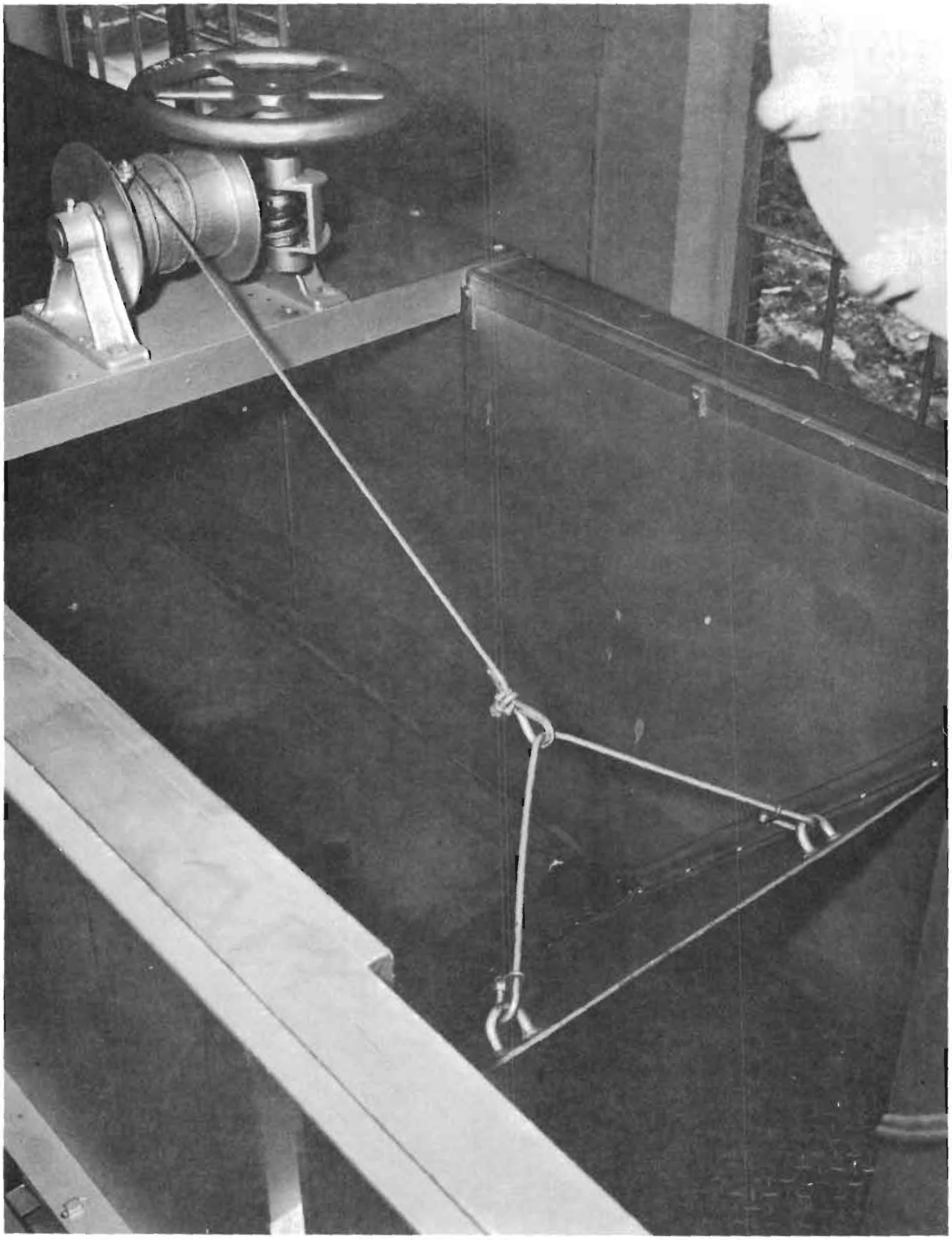

Figure 13. Tailwater Control Mechanism, Herman.

Figure 14. Model of Herman in Operation.

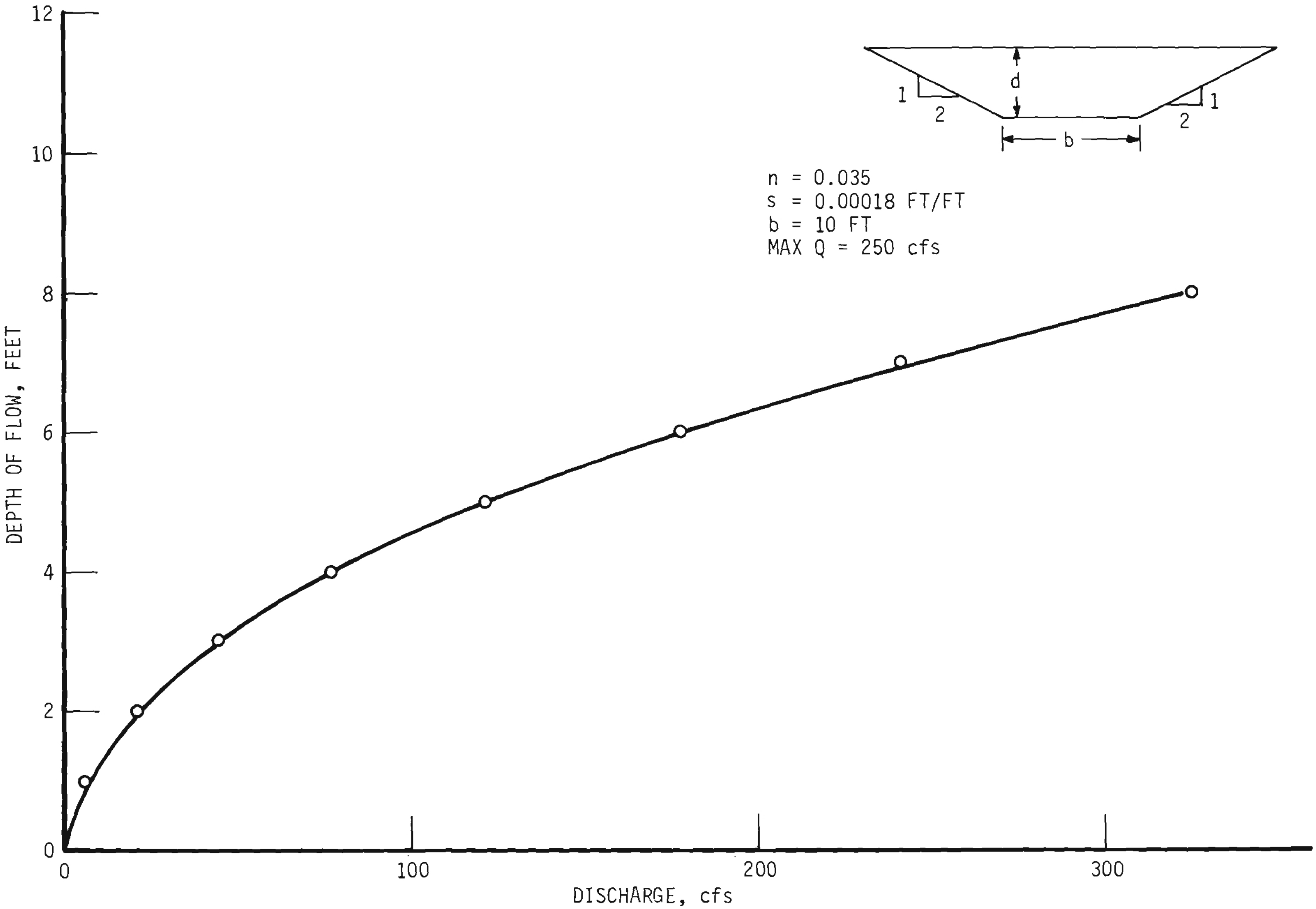

Figure 15. Uniform Flow Depth Variation in Taylor Creek, Near Herman.

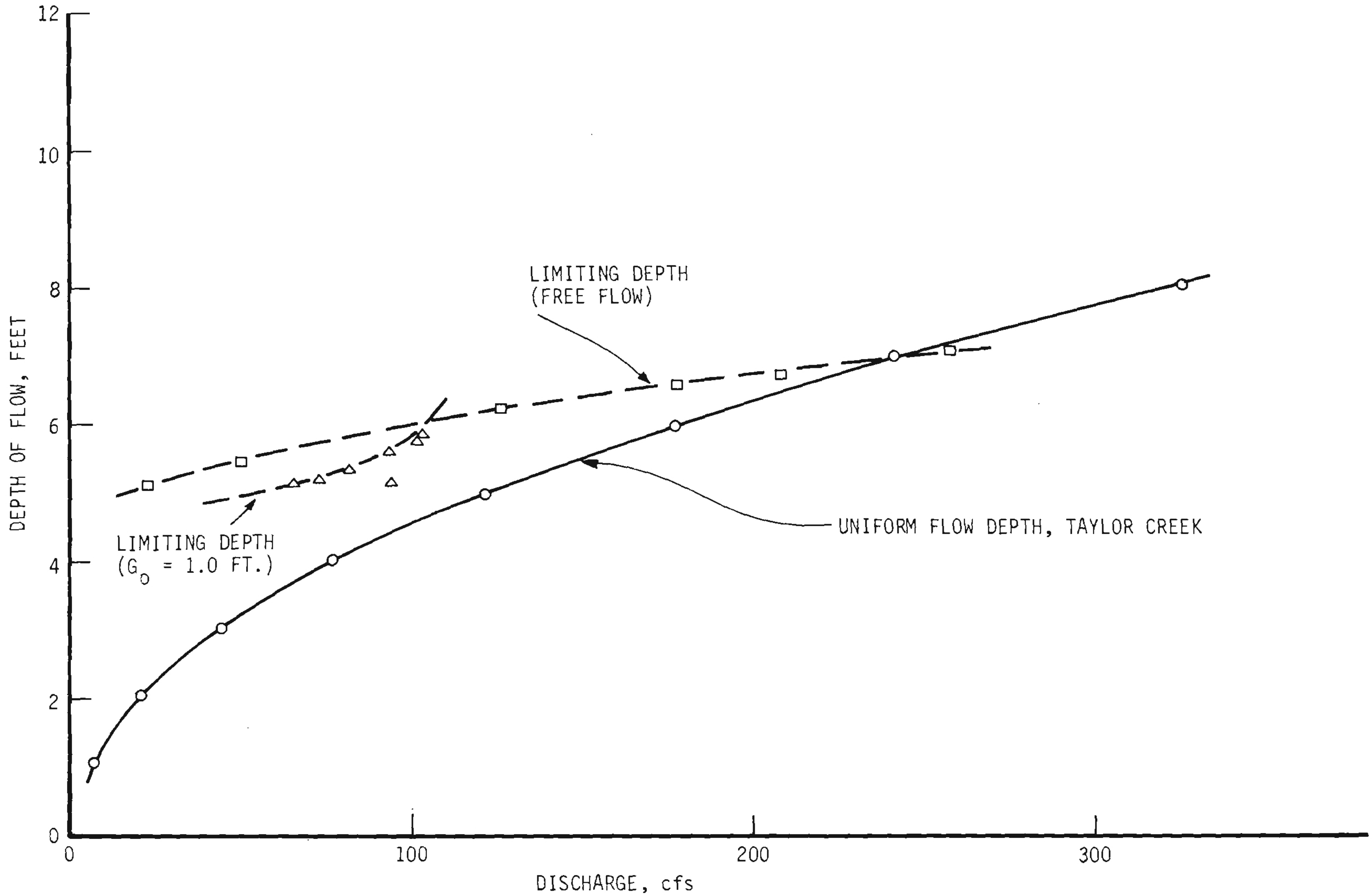

Figure 16. Limiting Tailwater Depth, Herman.

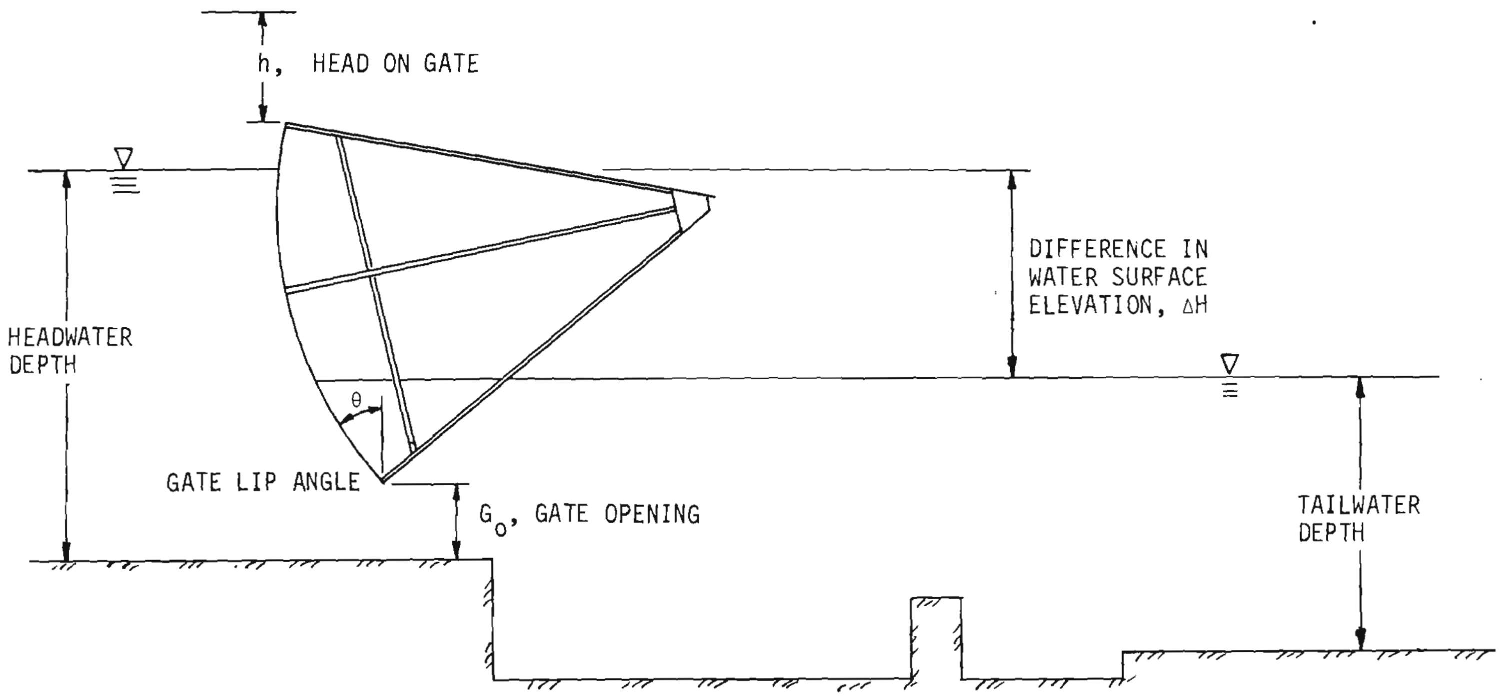

Figure 17. Definition Sketch.

