THE WALNUT GULCH SUPERCRITICAL

FLOW-MEASURING FLUME

By

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Clemson University
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Master of Science
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Name: Wendell Rudolph Gwinn Date of Degree: July 31, 1970

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: THE WALNUT GULCH SUPERCRITICAL FLOW-MEASURING FLUME

Pages in Study: 102 Candidate for Degree of Doctor of Philosophy

Major Field: Civil Engineering

Scope of Study: A new supercritical measuring flume is being used to gage sediment-laden ephemeral flows in steep channels. The transition from the natural channel to the straight modified trapezoidal measuring section of the flume consists of a cylindroid surface. The flume is kept free of deposition by a V-shaped floor which slopes 3 percent in the direction of flow. The head is measured at the midpoint of the straight section. Eight of these flumes were calibrated with models in the laboratory. The largest has a prototype bottom width of 120 feet and a capacity of 26,000 cubic feet per second.

Findings and Conclusions: Model tests are helpful in determining flume alignment if the flume is to be placed downstream of a sharp bend in the channel. Discharge ratings can be estimated for the higher flow ranges but model and field tests are required in the lower flow ranges. The location of critical depth within the flume can be predicted using the contraction ratio (area of flume divided by the approach flow area). Discharge coefficients computed using the contraction ratio relationship for the location of critical depth satisfactorily predicted the shape of the discharge coefficient versus piezometric head curve for flows controlled by the sides of the flume. The contraction ratio of the flume should be less than 0.5 for all discharge rates. Manning's n increased with depth of flow in the approach to the models.

ADVISER'S APPROVAL _____

THE WALNUT GULCH SUPERCRITICAL

FLOW-MEASURING FLUME

Thesis Approved:

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Thesis Adviser

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Dean of the Graduate College

PREFACE

The measurement of flow in an open channel is generally achieved by determining the water level upstream of a hydraulic structure that is designed to create a control in the channel. Streams with steep gradients carry a large amount of sediment and debris which cause fluctuations in the approach bed level. Therefore, errors in calibration can arise using the upstream water level. The Walnut Gulch Supercritical Flow-Measuring Flume uses a water level measurement within a fixed cross section of the flume to measure the flow. This dissertation is concerned with the design and laboratory performance of flumes used in the Walnut Gulch Watershed near Tombstone, Arizona.

The experiments reported herein were performed at the Water Conservation Structures Laboratory using the test facilities and materials of the USDA, Agricultural Research Service, Stillwater, Oklahoma. Indebtedness is acknowledged to Mr. W. O. Ree, Engineer in Charge, for his valuable guidance of the tests.

The author acknowledges with gratitude the suggestions and assistance of his major adviser, Professor Quintin B. Graves, and his valuable guidance in the preparation of this dissertation. To the members of the Advisory Committee, Dr. Richard N. DeVries, Dr. James E. Garton, Dr. Anthony F. Gaudy, Jr., and Dr. Don F. Kincannon go the author's thanks for their interest and assistance during the study.

In addition, the author would like to thank the following employees of the laboratory: Mrs. Amber N. Hudiburg for her typing excellence and advice; Mr. Curtis G. Ward for his assistance in the preparation of the figures; Mr. John C. Pierce (retired) for his skilled construction of the models; Dr. Donald McCool, Mr. F. L. Wimberley, and Mr. Walter C. Crane for their assistance in the construction of the models; and former employees Charles E. Rice, Charles A. Lindsey, and Jimmie D. Ramey for their assistance in the construction and testing of the models.

Finally, the author would like to express appreciation to his wife, Leona, and children, Neil, Sharon, Julia and Kenneth, whose understanding, encouragement, and sacrifice were instrumental in the preparation of this dissertation.

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CHAPTER I

INTRODUCTION

The Problem

Water supply and management have become very important to our nation in recent years. This interest and concern for water supply have led to large increases in water resources research programs. The acquisition of water-yield data from upstream watersheds is one of the top priority needs of this research. The effective use and management of water resources require accurate measurements and records of streamflow.

Measurement of waterflow in Walnut Gulch near Tombstone, Arizona, presented a difficult problem for the hydrographers studying the runoff from this area. The streambeds are steep and the flows are infrequent, flashy, and heavily laden with sediment. Hydraulic structures are often designed to create a "control point" in the channel. The desire is to have a unique head-discharge relationship which is independent of the channel conditions, that is, a rating curve that has identical values for all operating conditions.

The use of other methods of flow measurement was impractical. The time from zero flow to peak flows was fifteen minutes in some instances. Therefore, the use of the velocity-area method using a current meter was impractical. The chemical dilution method cannot supply a continuous record and single measurements are costly in terms of time and

effort. One of the oldest and most common hydraulic structures used is a weir. However, the transported material deposited in the approach seriously affects its accuracy.

The Solution

A new type of flow meter that would accurately and reliably measure flows under these adverse conditions was developed in the hydraulic laboratory. Using a flume, the control of the flow was obtained by contracting the stream from the sides. The flume has a straight portion 20 feet long and 10 feet deep, preceded by a curved entrance approach portion 15 feet long. The straight portion has a shallow V-shaped floor, sidewalls of 1 on 1 slope. The curved approach has a cylindroid surface. The flow passes through critical flow in the straight portion upstream of the head-measuring section. The structure has a floor slope of 0.03 in the downstream direction to insure movement of sand and gravel through the flume. The invert of the flume is normally placed about two feet above the streambed to reduce backwater on the flume. The head is measured at the midpoint of the narrow, straight portion of the flume. Velocities are supercritical at the head measuring section. This meter has been named the Walnut Gulch Supercritical Flow-Measuring Flume.

Objectives

The objectives of this study were to make an experimental analysis of eight individual model studies conducted by the author in the Water Conservation Structures Laboratory. The specific objective was to

develop a prediction method of obtaining a head-discharge rating in terms of pertinent hydraulic variables. All of these eight flumes are 35 feet long and differ only in width (5 feet $\leq W \leq$ 120 feet) and floor cross slopes ($7.5 < S_v < 15$). Friction factors of the approach to each flume will be reported.

CHAPTER II

REVIEW OF THE LITERATURE

Flow-measurement of streams has been carried out for many years. One of the first attempts to measure debris-laden flows was with a San Dimas flume as reported by Wilm, Cotton, and Storey (1). This flume was designed to measure mountain streams with steep gradients. The velocities in those channels were supercritical. The transported material in the streams measured by the San Dimas flume was estimated as high as 10 percent of the flow (1).

The San Dimas flume has performed satisfactorily for certain field conditions. However, in common with other measuring flumes of rectangular cross section, it has some limitations. Normal channels are not rectangular in shape. The San Dimas flume would be very expensive if the size was scaled up to measure large channel flow. It does not measure low discharges with great accuracy because of the wide bottom required to obtain the maximum capacity.

A trapezoidal cross section with a 3-percent flume floor was tested by Wilm (1). However, surface waves were produced by the over-abruptness of the conical entrance transition. This same conclusion was drawn by Bermel (2). However, trapezoidal flumes were used successfully by Robinson and Chamberlain (3). The advantages for use of the trapezoidal flume over the rectangular flume as listed by Robinson and Chamberlain (3) are:

1. Approach conditions seemed to have a minor effect on head-discharge (h - Q) relationships.

2. Material deposited in the approach did not change the h - Q relationships materially.

3. A large range of flows can be measured through the structure with a comparatively small change in head.

4. The flume will operate under greater submergence than rectangular flumes without corrections being necessary to determine the correct discharge.

5. The general trapezoidal shape fits the common channel section more closely than a rectangular one. Scour problems should be less with the trapezoidal shape.

The trapezoidal flume was also developed for the measurement of streamflow with steep gradient and heavy debris loads by Robinson (4). The flumes have a flat bottom, five feet wide at the entrance narrowing to one foot in the throat section. The bottom slope in the direction of flow is 5 percent. The sidewalls were flat with an angle of 30 degrees from the horizontal.

A different approach to the measurement of flow in steep streams was reported by Harrison and Owen (5). They conclude that for Froude numbers $[V/(gA/T)^{0.5}]$ greater than 0.5, no existing form of structure will give an accurate measurement of discharge. The principles of design as listed by Harrison and Owen (5) are:

The design of the structure was developed to meet the following requirements:

(a) The Froude number in the immediate approach should be reduced to a constant value not exceeding 0.5 .