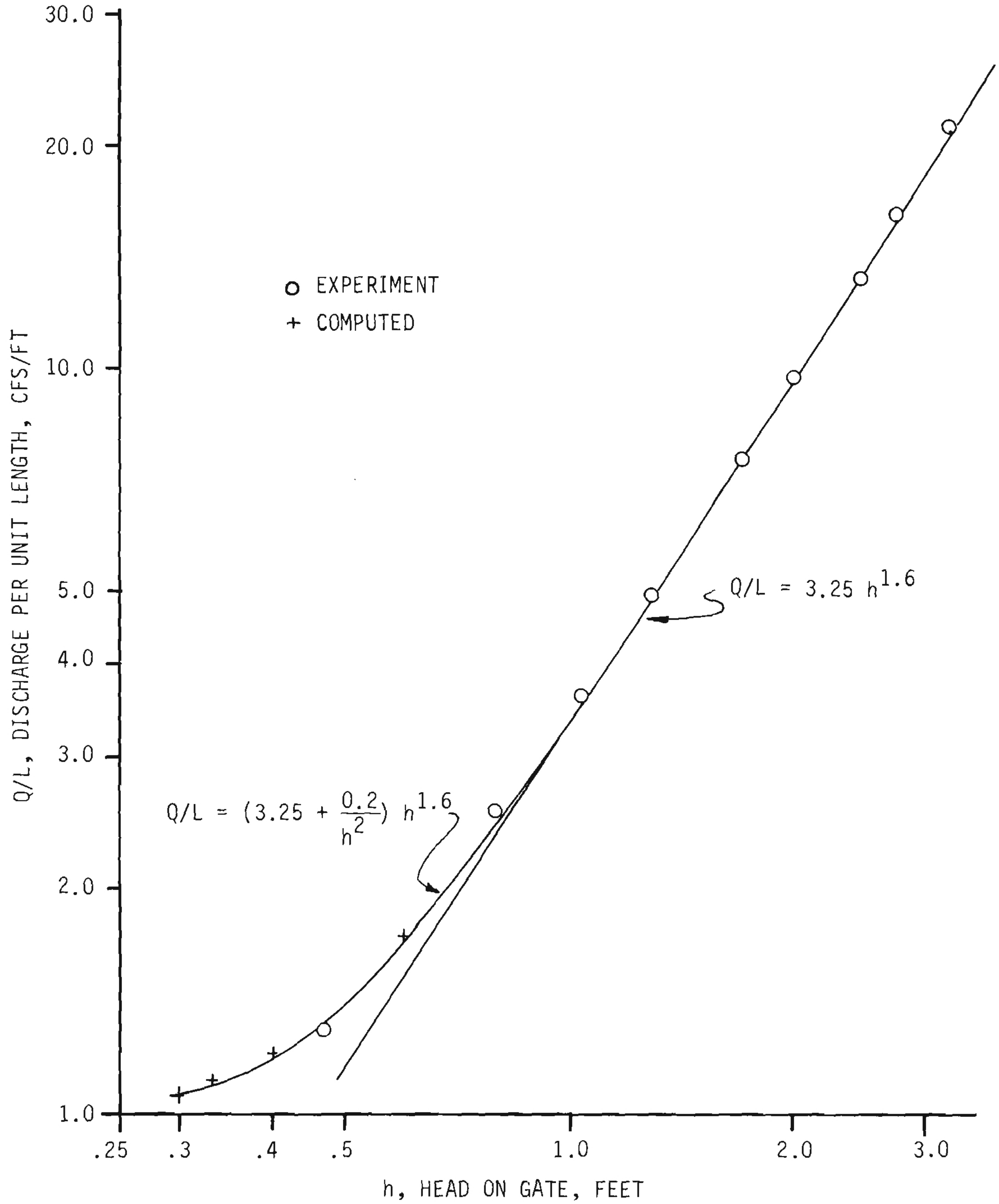

Figure 18. Overflow Discharge Curve, Richard.

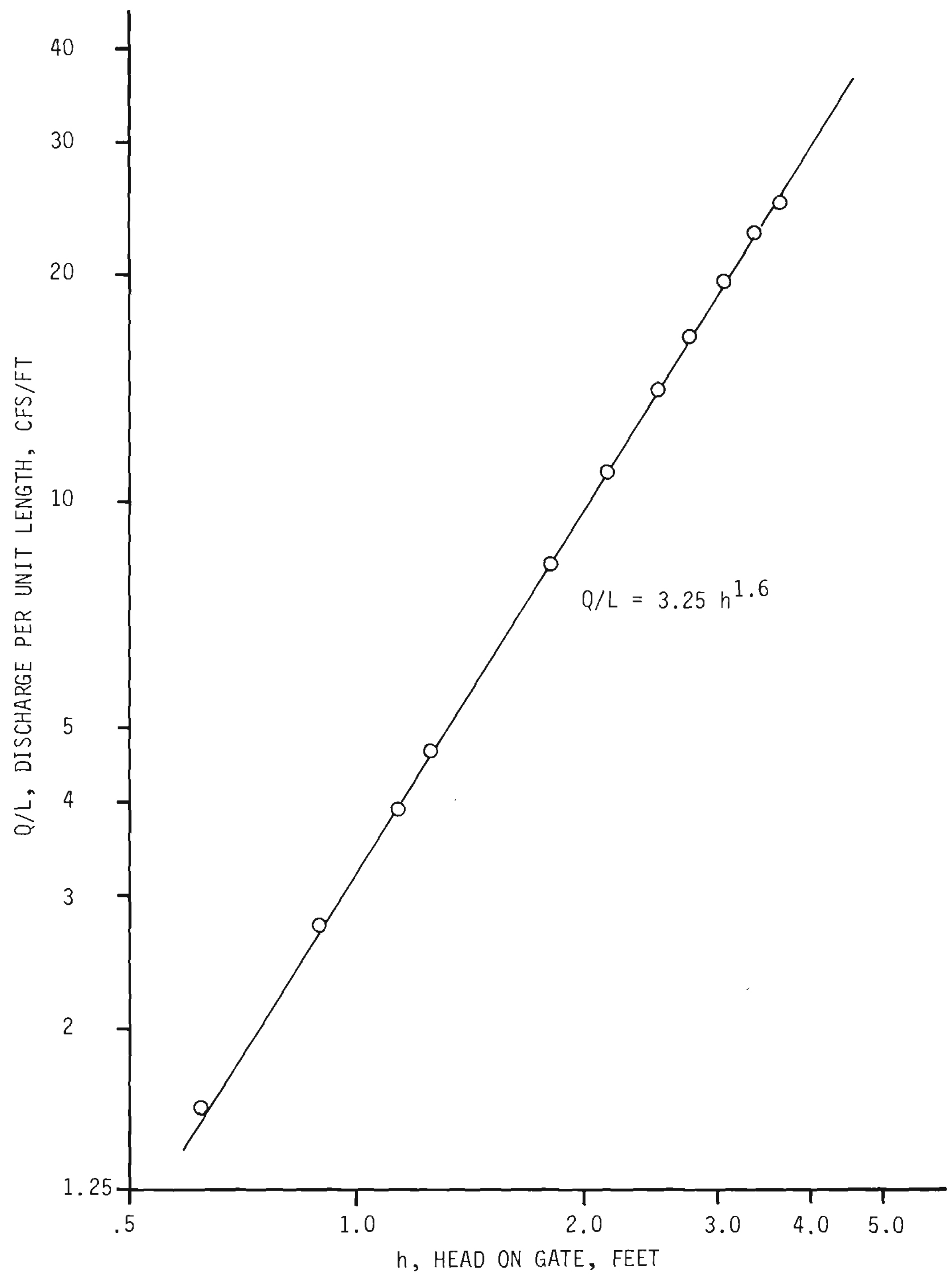

Figure 19. Overflow Discharge Curve, Herman.

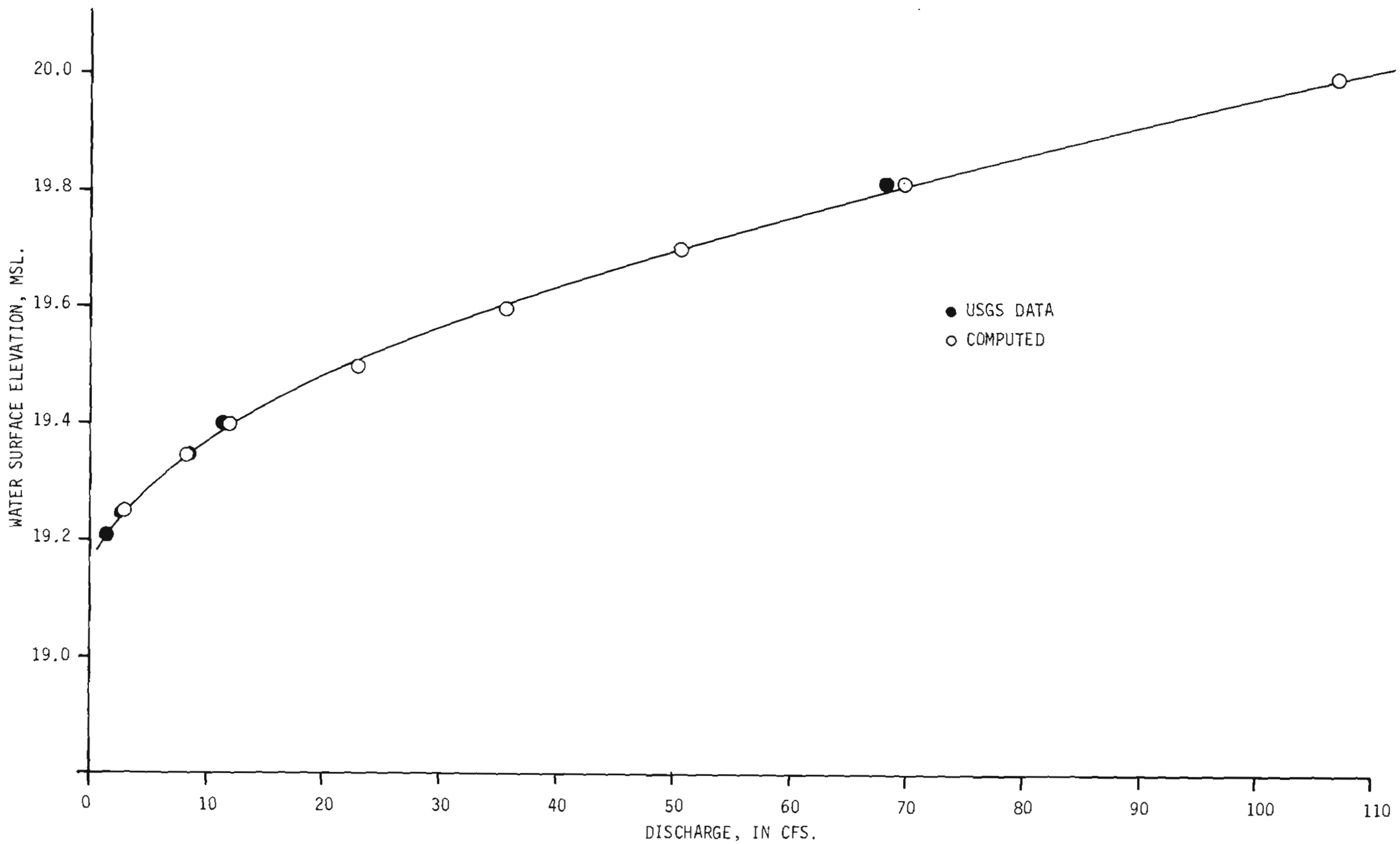

Figure 20. Model-Prototype Verification, Richard.

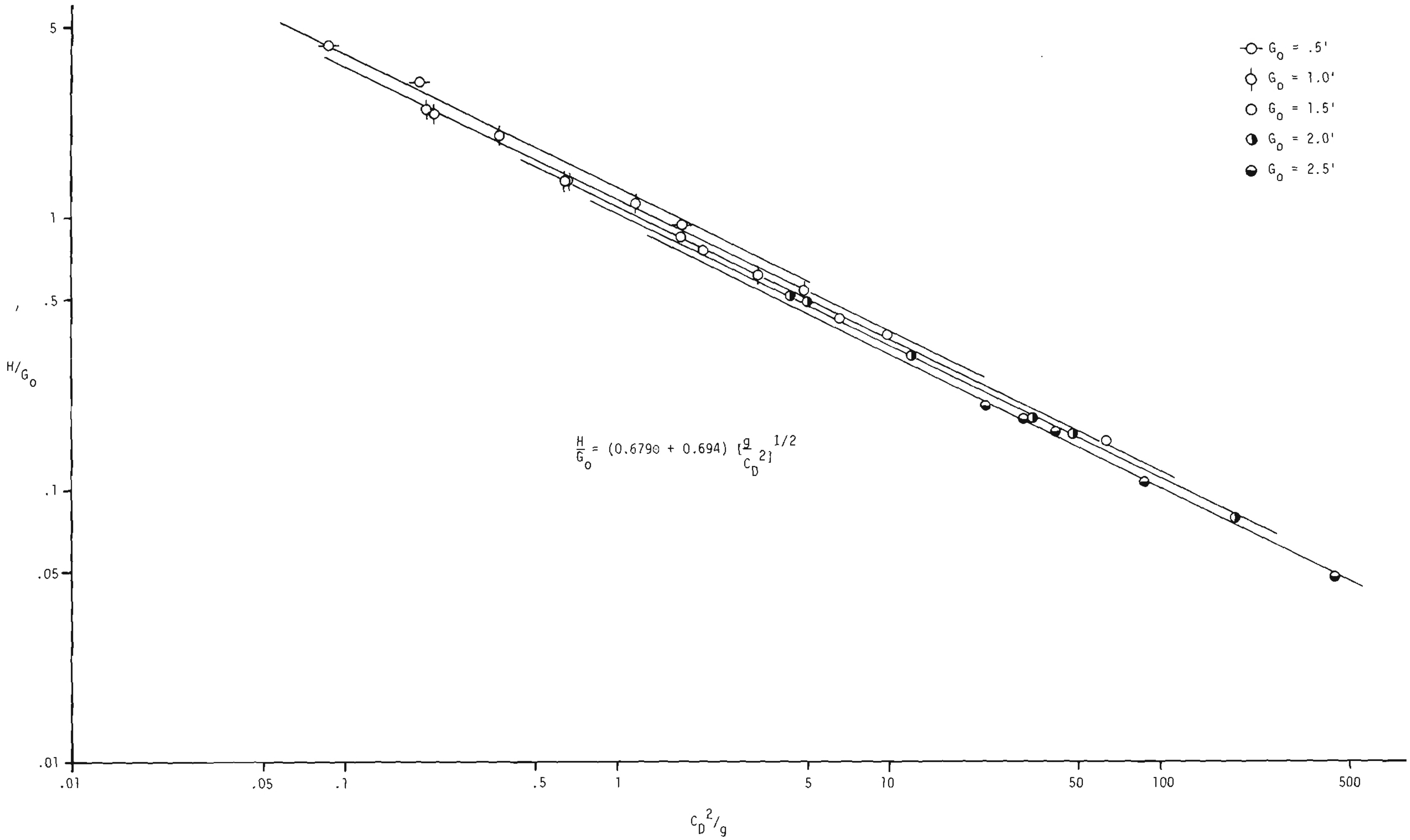

Figure 21. Underflow Through Richard, All Gates.

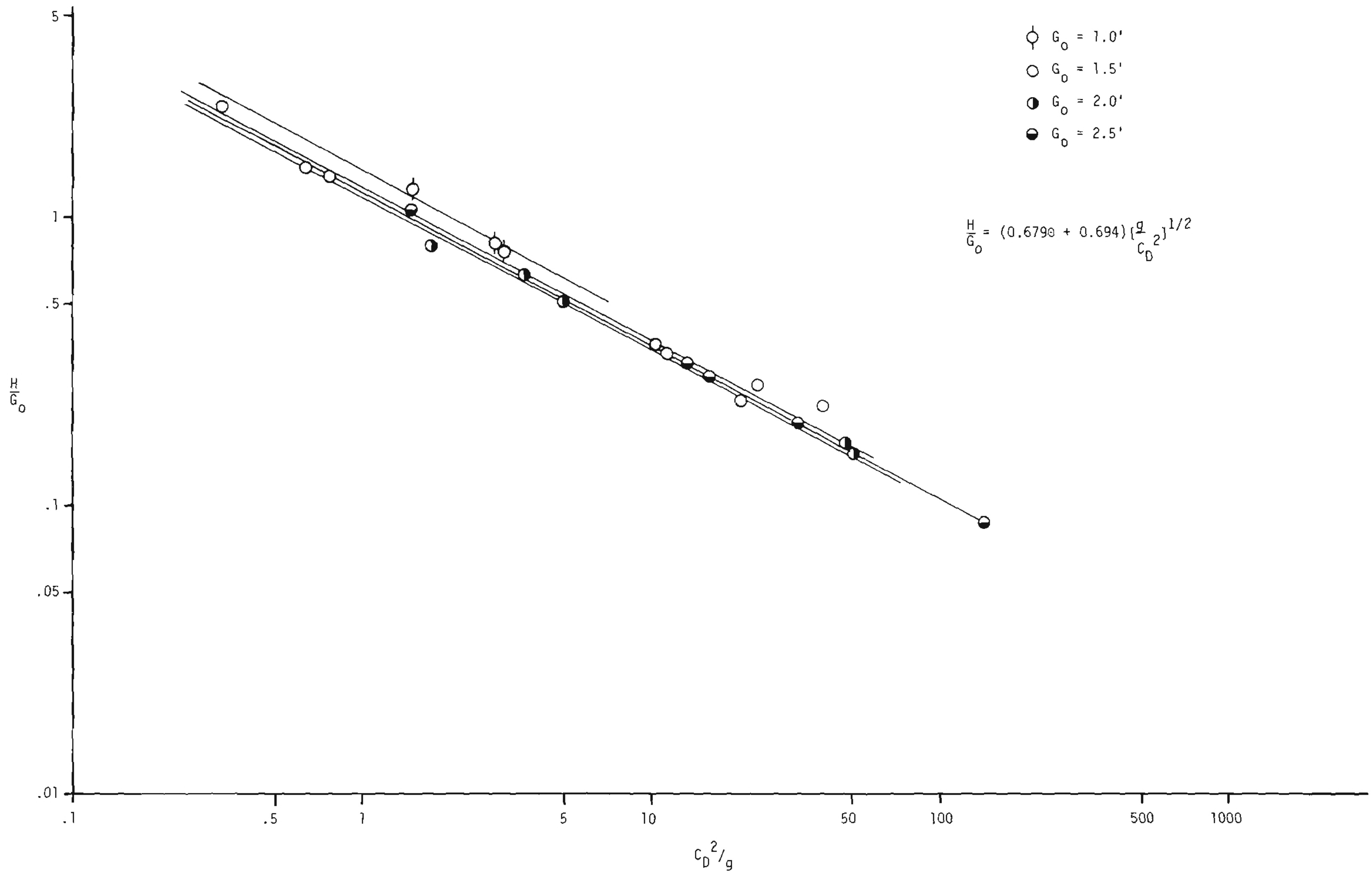

Figure 22. Underflow Through Richard, Gate B Only.