(b) Velocities in the approach and the natural channel should be nearly equal at all discharges so as to maintain sediment movement.

The new flume developed by Harrison and Owen (5) will operate in streams having Froude numbers up to 1.3 . The structure reduces the Froude number in the approach by increasing the depth and maintaining a constant cross-sectional area of flow. This increase in depth is achieved by using a ramp to lower the bed. However, this depth is only correct for one design discharge. Roughness strips were used on the floor and walls of the ramp to create extra energy loss to prevent supercritical flow at low discharges. The flume has vertical sides and a V-form bottom. The total length of the ramp, approach transition, and throat was 23 times the width of the throat. The depth of the throat was 4 times the width. Therefore, the construction cost of the flume on a large channel would be expensive. Excavation for the necessary depth could be a problem for rocky streams.

Critical depth flumes or Venturi flumes have been used extensively in irrigation canals and other flow measurement problems. These are usually used where the flow is subcritical. The first experimental work in the United States was reported by V. M. Cone(6). R. L. Parshall (7) modified the original Venturi flume by depressing the throat section or contracted portion of the flume and changing the angles of contraction and expansion. A study by S. Davis (8) has shown that a single semi-theoretical equation can be used to estimate the discharge for all Parshall flumes. Palmer and Bowlus (9) developed trapezoidal flumes for measurement of flows in circular conduits used for sewers. Wells and Gotaas (10) made extensive experimental studies to determine the accuracy and design criteria for the Palmer-Bowlus flumes. Robinson (11) used trapezoidal flumes in irrigation channel measurements. These were Venturi type with discharge tables up to 60 cubic feet per second.

Replogle (12) classified critical-depth flumes into two categories:

(1) Flumes for which the dimensions are such that critical flow occurs in a region where the flow lines are parallel, or nearly parallel, and (2) flumes where critical depth occurs in a region of curvilinear flow. For flumes in the first group, the calibration curve can be predicted for a wide variety of basic shapes.

Replogle (12) used the boundary-layer method outlined by Ackers and Harrison (13) to estimate the friction loss between the point of head measurement in the approach and the point of critical depth in the throat. The value of friction loss obtained in the laboratory calibration was only about one-half or less of the value calculated by the boundary-layer method. However, computation of the friction loss in the flume permits a prediction within plus or minus two percent for a flow range of 100 to 1. Replogle (12) recommends the throat section length be at least twice the maximum expected flow depth in the approach section.

Skogerboe and Hyatt (14) (15) developed the rectangular cutthroat flow measuring flume with a flat bottom. This flume is a Venturi flume with a zero throat length. The flume inlet has vertical sides with a convergence of 3:1. The flume exit has a divergence of 6:1. The flume is used to measure flows in a flat gradient channel under conditions of submerged flow or free flow. The advantage of a cutthroat flume is economy of construction.

CHAPTER III

THEORETICAL ANALYSIS

Flume Design

All flumes used in the analysis have a curved entrance approach (15 feet long) to a straight portion (20 feet long) that has a shallow V-shaped floor and sidewalls of 1 to 1 slope. Figure 1 shows the general design of a typical flume. The length of the straight portion should be about twice the maximum head (12). The curved approach has a cylindroid surface defined by the equation:

$$y = 0.03x + \frac{z - 0.03x^2}{0.00267x^2 + 1} \tag{1}$$

where

x = horizontal coordinate (ft.) positive in the upstream direction

y = vertical coordinate (ft.)

z = horizontal coordinate (ft.) normal to the centerline of the flume

See Figure 1 for the origin of the coordinates. A perspective view of this surface is shown in Figure 2.

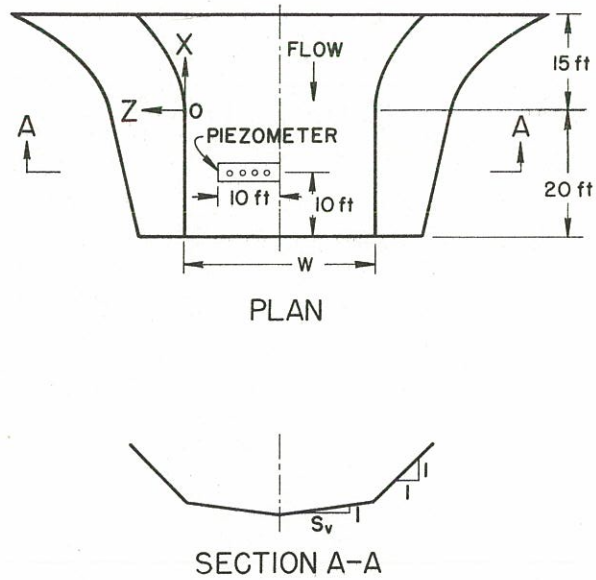

Figure 1. Walnut Gulch Super-critical Flow-Measuring Flume.

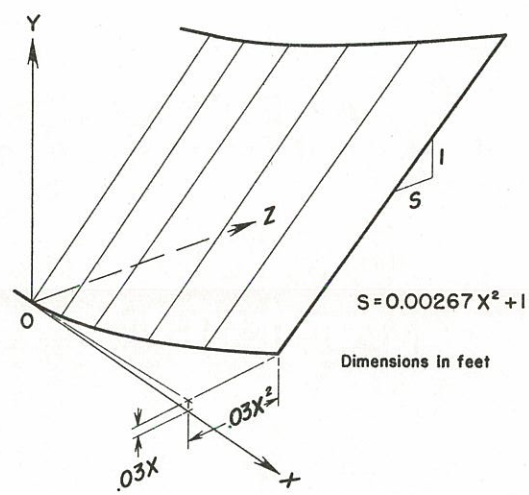

Figure 2. The Approach Cylindroid Surface.

Flume Theory

The energy at any section in an open channel when referenced to the channel bottom is known as specific energy. The specific energy, E, is given by:

$$E = y + \frac{\alpha V^2}{2g} \tag{2}$$

where

y = depth of flow

α = velocity distribution coefficient

V = average velocity

g = acceleration due to gravity

The equation of continuity is:

$$Q = AV \tag{3}$$

where

Q = discharge rate

A = area of section

Substituting equation (3) in equation (2) results in:

$$E = y + \frac{\alpha Q^2}{2gA^2} \tag{4}$$

The area, A, is a function of the depth, y. Therefore, for any given values of discharge, Q, and energy, E, there are two positive values of depth. These two values are identical when the energy is a minimum for a given Q. The flow is critical when this occurs. Differentiating equation (4) with respect to y and equating to 0,

$$\frac{dE}{dy} = 0 \tag{5}$$

$$0 = 1 - \frac{\alpha Q^2}{2g} \frac{2}{A^3} \frac{dA}{dy} \tag{6}$$

also

$$dA = T\,dy$$

or

$$T = \frac{dA}{dy} \tag{7}$$

where T = width of water surface.

Substituting equation (7) in equation (6) results in:

$$Q^2_c = \frac{gA_c^3}{\alpha_c T_c} \tag{8}$$

where c = subscript relating to the critical section.