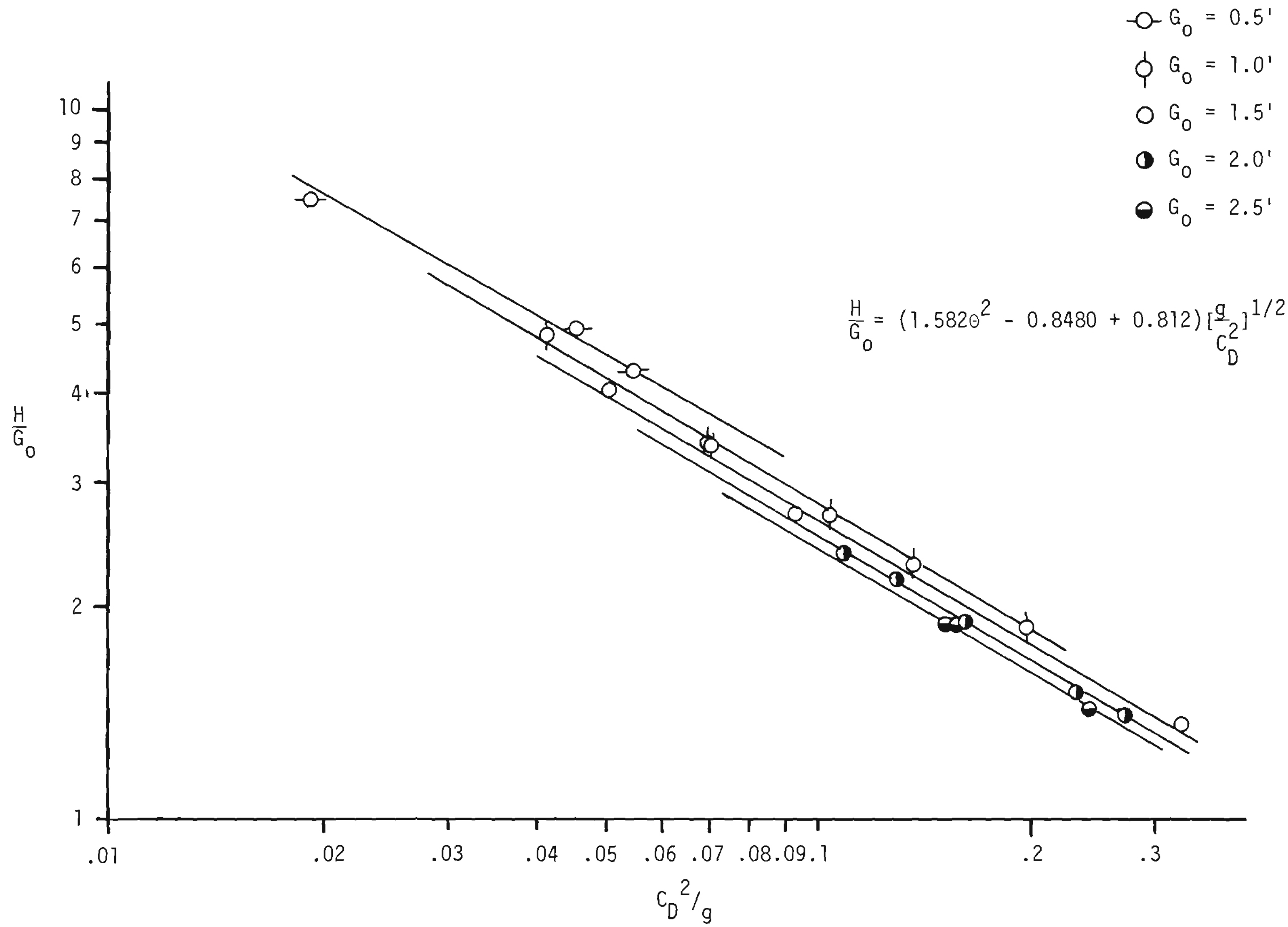

Figure 23. Underflow Through Herman.

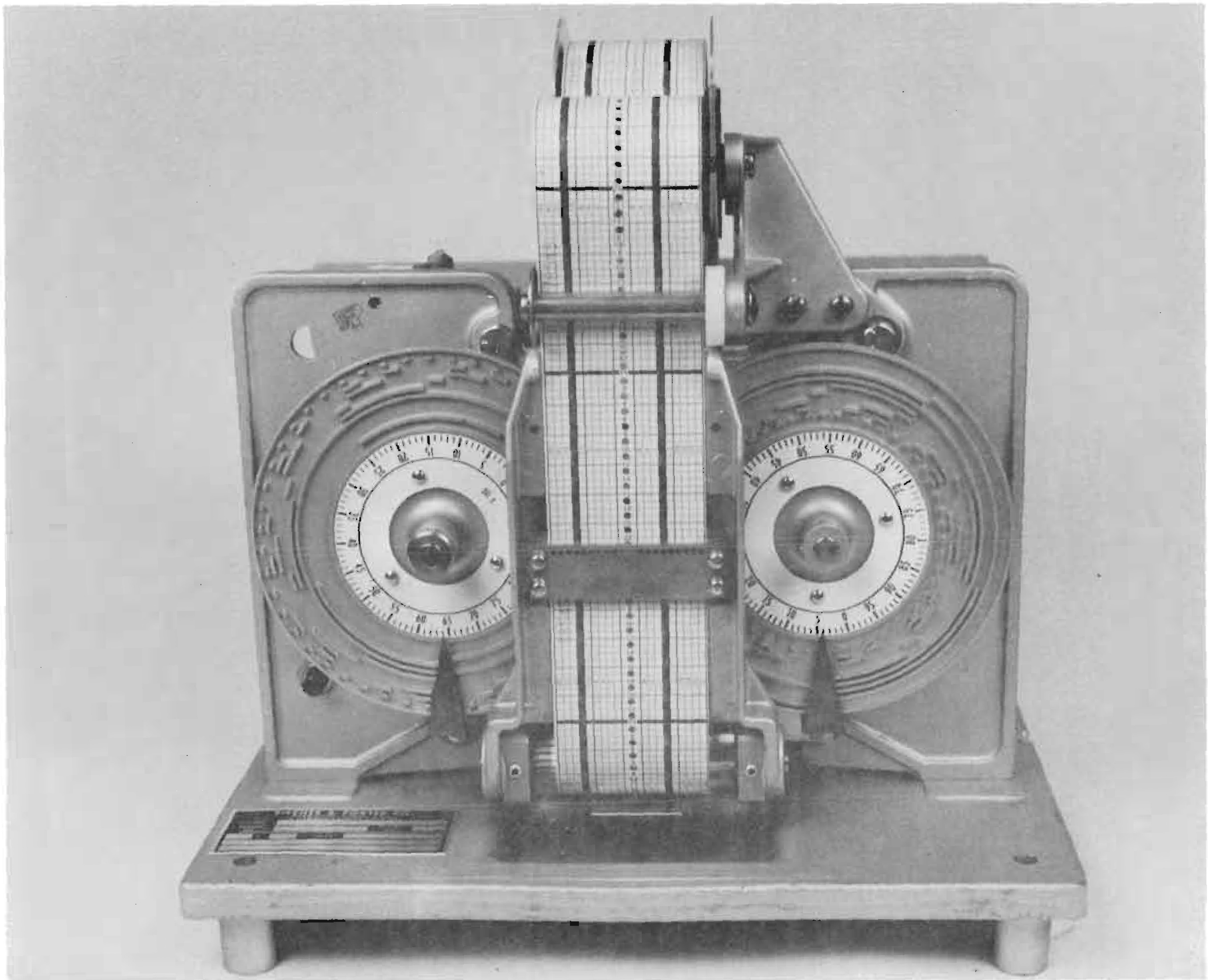

Figure 24. Front View of Digital Stage Recorder.

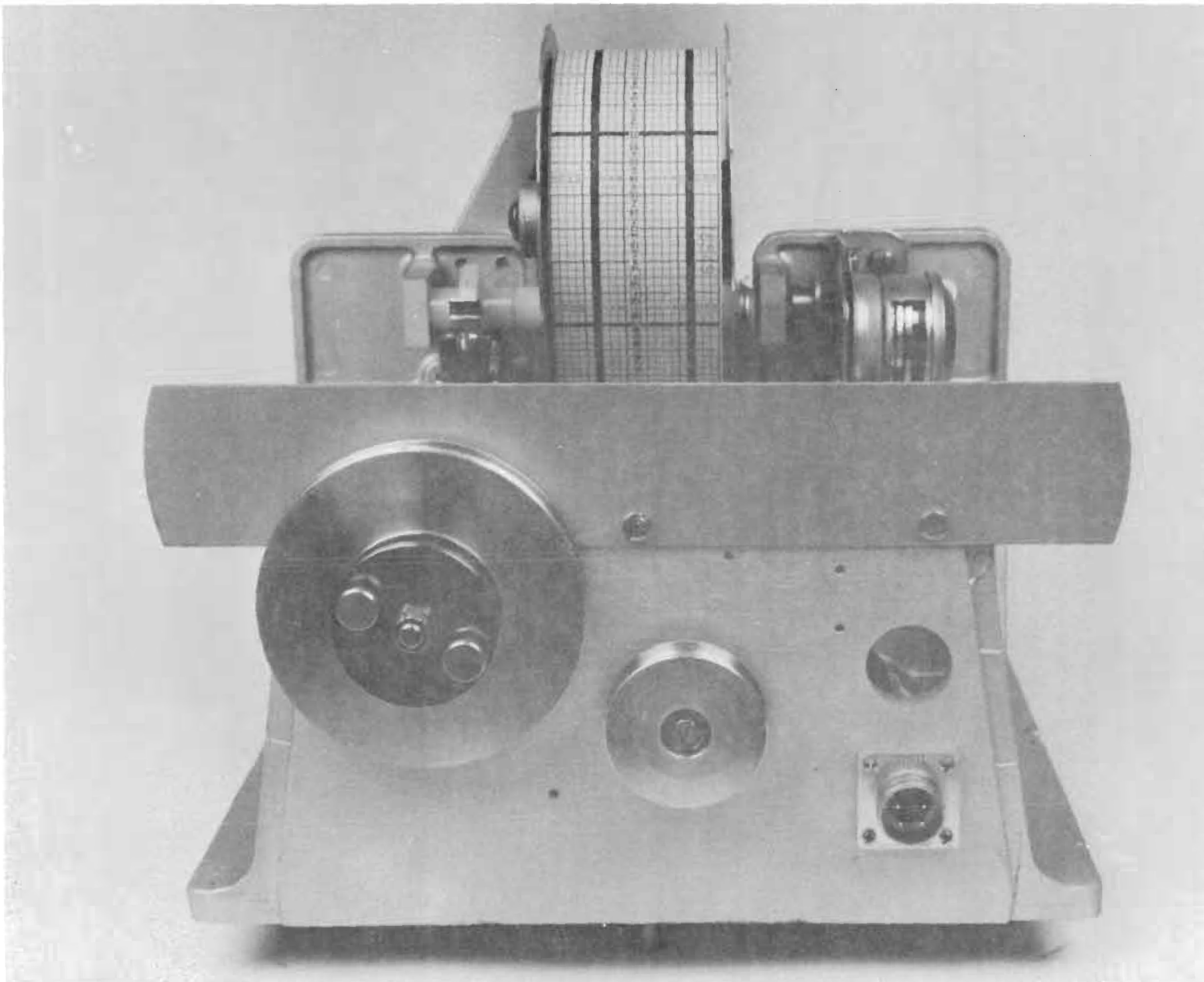

Figure 25. Back View of Digital Stage Recorder.

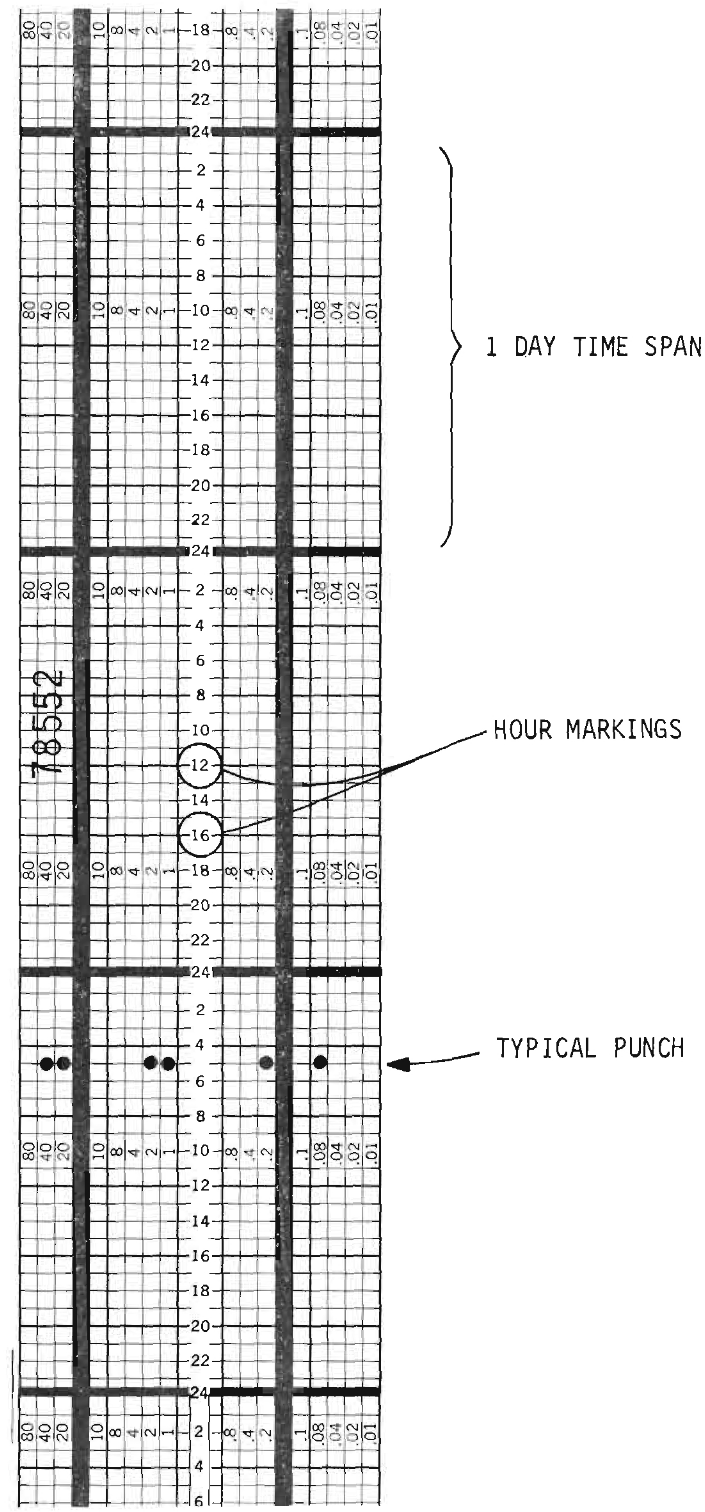

Figure 26. Sample of Recorder Punch Tape, Hourly Records.

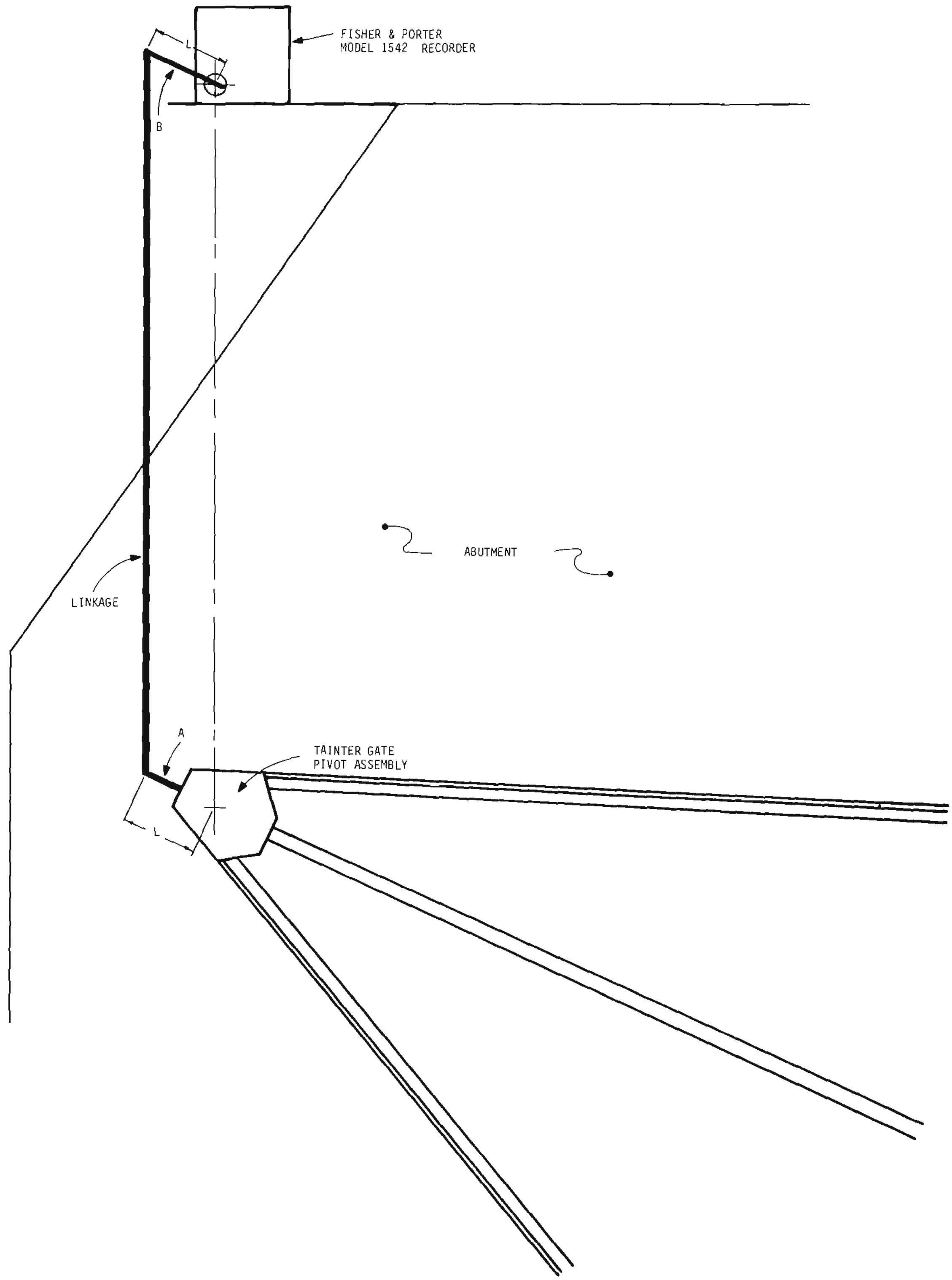

Figure 27. Diagram of Linkage Between Gate and Recorder.

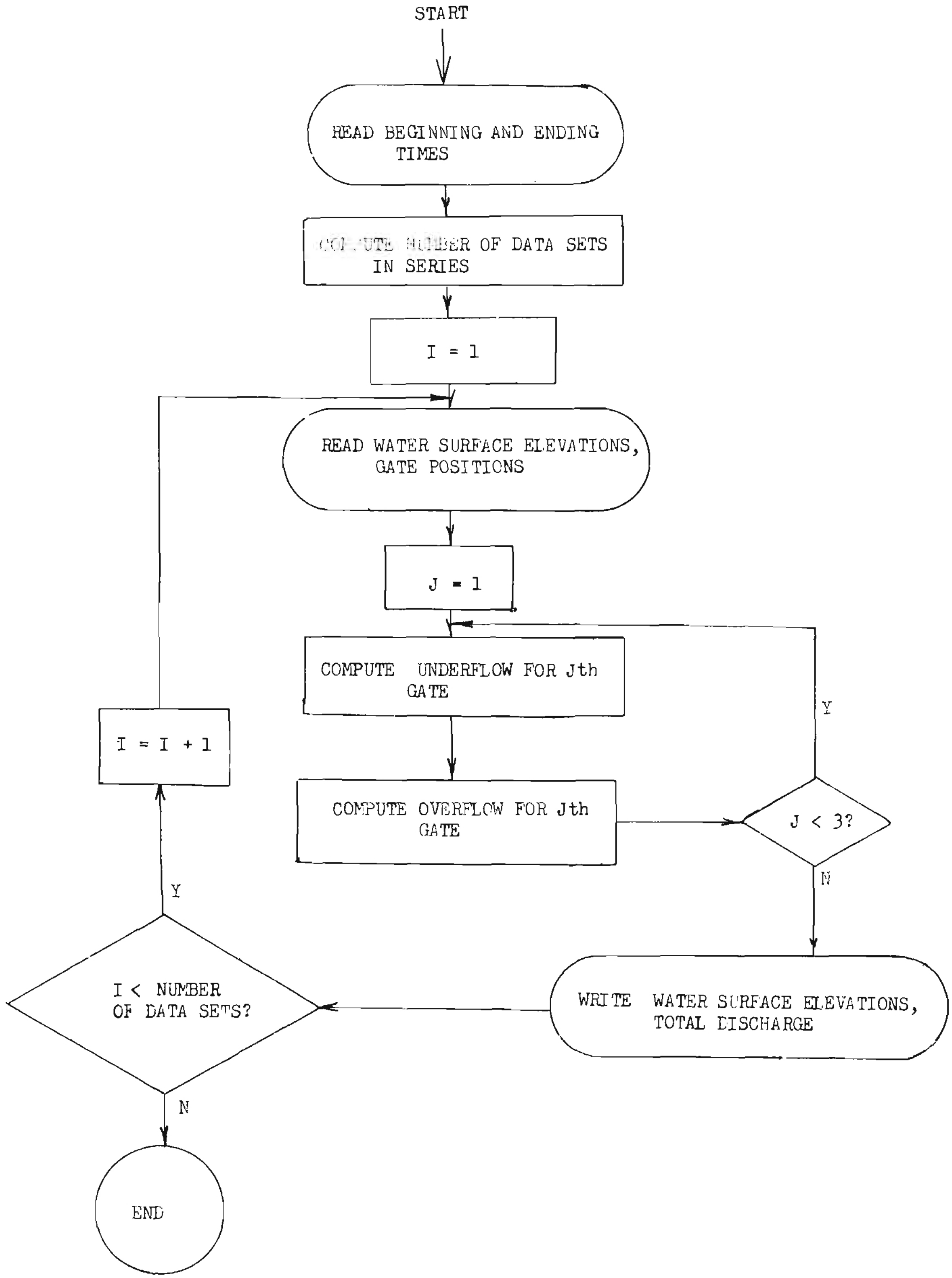

Figure 28. Flow Chart, Richard.

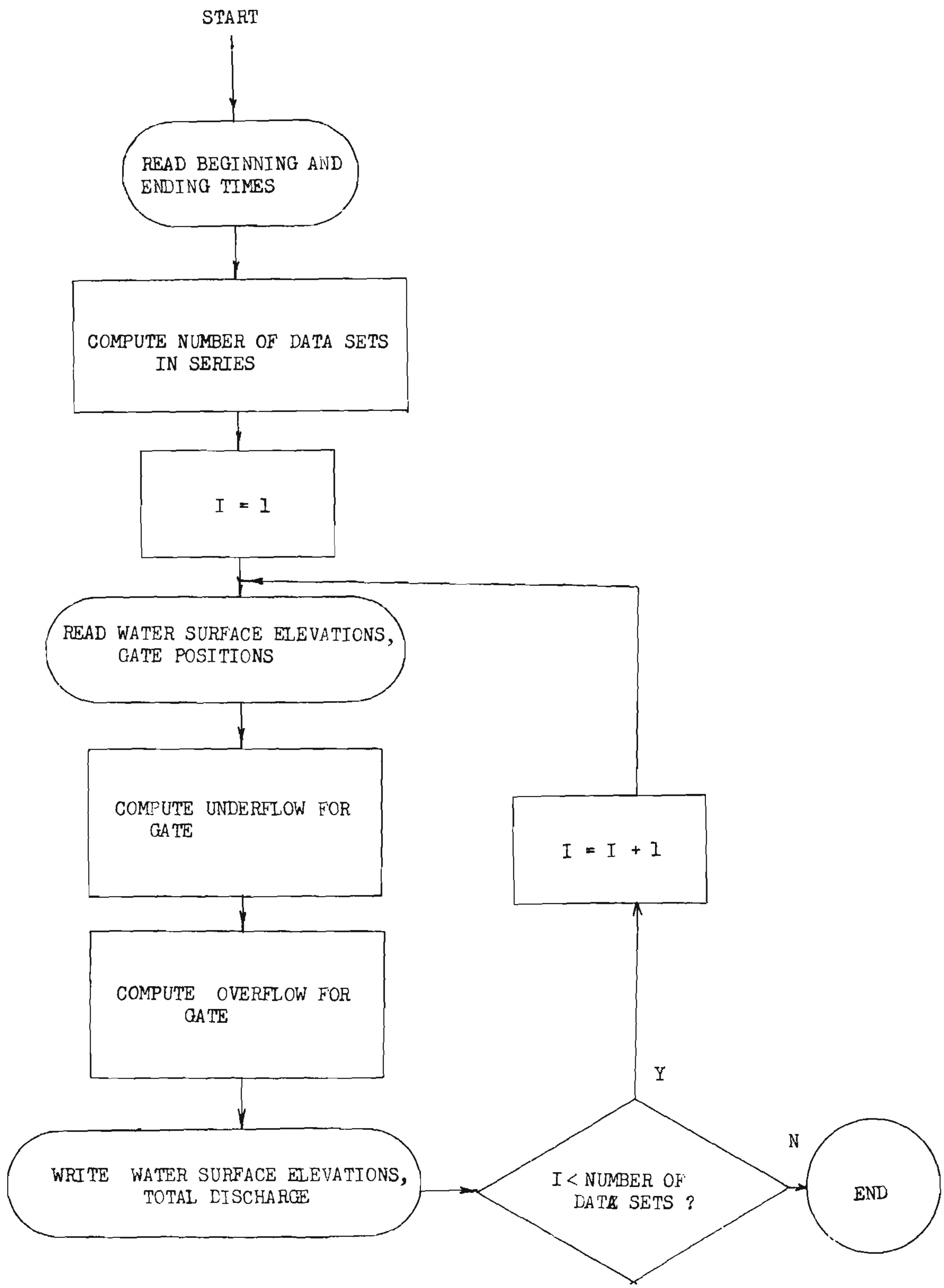

Figure 29. Flow Chart, Herman.

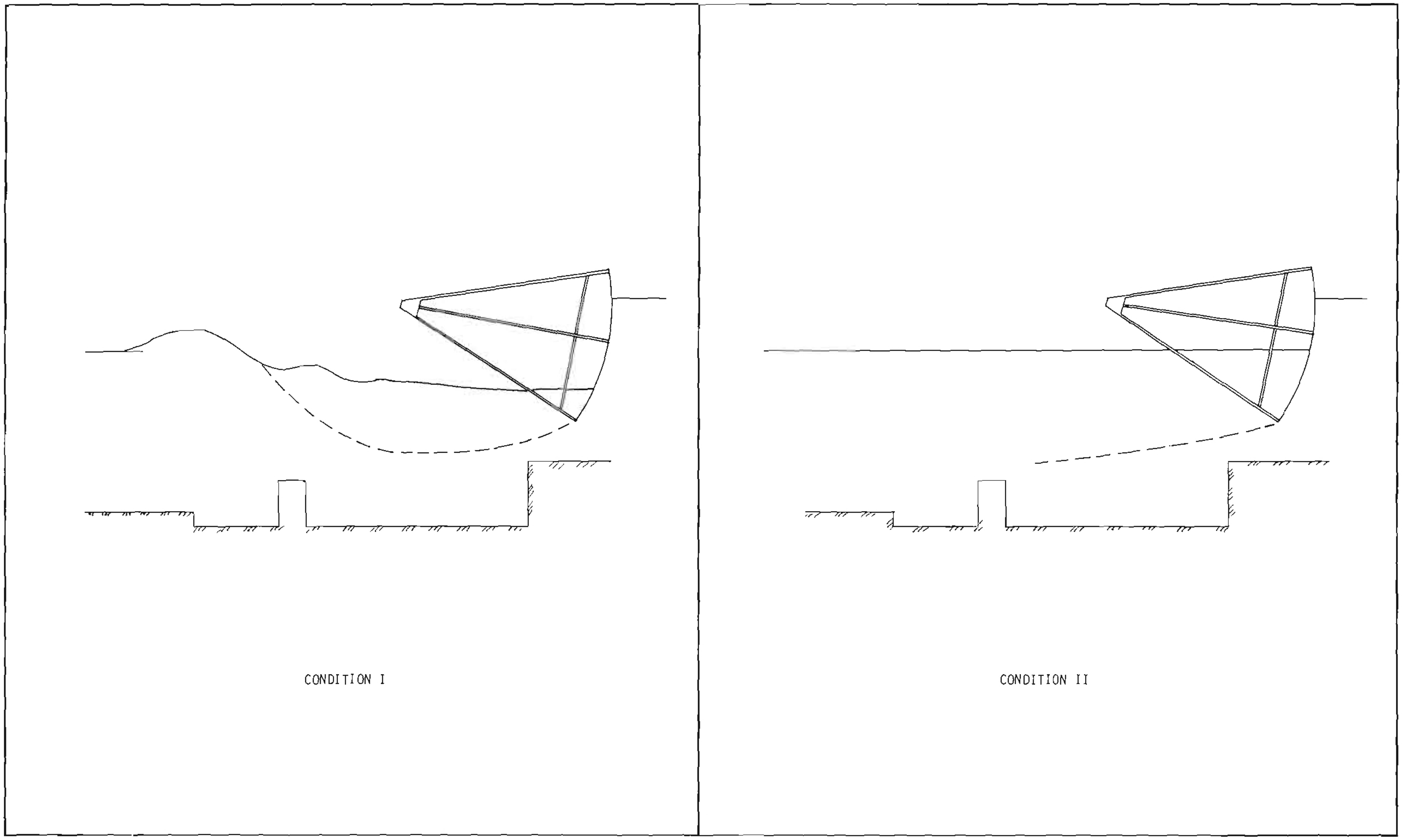

Figure 30. Definition Sketch of Laboratory Flow Conditions.