Critical discharge occurs in the straight portion of the flume. The specific energy, E_c, at this point would be:

$$E_c = h_c + \frac{\alpha_c V_c^2}{2g} \tag{9}$$

Substituting equations (3) and (8) into (9) results in:

$$E_c = h_c + \frac{A_c}{2T_c} \tag{10}$$

The slope of the flume floor in the direction of flow is 0.03 . This is necessary to insure movement of sand and gravel through the flumes. The total specific energy, E_p, above the flume zero at the point of head measurement would be:

$$E_p = E_c + 0.03\ L - \text{energy loss} \tag{11}$$

where L = horizontal length between critical section and point of head measurement. The flow is parallel and accelerating between these two

sections. Therefore, energy loss would be small and could be neglected. Substituting equation (10) in equation (11) and assuming no energy loss results in:

$$E_p = h_c + \frac{A_c}{2T_c} + 0.03\ L \tag{12}$$

The total specific energy, E_p, can also be expressed as:

$$E_p = h_p + \frac{\alpha_p V_p^2}{2g}$$

or

$$E_p = h_p + \frac{\alpha_p Q_c^2}{2g\ A_p^2} \tag{13}$$

where

h_p = depth of flow at the point of head measurement

p = subscript relating to the point of head measurement (see piezometer in Figure 1)

Subtracting equation (13) from equation (12) yields the relation:

$$h_p = h_c + \frac{A_c}{2T_c} + 0.03\ L - \frac{\alpha_p Q_c^2}{2g\ A_p^2} \tag{14}$$

This is the equation for the head-discharge relationship for the flume. The unknowns in the equation are the distance, L, and the velocity distribution coefficient, α_p. Experimentally determined velocity profiles in a Venturi have indicated that the velocity distribution is almost uniform (3). Therefore, it may be assumed that $\alpha = 1$. Starting with a selected value for h_c, A_c and T_c are computed using the flume surface equations. The discharge, Q_c, then could be computed using equation (8), assuming α to be unity. If a value for L is known, then

h_p and A_p could be computed by assuming h_p too low and incrementing until equation (14) is balanced. Bermel (2) recommended the area of throat to be one half the area of the approach channel. Therefore, a contraction ratio (A_p divided by the approach channel flow area) of 0.5 or less would be desirable for flume control of the flow. This flume is designed for steep streams that transport large amounts of sediment. Therefore, the channel will tend to fill if the flume is raised above the channel bed. Contraction can only be achieved by narrowing from the sides. The contraction ratio will vary depending on the actual site topography, maximum design discharge, and available head. The aggradation of the approach channel will tend to stabilize depending on the sediment size, supply, and sequence of flow events.

The distance, L, between the point of head measurement and the critical section becomes the important dimension in determining a predicted or computed rating. This distance, L, will vary depending on the contraction ratio (area of flume divided by the approach channel flow area). For flows controlled by the flume, the maximum limit of L would be 10 feet since this is the point where the cylindroid surface intercepts the straight section of the flume. The minimum L would be 0 or critical depth at the point of head measurement. For flows within the V-section and below the cylindroid surface, the control will be primarily channel control. Therefore, using equation (14), a predicted rating in this flow range would be inaccurate.

CHAPTER IV

EXPERIMENTAL PROCEDURE

The laboratory investigations were conducted in the Water Conservation Structures Laboratory of the United States Department of Agriculture, Agricultural Research Service, Stillwater, Oklahoma. This laboratory is located near Lake Carl Blackwell on property owned by Oklahoma State University.

Model Construction

Each field site was surveyed to obtain a topographic map of the stream channel. Detailed topographic data were obtained for a distance of about one thousand feet upstream from each site. The location, density, and size of any vegetation in the channel were determined and the nature of the bed material noted. This information was needed for construction of models.

Selection of the model scale was based on the size of the area to be modeled, laboratory basin, water supply, and the approximate roughness of the field channel. The model limits and scales are given in Table I. The basin used was 10 feet wide by 40 feet long and 2.5 feet deep with a 12-inch water supply line. The water used flows by gravity from Lake Carl Blackwell. The primary flow measurement was obtained using a calibrated set of orifice plates in the 12-inch water supply line. The set contained sizes 0.875-, 1.5-, 2.5-, 4.0-, 6.0- and

8.0-inch plates. The plates are sharp edged and have a thickness of 0.125 inch. The pressure piezometers were located 1 inch upstream and downstream of the plates. Differential manometer readings were recorded between 6 and 60 inches of water, 0.1 inch being the smallest increment.

TABLE I

SUMMARY OF WALNUT GULCH FLUMES CALIBRATED IN THE LABORATORY

Flume No.	Floor Cross Slope S_v	Flume Width W	Maximum Discharge	Model Length Scale	Length of Approach Channel	Total Length of Channel	Width of Channel
		(ft.)	(c.f.s.)		(ft.)	(ft.)	(ft.)
1	15	120	26,000	1:40	840	1,160	400
3	7.5	30	6,000	1:32	672	928	320
4	10	5	1,000	1:30	270	330	180
6	10	70	16,500	1:30	570	800	300
7	10	40	8,600	1:30	700	840	300
8	10	40	8,600	1:30	870	1,050	300
11	10	30	6,000	1:30	630	840	300
15	10	40	8,300	1:30	640	840	300

Each flume model was carefully constructed of redwood and varnished to produce a smooth surface. A 6-inch concrete cutoff wall was used to support the upstream end of the flume. The flume was leveled and the downstream slope set to 0.03 using an engineer's level. The downstream end of the flume was supported using 3/8-inch threaded rods set in the basin floor. The leveling operation is shown in Figure 3. The topographic details of the channel were carefully modeled in the basin with Portland cement mortar over a well compacted sand bed. Cross sections of the surface were set every one foot and in some instances for each one-half foot of the model length. Each cross section was set using preset steel pins supported by an aluminum H-beam drilled every 0.1 foot. This is shown in Figure 4. Adjustable collars were preset to prototype elevation on the steel pins. The steel pin could then be lowered until the collar rested on top of the H-beam. The profile of the section was molded by hand until it was brought to the correct elevation as defined by the bottom of the pin. The section was then marked for location. The H-beam was then removed and used to set the next section. The area between each section was filled and molded by hand using the topographic map as a guide. Flush mounted piezometers were installed at several points in the bed of the approach channel to obtain data needed for calculating the friction factor. The pressures from these piezometers were measured in gage wells outside the basin equipped with point gages that measure to the nearest 0.001 foot. Prototype vegetation was simulated in the model with screen wire.

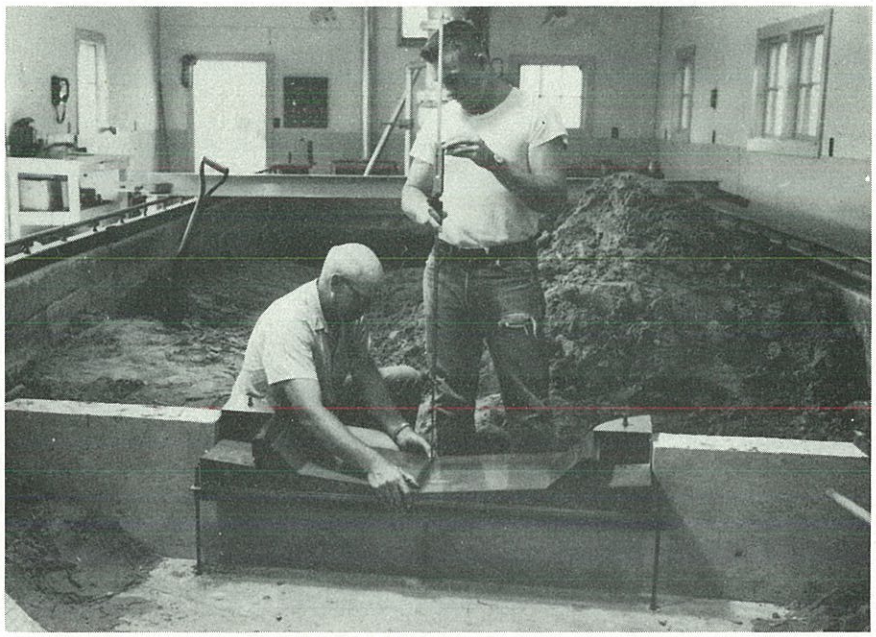

Figure 3. Installation of Walnut Gulch Flume 6 in the Model Basin. J. Pierce and W. Fry Show the Method Used to Check the Flume Slope.

Figure 4. Construction of the Topography for Walnut Gulch Flume 6. C. Rice Shows the Method Used to Obtain Each Cross Section Profile.

The water from the supply line was properly baffled and floating booms were used to reduce any wave action in the model forebay. Each point gage used to measure water surface elevations was zeroed to the nearest 0.001 foot using an engineer's level.

Test Procedure

Approximately 50 test flows were used in calibrating each variation of a particular model. The discharge rate was set using a gate valve in the 12-inch supply line. A period of 5 to 10 minutes was required to obtain a steady flow rate throughout the model. A water level recorder located in the model forebay was used to determine steady flow. Water temperature and general flow conditions were recorded prior to each test. After steady flow was established, twenty readings (ten on each side) of the differential manometer were recorded. The next step was to record consecutively the water surface elevations at each piezometer until a total of ten readings was obtained on each gage. Twenty more readings were then read to check any changes in flow rate during the test. The arithmetic mean of the readings was used to determine the average value. The zero of each point gage was checked for changes at the end of each day of testing.

The shape of each flume was measured to the nearest 0.001 foot in both vertical and horizontal distances. Surface equations were derived for the head measuring section using the method of least squares. The flume zero was obtained from the intercept of the two equations for the V-shaped floor.

Model-Prototype Relationships

The models were geometrically similar to prototype channels. For open channel flow the force of gravity is considered to be the predominant factor (16). For this case the ratio of the model Froude number to the prototype Froude number must be one, thus fixing the ratio of the velocities. The model-prototype relationships are shown in Table II. The same value for g was used in the model and the prototype.

TABLE II

MODEL-PROTOTYPE TRANSFER EQUATIONS WHERE L EQUALS LENGTH SCALE RATIO

Property	Undistorted Open Channel Models	Model Scales		
Length	L	1:30	1:32	1:40
Area	L^2	1:900	1:1024	1:1600
Velocity	$L^{1/2}$	1:5.477	1:5.657	1:6.325
Discharge	$L^{5/2}$	1:4929.5	1:5792.6	1:10119
Hydraulic Radius	L	1:30	1:32	1:40
Roughness (Manning)	$L^{1/6}$	1:1.7613	1:1.782	1:1.849

Friction Analysis

The analysis of the friction loss in the approach channel to each flume was made using the Manning formula (17):

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \tag{15}$$

where

V = velocity in (feet per second)

R = hydraulic radius (feet), $\frac{\text{area}}{\text{wetted perimeter}}$

S = hydraulic slope

n = Manning's roughness coefficient

Using the equation of continuity in equation (15) results in

$$n = \frac{1.486}{Q} A R^{2/3} S^{1/2} \tag{16}$$

where

A = area (square feet)

Q = discharge (cubic feet per second)

The discharge is a constant for each test. However, the area, A, and hydraulic radius, R, are different for each end of the reach. The arithmetic mean of value of $A R^{2/3}$ for each end of the reach was used in the analysis. The hydraulic slope, S, was obtained using the following formula:

$$S = (E_1 + \alpha_1 \frac{V_1^2}{2g} - E_2 - \alpha_2 \frac{V_2^2}{2g})/L \tag{17}$$

where

E = elevation of water surface (feet)

V = velocity (feet/second)

1 = subscript relating to the upstream station

2 = subscript relating to the downstream station

g = acceleration due to gravity (feet/second squared)

L = length of reach (feet)

If we assume $\alpha_1 = \alpha_2 = 1$ and use the equation of continuity, equation (17) may be written in the following form:

$$S = (E_1 + \frac{Q^2}{2g\ A_1^{\ 2}} - E_2 - \frac{Q^2}{2g\ A_2^{\ 2}})\ /\ L \tag{18}$$

The resulting equation for Manning's n used in the analysis was:

$$n = \frac{1.486}{Q}\ \frac{A_1\ R_1^{\ 2/3} + A_2\ R_2^{\ 2/3}}{2}$$

$$[(E_1 + \frac{Q^2}{2g\ A_1^{\ 2}} - E_2 - \frac{Q^2}{2g\ A_2^{\ 2}})/\ L]^{1/2} \tag{19}$$

The values for area and hydraulic radius were computed for each test using the water surface elevations and cross sections of the channel taken normal to the flow. Elevation of the channel bottom was recorded for each one-tenth of a foot (model) normal to the flow. The area of the brush was not included in the determination of n because the flow within the brush along the banks was small compared to the total flow. In the analysis of n this flow was assumed to be zero.

At least three gaging stations were used to determine the friction loss. Average values of n and R were computed between each of the three stations.

Discharge Coefficient Analysis

Slight deviations in the shape of a flume can occur even with a skilled craftsman. The effect of the dimensional errors may be removed by using discharge coefficients in the analysis. The fundamental equation for triangular weirs is (17):

$$Q = C_d \; 8/15 \; (2g)^{0.5} \tan \frac{\theta}{2} h^{2.5} \tag{20}$$

The C_d multiplied by 8/15 can be combined into one coefficient.

$$C = C_d \; 8/15 \tag{21}$$

Also $$\tan \frac{\theta}{2} h = \frac{T}{2} \tag{22}$$

where

T = top width at elevation h

Substituting equations (21) and (22) into equation (20) results in:

$$Q = C \; (2g)^{0.5} \frac{T}{2} h_p^{1.5} \tag{23}$$

where

Q = discharge in cubic feet per second

C = discharge coefficient

T = top width in feet

h_p = head measured at the center of the straight section

g = acceleration due to gravity in feet per second per second

The T/2 values were computed using the surface equations of the flume in the head measuring section.

CHAPTER V

PRESENTATION, ANALYSIS AND DISCUSSION OF DATA

Walnut Gulch Flume No. 1

Flume No. 1 is the largest of all the flumes tested. The flume had a width, W, of 120 feet and a floor cross slope, S_v, of 1:15. The prototype capacity of this flume is 26,000 cubic feet per second. The 1:40 scale model of Flume No. 1 is shown in Figure 5. The completed prototype structure is shown in Figure 6.

Discharge coefficients, C, were computed using equation (23). These C values are plotted against the corresponding values of head, h_p, on Figure 7 and labeled "measured." The dashed line labeled "computed" will be discussed later.

The flume has a half width of 60 feet and a floor cross slope of 1 on 15. Therefore, there is a rise of 4 feet from the bottom of the V to the intersection of the floor and the 1 on 1 sidewall. This accounts for the reversal point in the C curve for h_p value of 4.0 feet (see Figure 7). Another sharp reversal point in the C curve is noted for h_p value of 6.2 . This was produced by a standing wave trough passing over the head measuring piezometers. The approach channel (see the left side of Figure 5) contains a conglomerate point that protrudes

Figure 5. A 1:40 Model of Walnut Gulch Flume No. 1 With a Prototype Discharge of 100 Cubic Feet Per Second and a Prototype Head of 0.75 Foot.

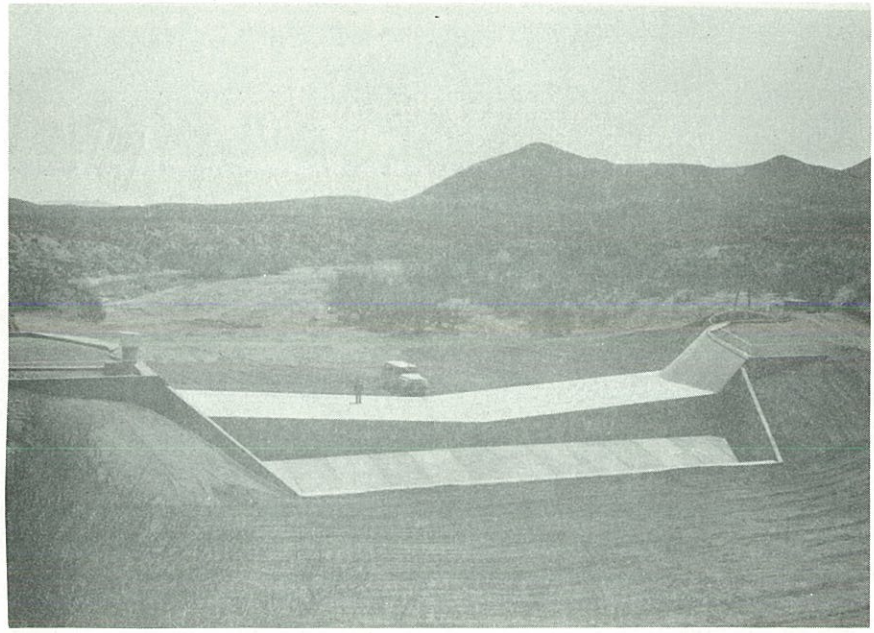

Figure 6. Prototype View of Walnut Gulch Flume No. 1

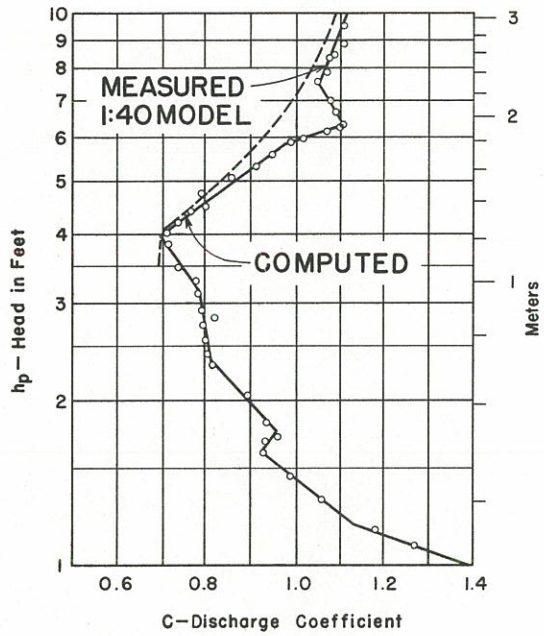

Figure 7. Discharge Coefficients for Walnut Gulch Flume No. 1.

into the stream near the same location of braided brush. This point produced standing waves in the channel approach for h_p values of approximately 6.2 feet.