VII. APPENDIX A, RICHARD I LABORATORY DATA

Legend:

RUN, number of test

WSU, water surface elevation above sill of gate, upstream, in feet

WSD, water surface elevation above sill of gate, downstream, in feet

HGA, head above top of gate A, in feet

HGB, head above top of gate B, in feet

HGC, head above top of gate C, in feet

Q, discharge, in cfs

GATE OPENING A, in feet

GATE OPENING B, in feet

GATE OPENING C, in feet

REMARKS A(*)

REMARKS B(*)

REMARKS C(*)

(*) 0001, Condition I, stilling basin ineffective, wavy surface

0002, Condition II, stilling basin effective

0003, Jet from underflow unsubmerged

Note: The hydraulic model Richard I had smooth-faced Tainter gates and wooden gate supports. These supports came apart and the model had to be abandoned. No calculations were carried out with these data.

RICHARD I DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	B	C	REMARKS A	B	C
1001	0.765	0.427	0.090	0.090	0.090	0.525	0.000	0.000	0.000	0003	0003	0003
1002	0.748	0.463	0.073	0.073	0.017	0.525	0.000	0.000	0.047	0003	0003	0003
1003	0.721	0.463	0.000	0.046	0.000	0.525	0.047	0.000	0.047	0003	0003	0003
1004	0.627	0.467	0.000	0.000	0.000	0.525	0.047	0.047	0.047	0003	0003	0003
1005	0.559	0.468	0.000	0.000	0.000	0.525	0.047	0.047	0.094	0003	0003	0003
1006	0.700	-0.002	0.025	0.025	0.025	0.182	0.000	0.000	0.000	0003	0003	0003
1007	0.216	-0.002	0.000	0.000	0.000	0.182	0.000	0.000	0.047	0003	0003	0003
1008	0.127	-0.002	0.000	0.000	0.000	0.182	0.000	0.000	0.094	0003	0003	0003
1009	0.221	-0.002	0.000	0.000	0.000	0.182	0.000	0.047	0.000	0003	0003	0003
1010	0.129	-0.002	0.000	0.000	0.000	0.182	0.000	0.094	0.000	0003	0003	0003
1011	0.079	-0.002	0.000	0.000	0.000	0.182	0.000	0.047	0.047	0003	0003	0003
1012	0.078	-0.002	0.000	0.000	0.000	0.182	0.000	0.047	0.094	0003	0003	0003
1013	0.079	-0.002	0.000	0.000	0.000	0.182	0.000	0.094	0.094	0003	0003	0003
1014	0.046	-0.002	0.000	0.000	0.000	0.182	0.047	0.047	0.047	0003	0003	0003
1015	0.201	-0.002	0.000	0.000	0.000	0.182	0.047	0.000	0.000	0003	0003	0003
1016	0.729	0.045	0.054	0.054	0.054	0.314	0.000	0.000	0.000	0003	0003	0003
1017	0.584	0.045	0.000	0.000	0.000	0.313	0.000	0.000	0.047	0003	0003	0003
1018	0.234	0.045	0.000	0.000	0.000	0.313	0.000	0.000	0.094	0003	0003	0003
1019	0.188	0.045	0.000	0.000	0.000	0.313	0.000	0.000	0.142	0003	0003	0003
1020	0.598	0.045	0.000	0.000	0.000	0.313	0.000	0.047	0.000	0003	0003	0003
1021	0.233	0.045	0.000	0.000	0.000	0.313	0.000	0.094	0.000	0003	0003	0003
1022	0.187	0.045	0.000	0.000	0.000	0.313	0.000	0.142	0.000	0003	0003	0003
1023	0.181	0.045	0.000	0.000	0.000	0.313	0.000	0.047	0.000	0003	0003	0003
1024	0.125	0.045	0.000	0.000	0.000	0.313	0.000	0.047	0.094	0003	0003	0003
1025	0.111	0.045	0.000	0.000	0.000	0.313	0.000	0.094	0.094	0003	0003	0003
1026	0.095	0.045	0.000	0.000	0.000	0.313	0.047	0.047	0.047	0003	0003	0003
1027	0.087	0.045	0.000	0.000	0.000	0.313	0.047	0.047	0.094	0003	0003	0003
1028	0.088	0.045	0.000	0.000	0.000	0.313	0.047	0.094	0.047	0003	0003	0003
1029	0.081	0.045	0.000	0.000	0.000	0.313	0.047	0.094	0.094	0003	0003	0003
1030	0.077	0.045	0.000	0.000	0.000	0.313	0.094	0.094	0.094	0003	0003	0003

RICHARD I DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
1031	0.618	0.094	0.000	0.000	0.000	0.313	0.000	0.000	0.047	0003	0003	0003
1032	0.234	0.094	0.000	0.000	0.000	0.313	0.000	0.000	0.094	0003	0003	0003
1033	0.188	0.094	0.000	0.000	0.000	0.313	0.000	0.000	0.142	0003	0003	0003
1034	0.665	0.094	0.000	0.000	0.000	0.313	0.000	0.047	0.000	0003	0003	0003
1035	0.249	0.094	0.000	0.000	0.000	0.313	0.000	0.094	0.000	0003	0003	0003
1036	0.189	0.094	0.000	0.000	0.000	0.313	0.000	0.142	0.000	0003	0003	0003
1037	0.196	0.094	0.000	0.000	0.000	0.313	0.000	0.047	0.047	0003	0003	0003
1038	0.143	0.094	0.000	0.000	0.000	0.313	0.000	0.047	0.094	0003	0003	0003
1039	0.139	0.094	0.000	0.000	0.000	0.313	0.000	0.047	0.142	0003	0003	0003
1040	0.139	0.094	0.000	0.000	0.000	0.313	0.000	0.094	0.047	0003	0003	0003
1041	0.138	0.094	0.000	0.000	0.000	0.313	0.000	0.142	0.047	0003	0003	0003
1042	0.186	0.094	0.000	0.000	0.000	0.313	0.047	0.000	0.047	0003	0003	0003
1043	0.153	0.094	0.000	0.000	0.000	0.313	0.047	0.000	0.094	0003	0003	0003
1044	0.141	0.094	0.000	0.000	0.000	0.313	0.047	0.000	0.142	0003	0003	0003
1045	0.142	0.094	0.000	0.000	0.000	0.313	0.047	0.047	0.047	0003	0003	0003
1046	0.123	0.094	0.000	0.000	0.000	0.313	0.047	0.047	0.094	0003	0003	0003
1047	0.117	0.094	0.000	0.000	0.000	0.313	0.047	0.047	0.142	0003	0003	0003
1048	0.112	0.094	0.000	0.000	0.000	0.313	0.047	0.094	0.047	0003	0003	0003
1049	0.102	0.094	0.000	0.000	0.000	0.313	0.047	0.094	0.094	0003	0003	0003
1050	0.106	0.094	0.000	0.000	0.000	0.313	0.047	0.094	0.142	0003	0003	0003
1051	0.105	0.094	0.000	0.000	0.000	0.313	0.047	0.142	0.142	0003	0003	0003
1052	0.108	0.094	0.000	0.000	0.000	0.313	0.094	0.047	0.094	0003	0003	0003
1053	0.097	0.094	0.000	0.000	0.000	0.313	0.094	0.094	0.094	0003	0003	0003
1054	0.099	0.094	0.000	0.000	0.000	0.313	0.142	0.142	0.142	0003	0003	0003
1055	0.776	0.236	0.101	0.101	0.101	0.594	0.000	0.000	0.000	0003	0003	0003
1056	0.741	0.236	0.066	0.066	0.010	0.593	0.000	0.000	0.047	0003	0003	0003
1057	0.650	0.236	0.000	0.000	0.000	0.593	0.000	0.000	0.094	0003	0003	0003
1058	0.399	0.236	0.000	0.000	0.000	0.593	0.000	0.000	0.142	0003	0003	0003
1059	0.322	0.236	0.000	0.000	0.000	0.593	0.000	0.000	0.189	0003	0003	0003
1060	0.309	0.236	0.000	0.000	0.000	0.593	0.000	0.000	0.236	0003	0003	0003

RICHARD I DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
1061	0.309	0.236	0.000	0.000	0.000	0.593	0.000	0.000	0.283	0003	0003	0003
1062	0.745	0.236	0.070	0.014	0.070	0.593	0.000	0.047	0.000	0003	0003	0003
1063	0.594	0.236	0.000	0.000	0.000	0.593	0.000	0.094	0.000	0003	0003	0003
1064	0.396	0.236	0.000	0.000	0.000	0.593	0.000	0.142	0.000	0003	0003	0003
1065	0.314	0.236	0.000	0.000	0.000	0.593	0.000	0.189	0.000	0003	0003	0003
1066	0.301	0.236	0.000	0.000	0.000	0.593	0.000	0.236	0.000	0003	0003	0003
1067	0.625	0.236	0.000	0.000	0.000	0.593	0.000	0.047	0.047	0003	0003	0003
1068	0.392	0.236	0.000	0.000	0.000	0.593	0.000	0.047	0.094	0003	0003	0003
1069	0.315	0.236	0.000	0.000	0.000	0.593	0.000	0.047	0.142	0003	0003	0003
1070	0.287	0.236	0.000	0.000	0.000	0.593	0.000	0.047	0.189	0003	0003	0003
1071	0.323	0.236	0.000	0.000	0.000	0.593	0.000	0.047	0.236	0003	0003	0003
1072	0.382	0.236	0.000	0.000	0.000	0.593	0.000	0.094	0.047	0003	0003	0003
1073	0.269	0.236	0.000	0.000	0.000	0.593	0.000	0.094	0.094	0003	0003	0003
1074	0.285	0.236	0.000	0.000	0.000	0.593	0.000	0.094	0.142	0003	0003	0003
1075	0.264	0.236	0.000	0.000	0.000	0.593	0.000	0.094	0.189	0003	0003	0003
1076	0.262	0.236	0.000	0.000	0.000	0.593	0.000	0.094	0.236	0003	0003	0003
1077	0.308	0.236	0.000	0.000	0.000	0.593	0.000	0.142	0.047	0003	0003	0003
1078	0.282	0.236	0.000	0.000	0.000	0.593	0.000	0.142	0.094	0003	0003	0003
1079	0.267	0.236	0.000	0.000	0.000	0.593	0.000	0.142	0.142	0003	0003	0003
1080	0.253	0.236	0.000	0.000	0.000	0.593	0.000	0.142	0.189	0003	0003	0003
1081	0.286	0.236	0.000	0.000	0.000	0.593	0.000	0.189	0.047	0003	0003	0003
1082	0.269	0.236	0.000	0.000	0.000	0.593	0.000	0.189	0.094	0003	0003	0003
1083	0.259	0.236	0.000	0.000	0.000	0.593	0.000	0.189	0.142	0003	0003	0003
1084	0.282	0.236	0.000	0.000	0.000	0.593	0.000	0.236	0.047	0003	0003	0003
1085	0.269	0.236	0.000	0.000	0.000	0.593	0.000	0.236	0.094	0003	0003	0003
1086	0.257	0.236	0.000	0.000	0.000	0.593	0.000	0.236	0.142	0003	0003	0003
1087	0.420	0.236	0.000	0.000	0.000	0.593	0.047	0.047	0.047	0003	0003	0003
1088	0.329	0.236	0.000	0.000	0.000	0.593	0.047	0.047	0.094	0003	0003	0003
1089	0.289	0.236	0.000	0.000	0.000	0.593	0.047	0.047	0.142	0003	0003	0003
1090	0.270	0.236	0.000	0.000	0.000	0.593	0.047	0.047	0.189	0003	0003	0003

RICHARD I DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	B	C	REMARKS A	B	C
1091	0.267	0.236	0.000	0.000	0.000	0.593	0.047	0.047	0.236	0003	0003	0003
1092	0.344	0.236	0.000	0.000	0.000	0.593	0.047	0.094	0.047	0003	0003	0003
1093	0.305	0.236	0.000	0.000	0.000	0.593	0.047	0.094	0.094	0003	0003	0003
1094	0.277	0.236	0.000	0.000	0.000	0.593	0.047	0.094	0.142	0003	0003	0003
1095	0.296	0.236	0.000	0.000	0.000	0.593	0.047	0.142	0.047	0003	0003	0003
1096	0.276	0.236	0.000	0.000	0.000	0.593	0.047	0.142	0.094	0003	0003	0003
1097	0.262	0.236	0.000	0.000	0.000	0.593	0.047	0.142	0.142	0003	0003	0003
1098	0.268	0.236	0.000	0.000	0.000	0.593	0.047	0.189	0.047	0003	0003	0003
1099	0.258	0.236	0.000	0.000	0.000	0.593	0.047	0.189	0.094	0003	0003	0003
1100	0.267	0.236	0.000	0.000	0.000	0.593	0.047	0.236	0.047	0003	0003	0003
1101	0.257	0.236	0.000	0.000	0.000	0.593	0.047	0.236	0.094	0003	0003	0003
1102	0.299	0.236	0.000	0.000	0.000	0.593	0.094	0.047	0.094	0003	0003	0003
1103	0.275	0.236	0.000	0.000	0.000	0.593	0.094	0.047	0.142	0003	0003	0003
1104	0.258	0.236	0.000	0.000	0.000	0.593	0.094	0.047	0.189	0003	0003	0003
1105	0.279	0.236	0.000	0.000	0.000	0.593	0.094	0.094	0.094	0003	0003	0003
1106	0.266	0.236	0.000	0.000	0.000	0.593	0.094	0.142	0.094	0003	0003	0003
1107	0.266	0.236	0.000	0.000	0.000	0.593	0.094	0.094	0.142	0003	0003	0003
1108	0.257	0.236	0.000	0.000	0.000	0.593	0.094	0.142	0.142	0003	0003	0003
1109	0.257	0.236	0.000	0.000	0.000	0.593	0.142	0.000	0.142	0003	0003	0003
1110	0.267	0.236	0.000	0.000	0.000	0.593	0.142	0.047	0.142	0003	0003	0003
1111	0.258	0.236	0.000	0.000	0.000	0.593	0.142	0.094	0.142	0003	0003	0003
1112	0.274	0.236	0.000	0.000	0.000	0.593	0.189	0.000	0.094	0003	0003	0003
1113	0.262	0.236	0.000	0.000	0.000	0.593	0.189	0.000	0.142	0003	0003	0003
1114	0.271	0.236	0.000	0.000	0.000	0.593	0.236	0.000	0.094	0003	0003	0003
1114	0.643	0.236	0.000	0.000	0.000	0.593	0.047	0.000	0.047	0003	0003	0003
1115	0.404	0.236	0.000	0.000	0.000	0.593	0.047	0.000	0.094	0003	0003	0003
1116	0.320	0.236	0.000	0.000	0.000	0.593	0.047	0.000	0.142	0003	0003	0003
1117	0.291	0.236	0.000	0.000	0.000	0.593	0.047	0.000	0.189	0003	0003	0003
1118	0.285	0.236	0.000	0.000	0.000	0.593	0.047	0.000	0.236	0003	0003	0003
1119	0.285	0.236	0.000	0.000	0.000	0.593	0.047	0.000	0.283	0003	0003	0003

RICHARD I DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
1120	0.333	0.236	0.000	0.000	0.000	0.593	0.094	0.000	0.094	0003	0003	0003
1121	0.290	0.236	0.000	0.000	0.000	0.593	0.094	0.000	0.142	0003	0003	0003
1122	0.259	0.236	0.000	0.000	0.000	0.593	0.047	0.094	0.189	0003	0003	0003
1123	0.742	0.135	0.067	0.067	0.011	0.593	0.000	0.000	0.047	0003	0003	0003
1124	0.636	0.135	0.000	0.000	0.000	0.593	0.000	0.000	0.094	0003	0003	0003
1125	0.384	0.135	0.000	0.000	0.000	0.593	0.000	0.000	0.142	0003	0003	0003
1126	0.305	0.135	0.000	0.000	0.000	0.593	0.000	0.000	0.189	0003	0003	0003
1127	0.287	0.135	0.000	0.000	0.000	0.593	0.000	0.000	0.236	0003	0003	0003
1128	0.745	0.135	0.070	0.014	0.070	0.593	0.000	0.047	0.000	0003	0003	0003
1129	0.645	0.135	0.000	0.000	0.000	0.593	0.000	0.094	0.000	0003	0003	0003
1130	0.394	0.135	0.000	0.000	0.000	0.593	0.000	0.142	0.000	0003	0003	0003
1131	0.300	0.135	0.000	0.000	0.000	0.593	0.000	0.189	0.000	0003	0003	0003
1132	0.286	0.135	0.000	0.000	0.000	0.593	0.000	0.236	0.000	0003	0003	0003
1133	0.509	0.135	0.000	0.000	0.000	0.593	0.000	0.047	0.047	0003	0003	0003
1134	0.301	0.135	0.000	0.000	0.000	0.593	0.000	0.047	0.094	0003	0003	0003
1135	0.308	0.135	0.000	0.000	0.000	0.593	0.000	0.094	0.047	0003	0003	0003
1136	0.593	0.135	0.000	0.000	0.000	0.593	0.047	0.000	0.047	0003	0003	0003
1137	0.322	0.135	0.000	0.000	0.000	0.593	0.047	0.000	0.094	0003	0003	0003
1138	0.292	0.135	0.000	0.000	0.000	0.593	0.047	0.047	0.047	0003	0003	0003
1139	0.755	0.371	0.080	0.080	0.024	0.593	0.000	0.000	0.047	0003	0003	0003
1140	0.692	0.371	0.017	0.017	0.000	0.593	0.000	0.000	0.094	0003	0003	0003
1141	0.554	0.371	0.000	0.000	0.000	0.593	0.000	0.000	0.142	0003	0003	0003