Manning's n values were computed using equation (19). Three floor piezometers located upstream of the conglomerate point were used to obtain average values of n and hydraulic radius. These n values expressed in prototype terms are plotted against the average hydraulic radius, R_{123}, on Figure 8. The sharp increase in n for hydraulic radius values less than 1 foot is produced by laminar flow occurring in the

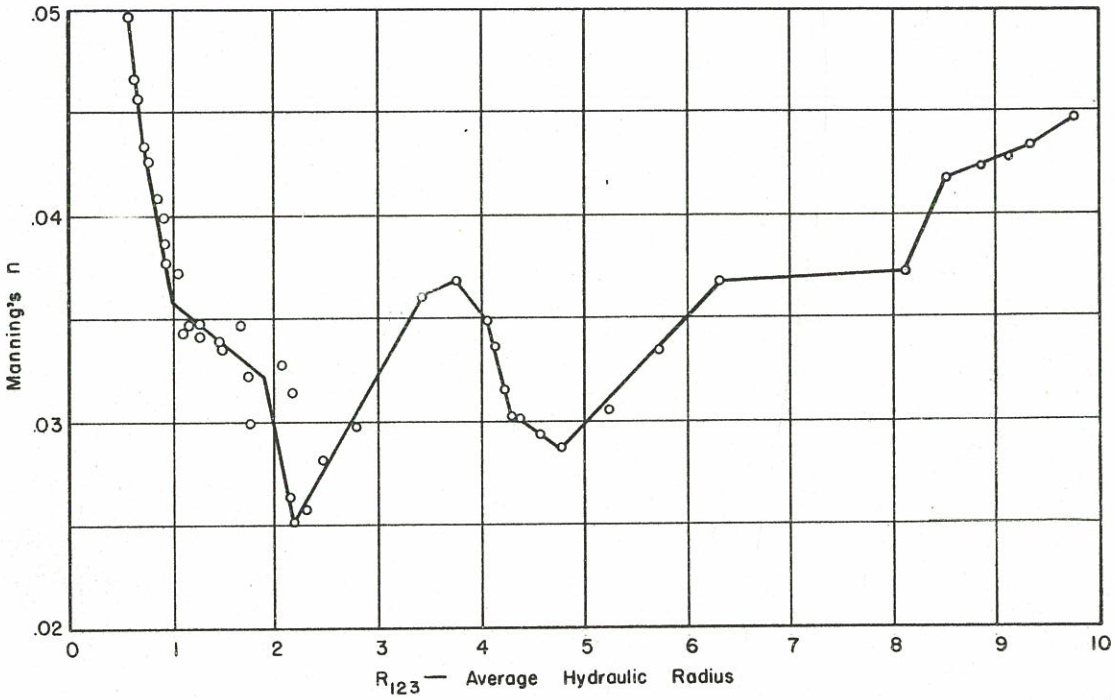

Figure 8. Prototype Values of Manning's n for 1:40 Model of Walnut Gulch Flume No. 1 Approach Channel.

model. Therefore, these n values would not be valid for the prototype. The general trend was for n to increase as the depth increased. The brush in the braided channel could account for this increase.

Walnut Gulch Flume No. 3

This flume is located on a tributary to Walnut Gulch Creek near Tombstone, Arizona. The design capacity was 6,000 cubic feet per second. The throat width, W, was 30 feet with a floor cross slope, S_v, of 1 on 7.5 . The model length scale used was 1:32. A general view of the model is shown in Figure 9. The approach channel was straight with brush along each bank. This is shown in Figure 10.

The measured discharge coefficients are plotted against the corresponding values of head, h_p, on Figure 11. The dashed curve labeled "computed" on Figure 11 will be discussed later. Channel control was present for flows with h_p values less than 1.6 . The flume has a rise of 2 feet from the bottom of the V to the intersection of the floor and the 1 on 1 sidewall. This accounts for the reversal in the C curve that occurs near 2 feet. The sidewalls exerted control of the flow for h_p values greater than 2 feet with no abrupt deviations.

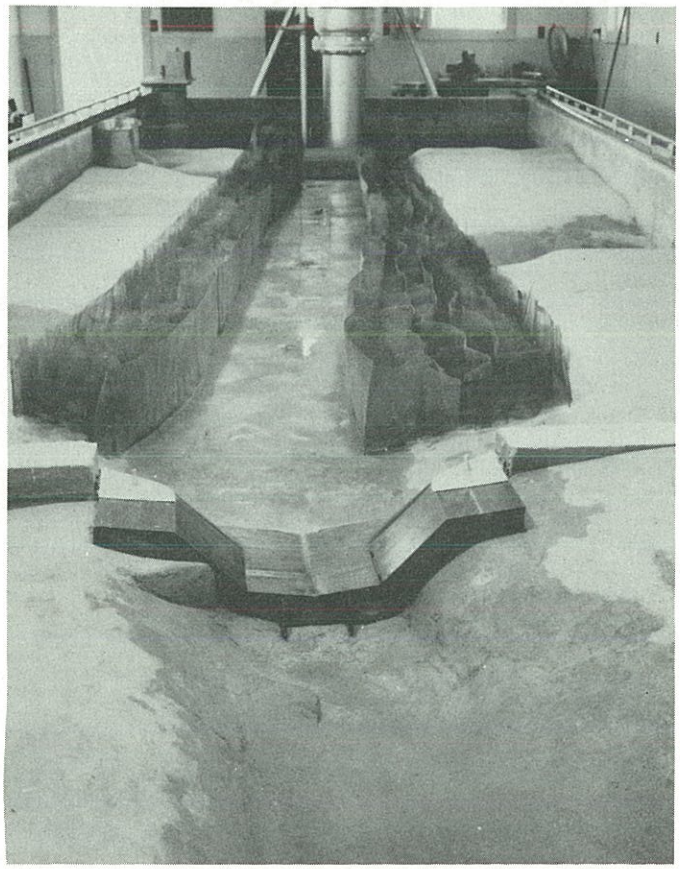

Figure 9. A 1:32 Scale Model of Walnut Gulch Flume No. 3.

Figure 10. General View of Walnut Gulch Flume No. 3 From Upstream.

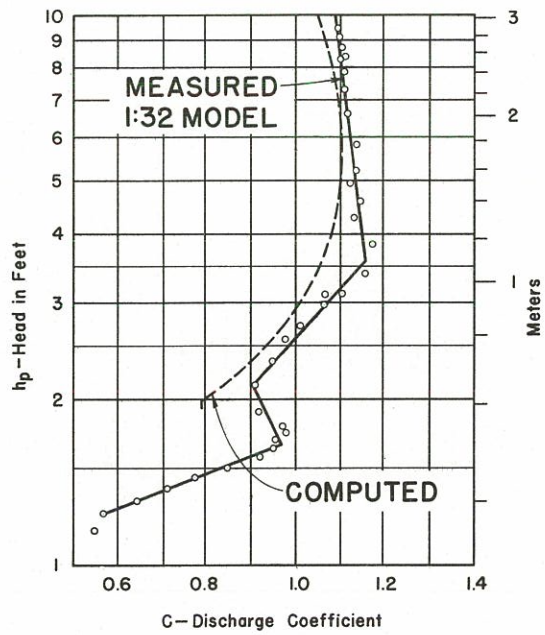

Figure 11. Discharge Coefficients for Walnut Gulch Flume No. 3.