VIII. APPENDIX B, RICHARD II LABORATORY DATA

Legend:

RUN, number of test

WSU, water surface elevation above sill of gate, upstream, in feet

WSD, water surface elevation above sill of gate, downstream, in feet

HGA, head above top of gate A, in feet

HGB, head above top of gate B, in feet

GHC, head above top of gate C, in feet

Q, discharge, in cfs

GATE OPENING A, in feet

GATE OPENING B, in feet

GATE OPENING C, in feet

REMARKS A (*)

REMARKS B (*)

REMARKS C (*)

(*) 0001, Condition I, stilling basin ineffective, wavy surface

0002, Condition II, stilling basin effective

0003, Jet from underflow unsubmerged

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
1	0.975	-0.838	0.300	0.300	0.300	2.620	0.000	0.000	0.000	0003	0003	0003
2	0.928	-0.838	0.253	0.253	0.253	2.000	0.000	0.000	0.000	0003	0003	0003
3	0.899	-0.838	0.224	0.224	0.224	1.640	0.000	0.000	0.000	0003	0003	0003
4	0.858	-0.838	0.183	0.183	0.183	1.200	0.000	0.000	0.000	0003	0003	0003
5	0.829	-0.838	0.154	0.154	0.154	0.933	0.000	0.000	0.000	0003	0003	0003
6	0.790	-0.838	0.115	0.115	0.115	0.608	0.000	0.000	0.000	0003	0003	0003
7	0.767	-0.838	0.092	0.092	0.092	0.448	0.000	0.000	0.000	0003	0003	0003
8	0.743	-0.838	0.068	0.068	0.068	0.315	0.000	0.000	0.000	0003	0003	0003
9	0.713	-0.838	0.038	0.038	0.038	0.160	0.000	0.000	0.000	0003	0003	0003
10	0.467	0.118	0.000	0.000	0.000	0.293	0.000	0.000	0.047	0003	0003	0003
11	0.198	0.118	0.000	0.000	0.000	0.293	0.000	0.047	0.047	0003	0003	0003
12	0.209	0.118	0.000	0.000	0.000	0.293	0.047	0.000	0.047	0003	0003	0003
13	0.162	0.118	0.000	0.000	0.000	0.293	0.047	0.047	0.047	0003	0003	0003
14	0.208	0.118	0.000	0.000	0.000	0.293	0.000	0.000	0.094	0003	0003	0003
15	0.143	0.118	0.000	0.000	0.000	0.293	0.000	0.094	0.094	0003	0003	0003
16	0.143	0.118	0.000	0.000	0.000	0.293	0.094	0.000	0.094	0003	0003	0003
17	0.191	0.118	0.000	0.000	0.000	0.293	0.000	0.000	0.142	0003	0003	0003
18	0.155	0.118	0.000	0.000	0.000	0.293	0.000	0.047	0.094	0003	0003	0003
19	0.159	0.118	0.000	0.000	0.000	0.293	0.047	0.000	0.094	0003	0003	0003
20	0.746	0.160	0.071	0.071	0.015	0.599	0.000	0.000	0.047	0003	0003	0003
21	0.747	0.160	0.072	0.016	0.072	0.599	0.000	0.047	0.000	0003	0003	0003
22	0.489	0.160	0.000	0.000	0.000	0.599	0.000	0.047	0.047	0003	0003	0003
23	0.492	0.160	0.000	0.000	0.000	0.599	0.047	0.000	0.047	0003	0003	0003
24	0.310	0.160	0.000	0.000	0.000	0.599	0.047	0.047	0.047	0003	0003	0003
25	0.602	0.160	0.000	0.000	0.000	0.599	0.000	0.000	0.094	0003	0003	0003
26	0.588	0.160	0.000	0.000	0.000	0.599	0.000	0.094	0.000	0003	0003	0003
27	0.372	0.160	0.000	0.000	0.000	0.599	0.000	0.000	0.142	0003	0003	0003
28	0.370	0.160	0.000	0.000	0.000	0.599	0.000	0.142	0.000	0003	0003	0003
29	0.311	0.160	0.000	0.000	0.000	0.599	0.000	0.189	0.000	0003	0003	0003
30	0.310	0.160	0.000	0.000	0.000	0.599	0.000	0.000	0.189	0003	0003	0003

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
31	0.304	0.160	0.000	0.000	0.000	0.599	0.000	0.094	0.047	0003	0003	0003
32	0.297	0.160	0.000	0.000	0.000	0.599	0.000	0.047	0.094	0003	0003	0003
33	0.309	0.160	0.000	0.000	0.000	0.599	0.047	0.000	0.094	0003	0003	0003
34	0.258	0.160	0.000	0.000	0.000	0.599	0.047	0.000	0.142	0003	0003	0003
35	0.764	0.392	0.033	0.089	0.089	0.599	0.047	0.000	0.000	0003	0003	0003
36	0.764	0.392	0.089	0.033	0.089	0.599	0.000	0.047	0.000	0003	0003	0003
37	0.594	0.392	0.000	0.000	0.000	0.599	0.047	0.047	0.047	0001	0002	0002
38	0.725	0.392	0.000	0.050	0.000	0.599	0.047	0.000	0.047	0001	0003	0001
39	0.733	0.392	0.002	0.058	0.002	0.599	0.047	0.000	0.047	0002	0003	0002
40	0.714	0.392	0.039	0.039	0.000	0.599	0.000	0.000	0.094	0003	0003	0002
41	0.705	0.392	0.030	0.030	0.000	0.599	0.000	0.000	0.094	0003	0003	0001
42	0.502	0.392	0.000	0.000	0.000	0.599	0.000	0.094	0.094	0003	0001	0001
43	0.506	0.392	0.000	0.000	0.000	0.599	0.094	0.000	0.094	0001	0003	0001
44	0.520	0.392	0.000	0.000	0.000	0.599	0.094	0.000	0.094	0002	0003	0002
45	0.451	0.392	0.000	0.000	0.000	0.599	0.094	0.094	0.094	0002	0002	0002
46	0.443	0.392	0.000	0.000	0.000	0.599	0.094	0.094	0.094	0001	0001	0001
47	0.715	0.392	0.040	0.000	0.040	0.599	0.000	0.094	0.000	0003	0002	0003
48	0.706	0.392	0.031	0.000	0.031	0.599	0.000	0.094	0.000	0003	0001	0003
49	0.577	0.392	0.000	0.000	0.000	0.599	0.000	0.000	0.142	0003	0003	0001
50	0.590	0.392	0.000	0.000	0.000	0.599	0.000	0.142	0.000	0003	0001	0003
51	0.400	0.392	0.000	0.000	0.000	0.599	0.000	0.142	0.142	0003	0002	0001
52	0.414	0.392	0.000	0.000	0.000	0.599	0.142	0.142	0.142	0003	0002	0001
53	0.445	0.392	0.000	0.000	0.000	0.599	0.142	0.000	0.142	0003	0003	0001
54	0.501	0.392	0.000	0.000	0.000	0.599	0.000	0.000	0.189	0003	0003	0001
55	0.421	0.392	0.000	0.000	0.000	0.599	0.000	0.189	0.189	0003	0003	0001
56	0.510	0.392	0.000	0.000	0.000	0.599	0.000	0.189	0.000	0003	0001	0003
57	0.407	0.392	0.000	0.000	0.000	0.599	0.189	0.189	0.189	0003	0001	0003
58	0.424	0.392	0.000	0.000	0.000	0.599	0.189	0.000	0.189	0003	0003	0003
59	0.466	0.392	0.000	0.000	0.000	0.599	0.000	0.000	0.236	0003	0003	0001
60	0.413	0.392	0.000	0.000	0.000	0.599	0.000	0.236	0.236	0003	0003	0001

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
61	0.404	0.392	0.000	0.000	0.000	0.599	0.236	0.236	0.236	0003	0003	0001
62	0.411	0.392	0.000	0.000	0.000	0.599	0.236	0.000	0.236	0003	0003	0001
63	0.468	0.392	0.000	0.000	0.000	0.599	0.000	0.236	0.000	0003	0001	0003
64	0.446	0.392	0.000	0.000	0.000	0.599	0.000	0.000	0.283	0003	0003	0001
65	0.448	0.392	0.000	0.000	0.000	0.599	0.000	0.283	0.000	0003	0003	0003
66	0.407	0.392	0.000	0.000	0.000	0.599	0.000	0.283	0.283	0003	0002	0002
67	0.400	0.392	0.000	0.000	0.000	0.599	0.283	0.283	0.283	0003	0002	0002
68	0.407	0.392	0.000	0.000	0.000	0.599	0.283	0.000	0.283	0003	0003	0002
69	0.439	0.392	0.000	0.000	0.000	0.599	0.000	0.000	0.330	0003	0003	0002
70	0.404	0.392	0.000	0.000	0.000	0.599	0.000	0.330	0.330	0003	0003	0002
71	0.435	0.392	0.000	0.000	0.000	0.599	0.000	0.330	0.000	0003	0003	0003
72	0.399	0.392	0.000	0.000	0.000	0.599	0.330	0.330	0.330	0003	0003	0003
73	0.405	0.392	0.000	0.000	0.000	0.599	0.330	0.000	0.330	0003	0003	0003
74	0.433	0.392	0.000	0.000	0.000	0.599	0.000	0.000	0.377	0003	0003	0003
75	0.403	0.392	0.000	0.000	0.000	0.599	0.000	0.377	0.377	0003	0003	0003
76	0.428	0.392	0.000	0.000	0.000	0.599	0.000	0.377	0.000	0003	0003	0003
77	0.400	0.392	0.000	0.000	0.000	0.599	0.377	0.377	0.377	0003	0003	0003
78	0.405	0.392	0.000	0.000	0.000	0.599	0.377	0.000	0.377	0003	0003	0003
79	0.430	0.392	0.000	0.000	0.000	0.599	0.000	0.000	0.425	0003	0003	0003
80	0.403	0.392	0.000	0.000	0.000	0.599	0.000	0.425	0.425	0003	0003	0003
81	0.398	0.392	0.000	0.000	0.000	0.599	0.425	0.425	0.425	0003	0003	0003
82	0.798	0.194	0.123	0.123	0.067	0.900	0.000	0.000	0.047	0003	0003	0003
83	0.760	0.194	0.085	0.029	0.029	0.900	0.000	0.047	0.047	0003	0003	0003
84	0.799	0.194	0.124	0.068	0.124	0.900	0.000	0.047	0.000	0003	0003	0003
85	0.522	0.194	0.000	0.000	0.000	0.900	0.047	0.047	0.047	0003	0003	0003
86	0.759	0.194	0.028	0.084	0.028	0.900	0.047	0.000	0.047	0003	0003	0003
87	0.810	0.341	0.135	0.135	0.079	0.902	0.000	0.000	0.047	0003	0003	0002
88	0.806	0.341	0.131	0.131	0.075	0.902	0.000	0.000	0.047	0003	0003	0001
89	0.787	0.341	0.112	0.056	0.056	0.902	0.000	0.047	0.047	0003	0002	0002
90	0.781	0.341	0.106	0.050	0.050	0.902	0.000	0.047	0.047	0003	0001	0001

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
91	0.806	0.341	0.131	0.075	0.131	0.902	0.000	0.047	0.000	0003	0001	0003
92	0.809	0.341	0.134	0.078	0.134	0.902	0.000	0.047	0.000	0003	0002	0003
93	0.757	0.341	0.026	0.026	0.026	0.902	0.047	0.047	0.047	0002	0002	0002
94	0.743	0.341	0.012	0.012	0.012	0.902	0.047	0.047	0.047	0001	0001	0001
95	0.788	0.341	0.057	0.113	0.057	0.902	0.047	0.000	0.047	0002	0003	0002
96	0.782	0.341	0.051	0.107	0.051	0.902	0.047	0.000	0.047	0001	0003	0001
97	0.763	0.341	0.088	0.088	0.000	0.902	0.000	0.000	0.094	0003	0003	0001
98	0.604	0.341	0.000	0.000	0.000	0.902	0.000	0.094	0.094	0003	0001	0002
99	0.575	0.341	0.000	0.000	0.000	0.902	0.000	0.094	0.094	0003	0001	0001
100	0.764	0.341	0.089	0.000	0.089	0.902	0.000	0.094	0.000	0003	0001	0003
101	0.777	0.341	0.102	0.000	0.102	0.902	0.000	0.094	0.000	0002	0003	0003
102	0.472	0.341	0.000	0.000	0.000	0.902	0.094	0.094	0.094	0002	0002	0002
103	0.448	0.341	0.000	0.000	0.000	0.902	0.094	0.094	0.094	0001	0001	0001
104	0.576	0.341	0.000	0.000	0.000	0.902	0.094	0.000	0.094	0001	0003	0001
105	0.683	0.341	0.008	0.008	0.000	0.902	0.000	0.000	0.142	0003	0003	0003
106	0.447	0.341	0.000	0.000	0.000	0.902	0.000	0.142	0.142	0003	0001	0001
107	0.686	0.341	0.011	0.000	0.011	0.902	0.000	0.142	0.000	0003	0003	0003
108	0.394	0.341	0.000	0.000	0.000	0.902	0.142	0.142	0.142	0003	0003	0003
109	0.457	0.341	0.000	0.000	0.000	0.902	0.142	0.000	0.142	0003	0003	0003
110	0.531	0.341	0.000	0.000	0.000	0.902	0.000	0.000	0.189	0003	0003	0003
111	0.402	0.341	0.000	0.000	0.000	0.902	0.000	0.189	0.189	0003	0003	0003
112	0.541	0.341	0.000	0.000	0.000	0.902	0.000	0.189	0.000	0003	0003	0003
113	0.372	0.341	0.000	0.000	0.000	0.902	0.189	0.189	0.189	0003	0003	0003
114	0.407	0.341	0.000	0.000	0.000	0.902	0.189	0.000	0.189	0003	0003	0003
115	0.469	0.341	0.000	0.000	0.000	0.902	0.000	0.000	0.236	0003	0003	0003
116	0.384	0.341	0.000	0.000	0.000	0.902	0.000	0.236	0.236	0003	0003	0003
117	0.381	0.341	0.000	0.000	0.000	0.902	0.000	0.236	0.000	0003	0003	0003
118	0.383	0.341	0.000	0.000	0.000	0.902	0.236	0.000	0.236	0003	0003	0003
119	0.453	0.341	0.000	0.000	0.000	0.902	0.000	0.000	0.283	0003	0003	0003
120	0.372	0.341	0.000	0.000	0.000	0.902	0.000	0.283	0.283	0003	0003	0003

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
121	0.440	0.341	0.000	0.000	0.000	0.902	0.000	0.283	0.000	0003	0003	0003
122	0.372	0.341	0.000	0.000	0.000	0.902	0.283	0.000	0.283	0003	0003	0003
123	0.444	0.341	0.000	0.000	0.000	0.902	0.000	0.000	0.330	0003	0003	0003
124	0.435	0.341	0.000	0.000	0.000	0.902	0.000	0.330	0.000	0003	0003	0003
125	0.439	0.341	0.000	0.000	0.000	0.902	0.000	0.000	0.377	0003	0003	0003
126	0.430	0.341	0.000	0.000	0.000	0.902	0.000	0.377	0.000	0003	0003	0003
127	0.822	0.590	0.147	0.147	0.091	0.902	0.000	0.000	0.047	0003	0003	0003
128	0.815	0.590	0.140	0.084	0.084	0.902	0.000	0.047	0.047	0003	0003	0003
129	0.821	0.590	0.146	0.090	0.146	0.902	0.000	0.047	0.000	0003	0003	0003
130	0.809	0.590	0.078	0.078	0.078	0.902	0.047	0.047	0.047	0003	0003	0003
131	0.816	0.590	0.085	0.141	0.085	0.902	0.047	0.000	0.047	0003	0003	0003
132	0.808	0.590	0.133	0.133	0.021	0.902	0.000	0.000	0.094	0003	0003	0003
133	0.777	0.590	0.102	0.000	0.000	0.902	0.000	0.094	0.094	0003	0003	0003
134	0.808	0.590	0.133	0.021	0.133	0.902	0.000	0.094	0.000	0003	0003	0003
135	0.719	0.590	0.000	0.000	0.000	0.902	0.094	0.094	0.094	0003	0003	0003
136	0.781	0.590	0.000	0.106	0.000	0.902	0.094	0.000	0.094	0003	0003	0003
137	0.781	0.590	0.106	0.106	0.000	0.902	0.000	0.000	0.142	0003	0003	0003
138	0.706	0.590	0.031	0.000	0.000	0.902	0.000	0.142	0.142	0003	0003	0003
139	0.781	0.590	0.106	0.000	0.106	0.902	0.000	0.142	0.000	0003	0003	0003
140	0.650	0.590	0.000	0.000	0.000	0.902	0.142	0.142	0.142	0003	0003	0003
141	0.713	0.590	0.000	0.038	0.000	0.902	0.142	0.000	0.142	0003	0003	0003
142	0.755	0.590	0.080	0.080	0.000	0.902	0.000	0.000	0.189	0003	0003	0003
143	0.665	0.590	0.000	0.000	0.000	0.902	0.000	0.189	0.189	0003	0003	0003
144	0.757	0.590	0.082	0.000	0.082	0.902	0.000	0.189	0.000	0003	0003	0003
145	0.625	0.590	0.000	0.000	0.000	0.902	0.189	0.189	0.189	0003	0003	0003
146	0.668	0.590	0.000	0.000	0.000	0.902	0.189	0.000	0.189	0003	0003	0003
147	0.729	0.590	0.054	0.054	0.000	0.902	0.000	0.000	0.236	0003	0003	0003
148	0.640	0.590	0.000	0.000	0.000	0.902	0.000	0.236	0.236	0003	0003	0003
149	0.733	0.590	0.058	0.000	0.058	0.902	0.000	0.236	0.000	0003	0003	0003
150	0.615	0.590	0.000	0.000	0.000	0.902	0.236	0.236	0.236	0003	0003	0003

RICHARD II DATA

							GATE OPENING			REMARKS		
RUN	WSU	WSD	HGA	HGB	HGC	Q	A	B	C	A	B	C
151	0.654	0.590	0.000	0.000	0.000	0.902	0.236	0.000	0.236	0003	0003	0003
152	0.706	0.590	0.031	0.031	0.000	0.902	0.000	0.000	0.283	0003	0003	0003
153	0.625	0.590	0.000	0.000	0.000	0.902	0.000	0.283	0.283	0003	0003	0003
154	0.713	0.590	0.038	0.000	0.038	0.902	0.000	0.283	0.000	0003	0003	0003
155	0.607	0.590	0.000	0.000	0.000	0.902	0.283	0.283	0.283	0003	0003	0003
156	0.626	0.590	0.000	0.000	0.000	0.902	0.283	0.000	0.283	0003	0003	0003
157	0.687	0.590	0.012	0.000	0.000	0.902	0.000	0.330	0.330	0003	0003	0003
158	0.616	0.590	0.000	0.000	0.000	0.902	0.000	0.330	0.330	0003	0003	0003
159	0.695	0.590	0.020	0.000	0.020	0.902	0.000	0.330	0.000	0003	0003	0003
160	0.599	0.590	0.000	0.000	0.000	0.902	0.330	0.330	0.330	0003	0003	0003
161	0.613	0.590	0.000	0.000	0.000	0.902	0.330	0.000	0.330	0003	0003	0003
162	0.670	0.590	0.000	0.000	0.000	0.902	0.000	0.000	0.377	0003	0003	0003
163	0.608	0.590	0.000	0.000	0.000	0.902	0.000	0.377	0.377	0003	0003	0003
164	0.676	0.590	0.001	0.000	0.001	0.902	0.000	0.377	0.000	0003	0003	0003
165	0.598	0.590	0.000	0.000	0.000	0.902	0.377	0.377	0.377	0003	0003	0003
166	0.611	0.590	0.000	0.000	0.000	0.902	0.377	0.000	0.377	0003	0003	0003
167	0.657	0.590	0.000	0.000	0.000	0.902	0.000	0.000	0.425	0003	0003	0003
168	0.605	0.590	0.000	0.000	0.000	0.902	0.000	0.425	0.425	0003	0003	0003
169	0.660	0.590	0.000	0.000	0.000	0.902	0.000	0.425	0.000	0003	0003	0003
170	0.598	0.590	0.000	0.000	0.000	0.902	0.425	0.425	0.425	0003	0003	0003
171	0.607	0.590	0.000	0.000	0.000	0.902	0.425	0.000	0.425	0003	0003	0003
172	0.642	0.590	0.000	0.000	0.000	0.902	0.000	0.000	0.472	0003	0003	0003
173	0.604	0.590	0.000	0.000	0.000	0.902	0.000	0.472	0.472	0003	0003	0003
174	0.641	0.590	0.000	0.000	0.000	0.902	0.000	0.472	0.000	0003	0003	0003
175	0.597	0.590	0.000	0.000	0.000	0.902	0.472	0.472	0.472	0003	0003	0003
176	0.604	0.590	0.000	0.000	0.000	0.902	0.472	0.000	0.472	0003	0003	0003
177	0.846	0.367	0.171	0.171	0.000	1.200	0.000	0.000	0.472	0003	0003	0003
178	0.826	0.367	0.151	0.095	0.095	1.200	0.000	0.047	0.047	0003	0003	0003
179	0.845	0.367	0.170	0.114	0.170	1.200	0.000	0.047	0.000	0003	0003	0003
180	0.812	0.367	0.081	0.081	0.081	1.200	0.047	0.047	0.047	0003	0003	0003

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
181	0.829	0.367	0.098	0.154	0.098	1.200	0.047	0.000	0.047	0003	0003	0003
182	0.817	0.367	0.142	0.142	0.030	1.200	0.000	0.000	0.094	0003	0003	0001
183	0.825	0.367	0.150	0.150	0.038	1.200	0.000	0.000	0.094	0003	0003	0002
184	0.741	0.367	0.066	0.000	0.000	1.200	0.000	0.094	0.094	0003	0001	0002
185	0.719	0.367	0.044	0.000	0.000	1.200	0.000	0.094	0.094	0003	0001	0001
186	0.818	0.367	0.143	0.031	0.143	1.200	0.000	0.094	0.000	0003	0001	0003
187	0.826	0.367	0.151	0.039	0.151	1.200	0.000	0.094	0.000	0003	0002	0003
188	0.557	0.367	0.000	0.000	0.000	1.200	0.094	0.094	0.094	0001	0001	0001
189	0.600	0.367	0.000	0.000	0.000	1.200	0.094	0.094	0.094	0002	0002	0002
190	0.748	0.367	0.000	0.073	0.000	1.200	0.094	0.000	0.094	0002	0003	0001
191	0.733	0.367	0.000	0.058	0.000	1.200	0.094	0.000	0.094	0001	0003	0001
192	0.769	0.367	0.094	0.094	0.000	1.200	0.000	0.000	0.142	0003	0003	0003
193	0.555	0.367	0.000	0.000	0.000	1.200	0.000	0.142	0.142	0003	0001	0001
194	0.758	0.367	0.083	0.000	0.083	1.200	0.000	0.142	0.000	0003	0003	0003
195	0.368	0.367	0.000	0.000	0.000	1.200	0.142	0.142	0.142	0001	0001	0001
196	0.559	0.367	0.000	0.000	0.000	1.200	0.142	0.000	0.142	0001	0003	0001
197	0.706	0.367	0:031	0.031	0.000	1.200	0.000	0.000	0.189	0003	0003	0003
198	0.706	0.367	0.031	0.000	0.031	1.200	0.000	0.189	0.000	0003	0003	0003
199	0.629	0.367	0.000	0.000	0.000	1.200	0.000	0.000	0.236	0003	0003	0003
200	0.619	0.367	0.000	0.000	0.000	1.200	0.000	0.236	0.000	0003	0003	0003
201	0.557	0.367	0.000	0.000	0.000	1.200	0.000	0.000	0.283	0003	0003	0003
202	0.559	0.367	0.000	0.000	0.000	1.200	0.000	0.283	0.000	0003	0003	0003
203	0.526	0.367	0.000	0.000	0.000	1.200	0.000	0.000	0.330	0003	0003	0003
204	0.511	0.367	0.000	0.000	0.000	1.200	0.000	0.330	0.000	0003	0003	0003
205	0.854	0.533	0.179	0.179	0.123	1.200	0.000	0.000	0.047	0003	0003	0003
206	0.846	0.533	0.171	0.115	0.115	1.200	0.000	0.047	0.047	0003	0003	0003
207	0.854	0.533	0.179	0.123	0.179	1.200	0.000	0.047	0.000	0003	0003	0003
208	0.857	0.533	0.126	0.126	0.126	1.200	0.047	0.047	0.047	0003	0003	0003
209	0.844	0.533	0.113	0.169	0.113	1.200	0.047	0.000	0.047	0003	0003	0003
210	0.840	0.533	0.165	0.165	0.053	1.200	0.000	0.000	0.094	0003	0003	0003

RICHARD II DATA

RUN	WSU	W.D	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
211	0.813	0.533	0.138	0.026	0.026	1.200	0.000	0.094	0.094	0003	0003	0003
212	0.841	0.533	0.166	0.054	0.166	1.200	0.000	0.094	0.000	0003	0003	0003
213	0.759	0.533	0.000	0.000	0.000	1.200	0.094	0.094	0.094	0003	0003	0003
214	0.817	0.533	0.030	0.142	0.030	1.200	0.094	0.000	0.094	0003	0003	0003
215	0.817	0.533	0.142	0.142	0.000	1.200	0.000	0.000	0.142	0003	0003	0003
216	0.731	0.533	0.056	0.000	0.000	1.200	0.000	0.142	0.142	0003	0003	0003
217	0.819	0.533	0.144	0.000	0.144	1.200	0.000	0.142	0.000	0003	0003	0003
218	0.640	0.533	0.000	0.000	0.000	1.200	0.142	0.142	0.142	0003	0003	0003
219	0.741	0.533	0.000	0.066	0.000	1.200	0.142	0.000	0.142	0003	0003	0003
220	0.786	0.533	0.111	0.111	0.000	1.200	0.000	0.000	0.189	0003	0003	0003
221	0.662	0.533	0.000	0.000	0.000	1.200	0.000	0.189	0.189	0003	0003	0003
222	0.789	0.533	0.114	0.000	0.114	1.200	0.000	0.189	0.000	0003	0003	0003
223	0.594	0.533	0.000	0.000	0.000	1.200	0.189	0.189	0.189	0003	0003	0003
224	0.669	0.533	0.000	0.000	0.000	1.200	0.189	0.000	0.189	0003	0003	0003
225	0.753	0.533	0.078	0.078	0.000	1.200	0.000	0.000	0.236	0003	0003	0003
226	0.617	0.533	0.000	0.000	0.000	1.200	0.000	0.236	0.236	0003	0003	0003
227	0.759	0.533	0.084	0.000	0.084	1.200	0.000	0.236	0.000	0003	0003	0003
228	0.572	0.533	0.000	0.000	0.000	1.200	0.236	0.236	0.236	0002	0001	0002
229	0.576	0.533	0.000	0.000	0.000	1.200	0.236	0.236	0.236	0002	0002	0002
230	0.621	0.533	0.000	0.000	0.000	1.200	0.236	0.000	0.236	0002	0003	0002
231	0.724	0.533	0.049	0.049	0.000	1.200	0.000	0.000	0.283	0003	0003	0002
232	0.594	0.533	0.000	0.000	0.000	1.200	0.000	0.283	0.283	0003	0003	0002
233	0.735	0.533	0.060	0.000	0.060	1.200	0.000	0.283	0.000	0003	0003	0003
234	0.560	0.533	0.000	0.000	0.000	1.200	0.283	0.283	0.283	0002	0002	0002
235	0.563	0.533	0.000	0.000	0.000	1.200	0.283	0.283	0.283	0002	0001	0002
236	0.596	0.533	0.000	0.000	0.000	1.200	0.283	0.000	0.283	0002	0003	0002
237	0.695	0.533	0.020	0.020	0.000	1.200	0.000	0.000	0.330	0003	0003	0002
238	0.578	0.533	0.000	0.000	0.000	1.200	0.000	0.330	0.330	0003	0003	0002
239	0.708	0.533	0.033	0.000	0.033	1.200	0.000	0.330	0.000	0003	0003	0003
240	0.551	0.533	0.000	0.000	0.000	1.200	0.330	0.330	0.330	0003	0003	0003

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	B	C	REMARKS A	B	C
241	0.580	0.533	0.000	0.000	0.000	1.200	0.330	0.000	0.330	0003	0003	0003
242	0.671	0.533	0.000	0.000	0.000	1.200	0.000	0.000	0.377	0003	0003	0003
243	0.567	0.533	0.000	0.000	0.000	1.200	0.000	0.377	0.377	0003	0003	0003
244	0.682	0.533	0.007	0.000	0.007	1.200	0.000	0.377	0.000	0003	0003	0003
245	0.549	0.533	0.000	0.000	0.000	1.200	0.377	0.377	0.377	0003	0003	0003
246	0.567	0.533	0.000	0.000	0.000	1.200	0.377	0.000	0.377	0003	0003	0003
247	0.643	0.533	0.000	0.000	0.000	1.200	0.000	0.000	0.425	0003	0003	0003
248	0.558	0.533	0.000	0.000	0.000	1.200	0.000	0.425	0.425	0003	0003	0003
249	0.633	0.533	0.000	0.000	0.000	1.200	0.000	0.425	0.000	0003	0003	0003
250	0.549	0.533	0.000	0.000	0.000	1.200	0.425	0.425	0.425	0003	0003	0003
251	0.567	0.533	0.000	0.000	0.000	1.200	0.425	0.000	0.425	0003	0003	0003
252	0.905	0.855	0.174	0.174	0.174	1.200	0.047	0.047	0.047	0003	0003	0003
253	0.915	0.855	0.128	0.128	0.128	1.200	0.094	0.094	0.094	0003	0003	0003
254	0.921	0.855	0.077	0.077	0.077	1.200	0.142	0.142	0.142	0003	0003	0003
255	0.920	0.855	0.020	0.020	0.020	1.200	0.189	0.189	0.189	0003	0003	0003
256	0.903	0.855	0.000	0.000	0.000	1.200	0.236	0.236	0.236	0003	0003	0003
257	0.892	0.855	0.000	0.000	0.000	1.200	0.283	0.283	0.283	0003	0003	0003
258	0.885	0.855	0.000	0.000	0.000	1.200	0.330	0.330	0.330	0003	0003	0003
259	0.880	0.855	0.000	0.000	0.000	1.200	0.377	0.377	0.377	0003	0003	0003
260	0.843	0.563	0.056	0.056	0.056	1.512	0.094	0.094	0.094	0003	0003	0003
261	0.656	0.563	0.000	0.000	0.000	1.512	0.189	0.189	0.189	0003	0003	0003
262	0.603	0.563	0.000	0.000	0.000	1.512	0.283	0.283	0.283	0003	0003	0003
263	0.581	0.563	0.000	0.000	0.000	1.512	0.377	0.377	0.377	0003	0003	0003
264	0.572	0.563	0.000	0.000	0.000	1.512	0.472	0.472	0.472	0003	0003	0003
265	0.927	0.856	0.252	0.252	0.252	1.512	0.000	0.000	0.000	0003	0003	0003
266	0.940	0.856	0.153	0.153	0.153	1.512	0.094	0.094	0.094	0003	0003	0003
267	0.946	0.856	0.046	0.046	0.046	1.512	0.189	0.189	0.189	0003	0003	0003
268	0.912	0.856	0.000	0.000	0.000	1.512	0.283	0.283	0.283	0003	0003	0003
269	0.893	0.856	0.000	0.000	0.000	1.512	0.377	0.377	0.377	0003	0003	0003
270	0.884	0.856	0.000	0.000	0.000	1.512	0.472	0.472	0.472	0003	0003	0003