Manning's n values are plotted on Figure 12 for two gaging stations in the approach channel to the flume. The general trend was for n to increase as the depth of flow was increased.

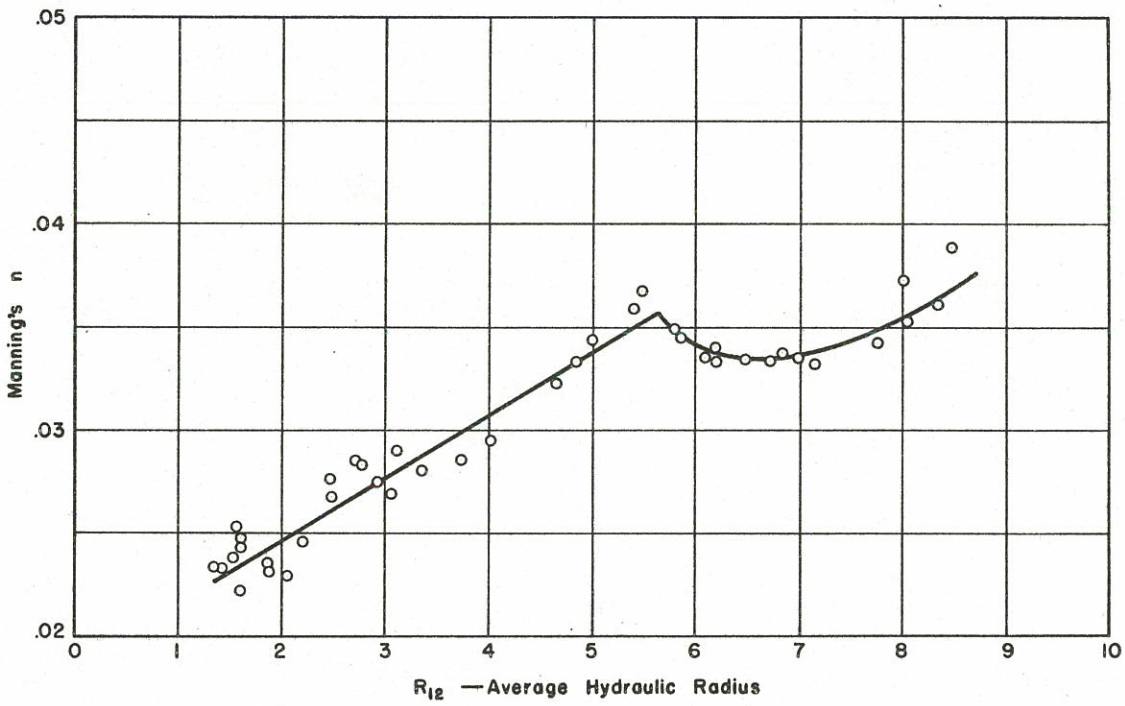

Figure 12. Prototype Values of Manning's n for 1:32 Model of Walnut Gulch Flume No. 3.

Walnut Gulch Flume No. 4

Flume No. 4 had the smallest contraction ratio (area of flume flow divided by the approach channel flow area) of all the flumes calibrated in the laboratory. The flume width, W, was 5 feet with a floor cross slope, S_v, of 1 on 10. This flume is located on a tributary to the main stem of Walnut Gulch Creek. A 1:30 scale model is shown in Figure 13. The flume design capacity of 1,000 cubic feet per second is shown in Figure 14. The approach channel contained a bend. However, with the low contraction ratio the flume controlled the flow throughout the flow range.

The discharge coefficients were computed using equation (23). The resulting C values are plotted against the corresponding values of head, h_p, on Figure 15. The channel approach was filled to a predicted level based on field measurements of sediment in other flumes. The maximum depth of this fill was 3.4 feet located 60 feet upstream of the entrance to the flume.

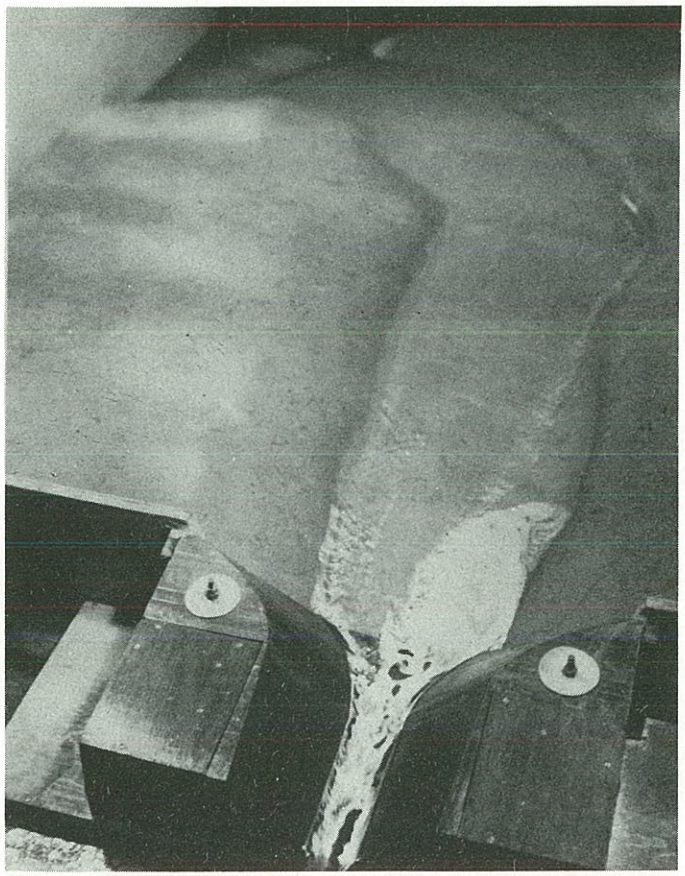

Figure 13. Walnut Gulch Flume No. 4 Model With a Prototype Discharge of 50 Cubic Feet Per Second and a Head of 1.2 Feet.

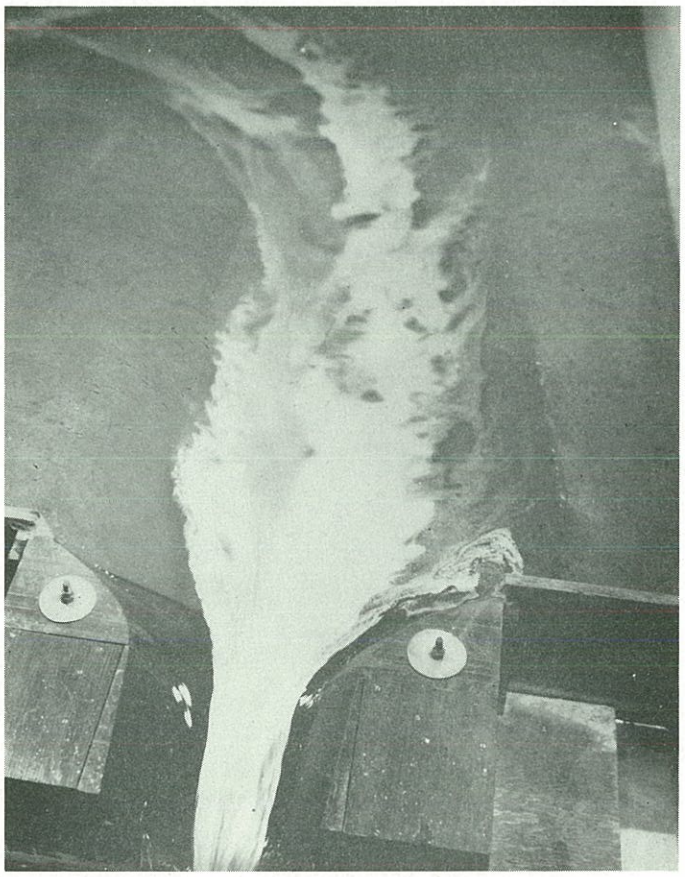

Figure 14. Walnut Gulch Flume No. 4 Model With a Prototype Discharge of 1,000 Cubic Feet Per Second and a Head of 6.4 Feet.