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
271	0.894	0.725	0.219	0.219	0.219	1.512	0.000	0.000	0.000	0003	0003	0003
272	0.894	0.725	0.107	0.107	0.107	1.512	0.094	0.094	0.094	0003	0003	0003
273	0.823	0.725	0.000	0.000	0.000	1.512	0.189	0.189	0.189	0003	0003	0003
274	0.770	0.725	0.000	0.000	0.000	1.512	0.283	0.283	0.283	0003	0003	0003
275	0.751	0.725	0.000	0.000	0.000	1.512	0.377	0.377	0.377	0003	0003	0003
276	0.742	0.725	0.000	0.000	0.000	1.512	0.472	0.472	0.472	0003	0003	0003
277	0.906	0.592	0.119	0.119	0.119	1.999	0.094	0.094	0.094	0003	0003	0003
278	0.752	0.592	0.000	0.000	0.000	1.999	0.189	0.189	0.189	0003	0003	0003
279	0.661	0.592	0.000	0.000	0.000	1.999	0.283	0.283	0.283	0003	0003	0003
280	0.937	0.750	0.262	0.262	0.262	1.999	0.000	0.000	0.000	0003	0003	0003
281	0.944	0.750	0.157	0.157	0.157	1.999	0.094	0.094	0.094	0003	0003	0003
282	0.916	0.750	0.016	0.016	0.016	1.999	0.189	0.189	0.189	0003	0003	0003
283	0.830	0.750	0.000	0.000	0.000	1.999	0.283	0.283	0.283	0003	0003	0003
284	0.794	0.750	0.000	0.000	0.000	1.999	0.377	0.377	0.377	0003	0003	0003
285	0.778	0.750	0.000	0.000	0.000	1.999	0.472	0.472	0.472	0003	0003	0003
286	0.946	0.832	0.273	0.273	0.273	1.999	0.000	0.000	0.000	0003	0003	0003
287	0.965	0.832	0.178	0.178	0.178	1.999	0.094	0.094	0.094	0003	0003	0003
288	0.969	0.832	0.069	0.069	0.069	1.999	0.189	0.189	0.189	0003	0003	0003
289	0.914	0.832	0.000	0.000	0.000	1.999	0.283	0.283	0.283	0003	0003	0003
290	0.878	0.832	0.000	0.000	0.000	1.999	0.377	0.377	0.377	0003	0003	0003
291	0.864	0.832	0.000	0.000	0.000	1.999	0.472	0.472	0.472	0003	0003	0003
292	0.967	0.751	0.067	0.067	0.067	2.504	0.189	0.189	0.189	0003	0003	0003
293	0.984	0.751	0.197	0.197	0. 97	2.504	0.094	0.094	0.094	0003	0003	0003
294	0.878	0.751	0.000	0.000	0.000	2.504	0.283	0.283	0.283	0003	0003	0003
295	0.824	0.751	0.000	0.000	0.000	2.504	0.377	0.377	0.377	0003	0003	0003
296	0.805	0.751	0.000	0.000	0.000	2.504	0.472	0.472	0.472	0003	0003	0003
297	1.005	0.846	0.218	0.218	0.218	2.504	0.094	0.094	0.094	0003	0003	0003
298	1.009	0.846	0.109	0.109	0. 09	2.504	0.189	0.189	0.189	0003	0003	0003
299	0.967	0.846	0.000	0.000	0.000	2.504	0.283	0.283	0.283	0003	0003	0003
300	0.915	0.846	0.000	0.000	0.000	2.504	0.377	0.377	0.377	0003	0003	0003

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
301	0.890	0.846	0.000	0.000	0.000	2.504	0.472	0.472	0.472	0003	0003	0003
302	0.874	0.820	0.000	0.000	0.000	3.012	0.472	0.472	0.472	0003	0003	0003
303	0.914	0.820	0.000	0.000	0.000	3.012	0.377	0.377	0.377	0003	0003	0003
304	0.999	0.820	0.000	0.000	0.000	3.012	0.283	0.283	0.283	0003	0003	0003
305	1.034	0.820	0.134	0.134	0.134	3.012	0.189	0.189	0.189	0003	0003	0003
306	1.032	0.820	0.245	0.245	0.245	3.012	0.094	0.094	0.094	0003	0003	0003
307	1.016	0.820	0.341	0.341	0.341	3.012	0.000	0.000	0.000	0003	0003	0003
308	0.318	0.316	0.000	0.000	0.000	0.594	0.942	0.942	0.942	0003	0003	0003
309	0.671	0.670	0.000	0.000	0.000	0.905	0.942	0.942	0.942	0003	0003	0003
310	0.857	0.855	0.000	0.000	0.000	1.196	0.942	0.942	0.942	0003	0003	0003
311	0.844	0.842	0.000	0.000	0.000	1.511	0.942	0.942	0.942	0003	0003	0003
312	0.823	0.819	0.000	0.000	0.000	1.976	0.942	0.942	0.942	0003	0003	0003
313	0.837	0.835	0.000	0.000	0.000	2.516	0.942	0.942	0.942	0003	0003	0003
314	0.870	0.864	0.000	0.000	0.000	2.988	0.942	0.942	0.942	0003	0003	0003
315	0.843	0.836	0.000	0.000	0.000	3.529	0.942	0.942	0.942	0003	0003	0003
316	0.811	0.802	0.000	0.000	0.000	4.460	0.942	0.942	0.942	0003	0003	0003
317	0.788	0.776	0.000	0.000	0.000	3.933	0.942	0.942	0.942	0003	0003	0003
318	0.386	0.334	0.000	0.000	0.000	0.298	0.000	0.142	0.000	0003	0003	0003
319	0.365	0.334	0.000	0.000	0.000	0.298	0.000	0.189	0.000	0003	0003	0003
320	0.447	0.351	0.000	0.000	0.000	0.517	0.000	0.189	0.000	0003	0003	0003
321	0.418	0.351	0.000	0.000	0.000	0.517	0.000	0.236	0.000	0003	0003	0003
322	0.485	0.440	0.000	0.000	0.000	0.440	0.000	0.236	0.000	0003	0003	0003
323	0.507	0.440	0.000	0.000	0.000	0.440	0.000	0.189	0.000	0003	0003	0003
324	0.519	0.420	0.000	0.000	0.000	0.273	0.000	0.094	0.000	0003	0003	0003
325	0.468	0.420	0.000	0.000	0.000	0.273	0.000	0.142	0.000	0003	0003	0003
326	0.449	0.420	0.000	0.000	0.000	0.273	0.000	0.189	0.000	0003	0003	0003
327	0.441	0.420	0.000	0.000	0.000	0.273	0.000	0.236	0.000	0003	0003	0003
328	0.481	0.414	0.000	0.000	0.000	0.217	0.000	0.094	0.000	0003	0003	0003
329	0.476	0.414	0.000	0.000	0.000	0.217	0.000	0.094	0.000	0003	0003	0003
330	0.438	0.405	0.000	0.000	0.000	0.212	0.000	0.142	0.000	0003	0003	0003

RICHARD II DATA

RUN	WSU	WSD	HGA	HGB	HGC	Q	GATE OPENING A	GATE OPENING B	GATE OPENING C	REMARKS A	REMARKS B	REMARKS C
331	0.472	0.434	0.000	0.000	0.000	0.275	0.000	0.142	0.000	0003	0003	0003
332	0.466	0.434	0.000	0.000	0.000	0.275	0.000	0.142	0.000	0003	0003	0003

IX. APPENDIX C, HERMAN LABORATORY DATA

Legend:

RUN, number of test

WSU, water surface elevation above sill of gate, upstream, in feet

WSD, water surface elevation above sill of gate, downstream, in feet

HG, head above top of gate, in feet

GATE, gate opening, in feet

Q, discharge, in cfs

REMARKS (*)

(*) 000001, Condition I, stilling basin ineffective, wavy surface

000002, Condition II, stilling basin effective

000003, Jet from underflow unsubmerged

HERMAN, DATA

RUN	WSU	WSD	HG	GATE	Q	REMARKS
1	1.109	-0.147	0.621	0.000	2.680	000003
2	1.062	-0.147	0.574	0.000	2.397	000003
3	1.019	-0.147	0.531	0.000	2.111	000003
4	0.967	-0.147	0.479	0.000	1.775	000003
5	0.927	-0.147	0.439	0.000	1.531	000003
6	0.865	-0.147	0.377	0.000	1.181	000003
7	0.809	-0.147	0.321	0.000	0.895	000003
8	0.720	-0.147	0.232	0.000	0.502	000003
9	0.700	-0.147	0.212	0.000	0.419	000003
10	0.661	-0.147	0.173	0.000	0.297	000003
11	0.616	-0.147	0.128	0.000	0.169	000003
13	0.195	-0.465	0.000	0.163	0.502	000003
12	0.400	-0.465	0.000	0.081	0.502	000003
14	0.658	0.385	0.150	0.081	0.502	000003
15	0.480	0.385	0.000	0.163	0.502	000003
16	0.430	0.385	0.000	0.244	0.502	000003
17	0.413	0.385	0.000	0.325	0.502	000003
18	0.407	0.385	0.000	0.407	0.502	000003
19	0.765	-0.117	0.257	0.081	1.016	000003
20	0.560	-0.117	0.033	0.163	1.016	000003
21	0.332	-0.117	0.000	0.244	1.016	000003
22	0.799	0.346	0.291	0.081	1.016	000002
23	0.791	0.346	0.283	0.081	1.016	000001
24	0.626	0.346	0.099	0.163	1.016	000001
25	0.467	0.346	0.000	0.244	1.016	000001
26	0.395	0.346	0.000	0.325	1.016	000003
27	0.389	0.346	0.000	0.407	1.016	000003
28	0.878	-0.203	0.370	0.081	1.522	000003
29	0.829	-0.203	0.302	0.163	1.522	000003
30	0.659	-0.203	0.113	0.244	1.522	000003

HERMAN, DATA

RUN	WSU	WSD	HG	GATE	Q	REMARKS
31	0.461	-0.203	0.000	0.325	1.522	000003
32	0.898	0.369	0.390	0.081	1.522	000001
33	0.903	0.369	0.395	0.081	1.522	000002
34	0.850	0.369	0.323	0.163	1.522	000003
35	0.684	0.369	0.138	0.244	1.522	000003
36	0.511	0.369	0.000	0.325	1.522	000003
37	0.456	0.369	0.000	0.407	1.522	000003
38	0.973	0.003	0.465	0.081	2.022	000003
39	0.941	0.003	0.414	0.163	2.022	000003
40	0.895	0.003	0.349	0.244	2.022	000003
41	0.715	0.003	0.151	0.325	2.022	000003
42	0.565	0.003	0.000	0.407	2.022	000003
43	0.989	0.319	0.481	0.081	2.022	000003
44	0.961	0.319	0.434	0.163	2.022	000002
45	0.955	0.319	0.428	0.163	2.022	000001
46	0.902	0.319	0.356	0.244	2.022	000003
47	0.757	0.319	0.193	0.325	2.022	000003
48	0.581	0.319	0.000	0.407	2.022	000003
49	1.045	0.007	0.537	0.081	2.472	000003
50	1.019	0.007	0.492	0.163	2.472	000003
51	0.989	0.007	0.443	0.244	2.472	000003
52	0.938	0.007	0.374	0.325	2.472	000003
53	0.767	0.007	0.185	0.407	2.472	000003
54	0.627	0.007	0.027	0.488	2.472	000003
55	1.057	0.328	0.549	0.081	2.472	000003
56	1.038	0.328	0.511	0.163	2.472	000003
57	1.002	0.328	0.456	0.244	2.472	000003
58	1.093	0.689	0.585	0.081	2.511	000003
59	1.098	0.689	0.571	0.163	2.511	000002
60	1.097	0.689	0.551	0.244	2.511	000002

HERMAN, DATA

RUN	WSU	WSD	HG	GATE	Q	REMARKS
61	1.079	0.689	0.533	0.244	2.511	000001
62	1.045	0.689	0.481	0.325	2.511	000003
63	0.991	0.689	0.409	0.407	2.511	000003
64	0.873	0.689	0.273	0.488	2.511	000003
65	0.803	0.689	0.186	0.569	2.511	000003
66	0.761	3.689	0.127	0.650	2.511	000003
67	0.754	0.689	0.104	0.732	2.511	000003
68	1.090	0.689	0.563	0.163	2.511	000001
69	1.100	0.155	0.592	0.081	2.763	000003
70	1.079	0.155	0.552	0.163	2.763	000003
71	1.079	0.155	0.533	0.244	2.763	000003
72	1.013	0.155	0.449	0.325	2.763	000003
73	0.904	0.155	0.322	0.407	2.763	000003
74	0.757	0.155	0.157	0.488	2.763	000003
75	0.669	0.155	0.052	0.569	2.763	000003
76	1.137	0.795	0.629	0.081	2.763	000001
77	1.141	0.795	0.633	0.081	2.763	000002
78	1.149	0.795	0.622	0.163	2.763	000002
79	1.158	0.795	0.612	0.244	2.763	000002
80	1.153	0.795	0.589	0.325	2.763	000002
81	1.096	0.795	0.514	0.407	2.763	000001
82	1.057	0.795	0.457	0.488	2.763	000001
83	0.968	0.795	0.351	0.569	2.763	000001
84	0.915	0.795	0.281	0.650	2.763	000001
85	0.861	0.795	0.211	0.732	2.763	000003
86	0.854	0.795	0.188	0.813	2.763	000003
87	0.130	0.124	0.000	1.626	0.227	000003
88	0.207	0.177	0.000	1.626	0.476	000003
89	0.365	0.243	0.000	1.626	1.199	000003
90	0.395	0.306	0.000	1.626	1.335	000003

HERMAN, DATA

RUN	WSU	WSD	HG	GATE	Q	REMARKS
91	0.519	0.369	0.000	1.626	1.895	000003
92	0.580	0.386	0.000	1.626	2.216	000003
93	0.634	0.453	0.000	1.626	2.533	000003
94	0.669	0.446	0.181	0.000	2.735	000003
95	0.548	0.130	0.021	0.163	1.000	000003
96	0.304	0.136	0.000	0.163	0.692	000003
97	0.372	0.136	0.000	0.163	0.782	000003
98	0.438	0.162	0.000	0.163	0.869	000003
99	0.550	0.206	0.023	0.163	1.002	000003
100	0.655	0.238	0.128	0.163	1.115	000003
101	0.688	0.253	0.161	0.163	1.145	000003
102	0.492	-0.176	0.000	0.163	0.938	000003
103	0.769	-0.176	0.187	0.407	2.429	000003
109	0.610	-0.176	0.102	0.081	0.615	000003
110	0.350	-0.176	0.000	0.081	0.450	000003
111	0.620	-0.176	0.056	0.325	1.833	000003
112	0.970	-0.176	0.482	0.000	1.833	000003
113	1.031	-0.176	0.543	0.000	2.223	000003
114	0.625	-0.176	0.043	0.407	2.223	000003
115	1.068	-0.176	0.580	0.000	2.451	000003
116	0.772	-0.176	0.190	0.407	2.451	000003
200	0.523	-0.176	0.015	0.081	0.557	000003
201	0.314	-0.178	0.000	0.163	0.705	000003
202	0.513	-0.178	0.000	0.163	0.961	000003
203	0.690	-0.178	0.163	0.163	1.161	000003
204	0.428	-0.178	0.000	0.244	1.161	000003
205	0.764	-0.178	0.218	0.244	1.667	000003
206	0.537	-0.178	0.000	0.325	1.667	000003
207	0.672	-0.178	0.072	0.488	2.604	000003
208	0.852	-0.178	0.270	0.407	2.604	000003

HERMAN, DATA

RUN	WSU	WSD	HG	GATE	Q	REMARKS
64	0.898	0.369	0.371	0.163	1.522	000001