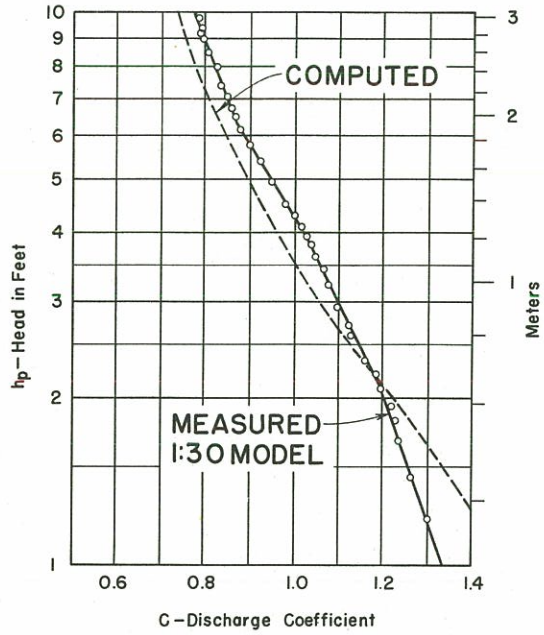

Figure 15. Discharge Coefficients for Walnut Gulch Flume No. 4.

There was no significant difference between the discharge coefficients for the filled and unfilled channel approach conditions.

Manning's n values for Flume No. 4 were not measured in the model because of the short approach channel and low contraction ratio.

Walnut Gulch Flume No. 6

Flume No. 6 is located downstream of a large S-type bend in the main channel of Walnut Gulch Creek. The flume width, W, was 70 feet with a floor cross slope, S_v, of 1 on 10. A general view of the model is shown in Figure 16. The design capacity was 16,500 cubic feet per second. The prototype structure was constructed in the field prior to model studies.

Measured discharge coefficients, C, are plotted versus the corresponding head, h_p, on Figure 17. The sharp bend in the approach channel produced concentrated high velocities along the left bank. The sharp increase in C for the flow range of h_p values of 4.0 to 4.5 feet was produced by the trough of a standing wave passing over the head measuring piezometers. This is shown in Figure 18. A prototype view of this same flow range is shown in Figure 19.

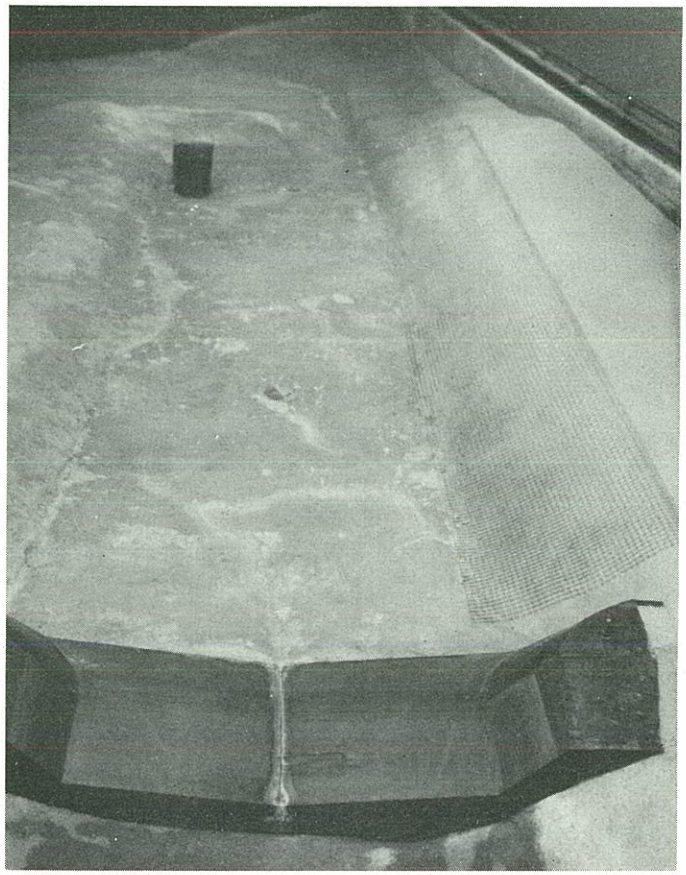

Figure 16. Walnut Gulch Flume No. 6
Model (Scale 1:30)

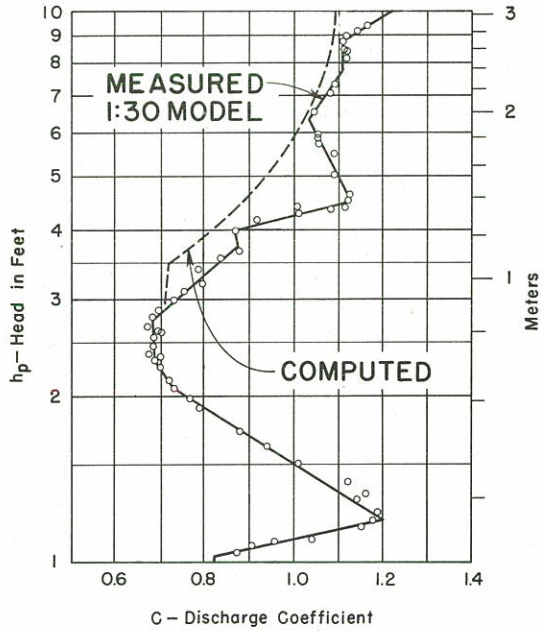

Figure 17. Discharge Coefficients for Walnut Gulch Flume No. 6.

The left bank of the prototype was conglomerate and contained little brush. However, a 1/2-inch mesh hardware cloth was used to roughen the bank slopes of the model. This is shown in Figure 16.

Manning's n values were computed between two gaging stations in the approach channel. The resulting n values are plotted against the corresponding average hydraulic radius, R, on Figure 20. The general trend was for n to increase with increase in depth.

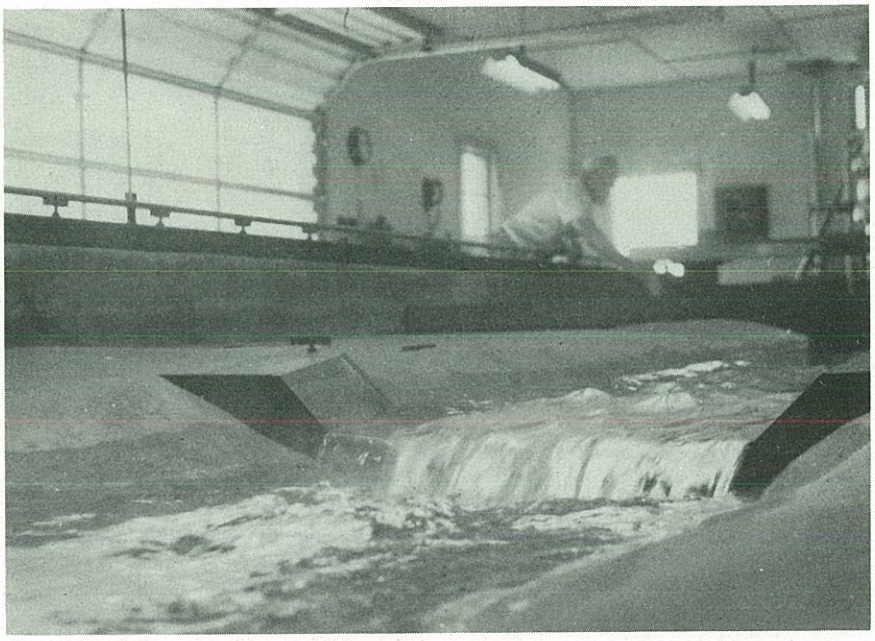

Figure 18. Walnut Gulch Flume No. 6 Model With a Prototype Discharge of 2,500 C.F.S. and a Head of 4.3 Feet.

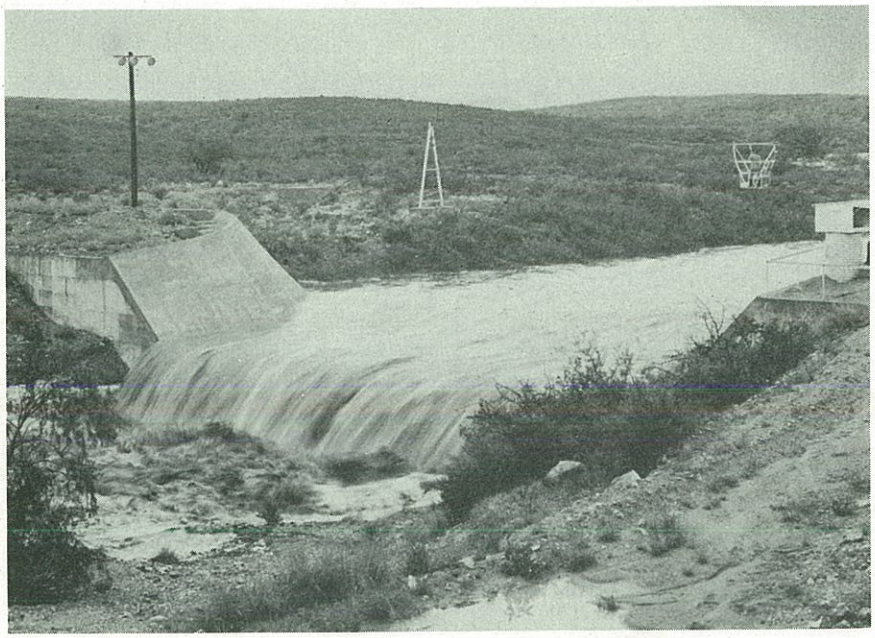

Figure 19. Walnut Gulch Flume No. 6 on August 19, 1963, 10:35 a.m. (Photographed by Dr. J. L. Gardner).

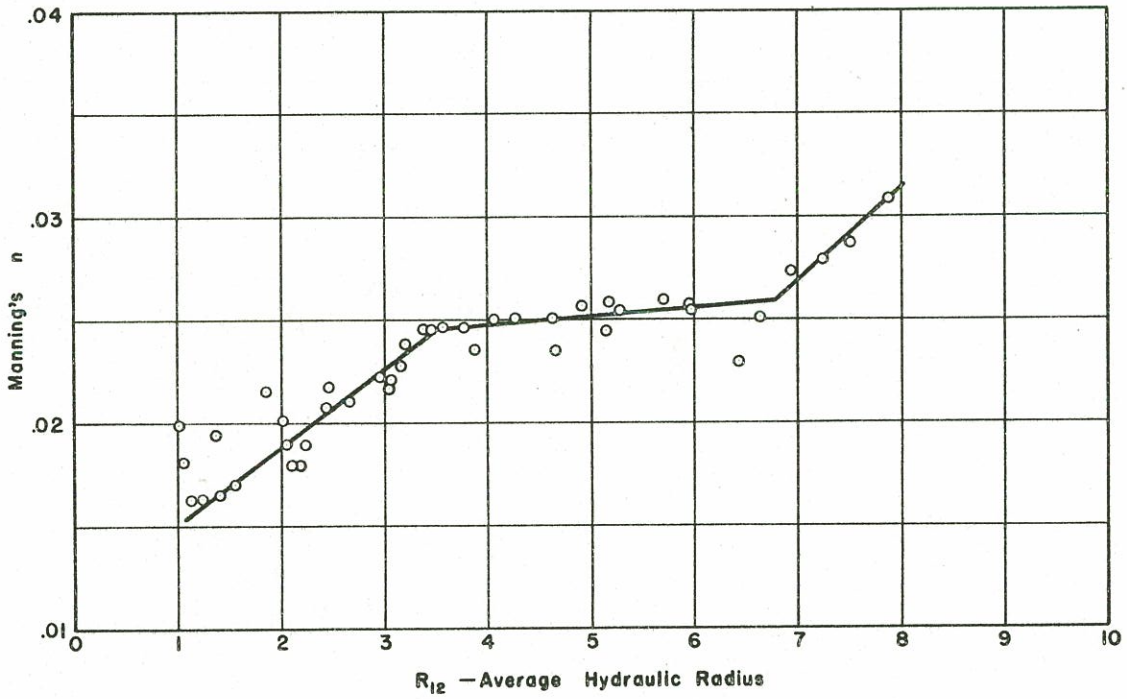

Figure 20. Prototype Values of Manning's n for 1:30 Model Walnut Gulch Flume No. 6.

Walnut Gulch Flume No. 7

Flume No. 7 had a width, W, of 40 feet and a floor cross slope of 1 on 10. The design capacity was 8,600 cubic feet per second. The approach channel contained a bend. However, the model was designed to permit changing the orientation and elevation of the flume with respect to the approach channel. The final design is shown in Figure 21. The approach channel contains granite tors or large boulders.

The discharge coefficients, C, are plotted on Figure 22. There is a vertical distance of 2 feet from the bottom of the V to the intersection of the floor and the 1 on 1 sidewall. Therefore, there is a sharp reversal in the C curve at this point. Flows below 2 feet are partially controlled by the approach channel. The curve above 2 feet was uniform except for a small increase in C at an h_p value of 7.3 feet. This was attributed to the approach channel bend and a large pile of tors on the left bank just upstream of the flume.

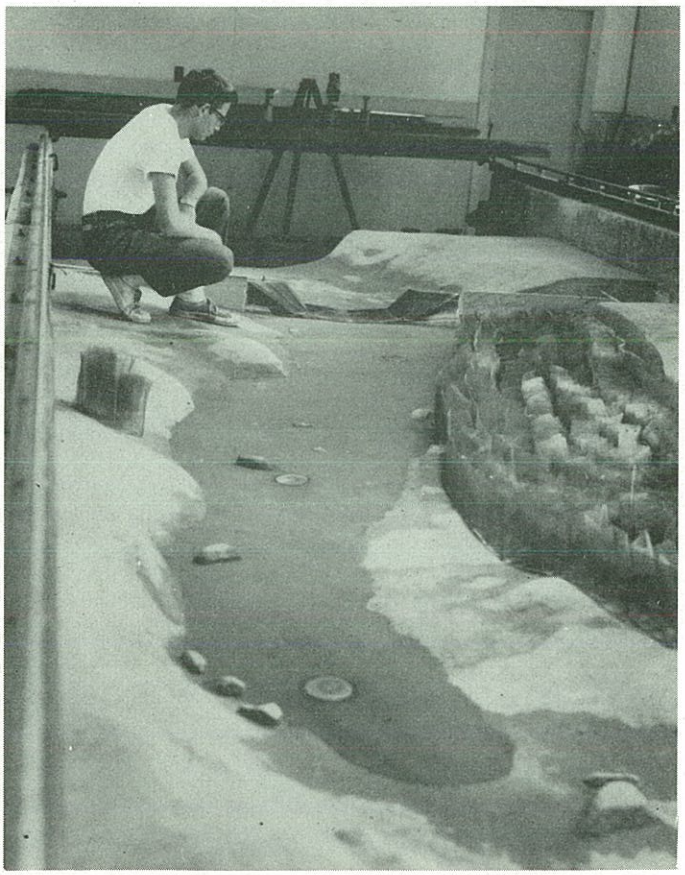

Figure 21. Walnut Gulch Flume No. 7 Model (Scale 1:30).

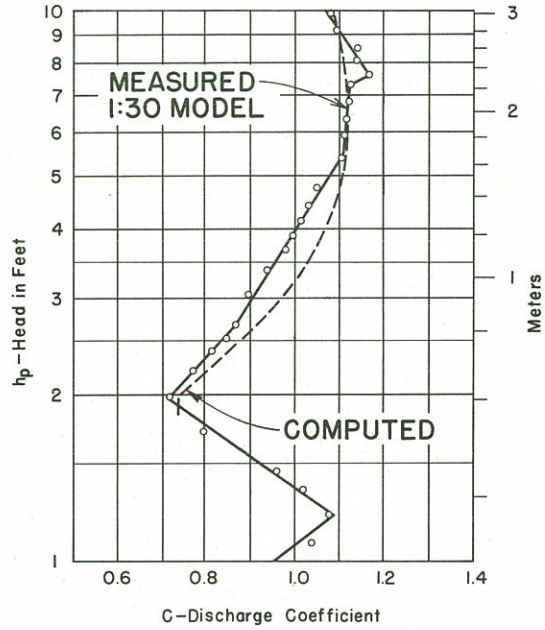

Figure 22. Discharge Coefficients for Walnut Gulch Flume No. 7.

Three floor piezometers in the approach channel were used to determine prototype n values. These n values are plotted against the average hydraulic radius, R_{123}, on Figure 23. The overall n values were high due to the bend, granite tors, and brush along the banks (see Figure 21).

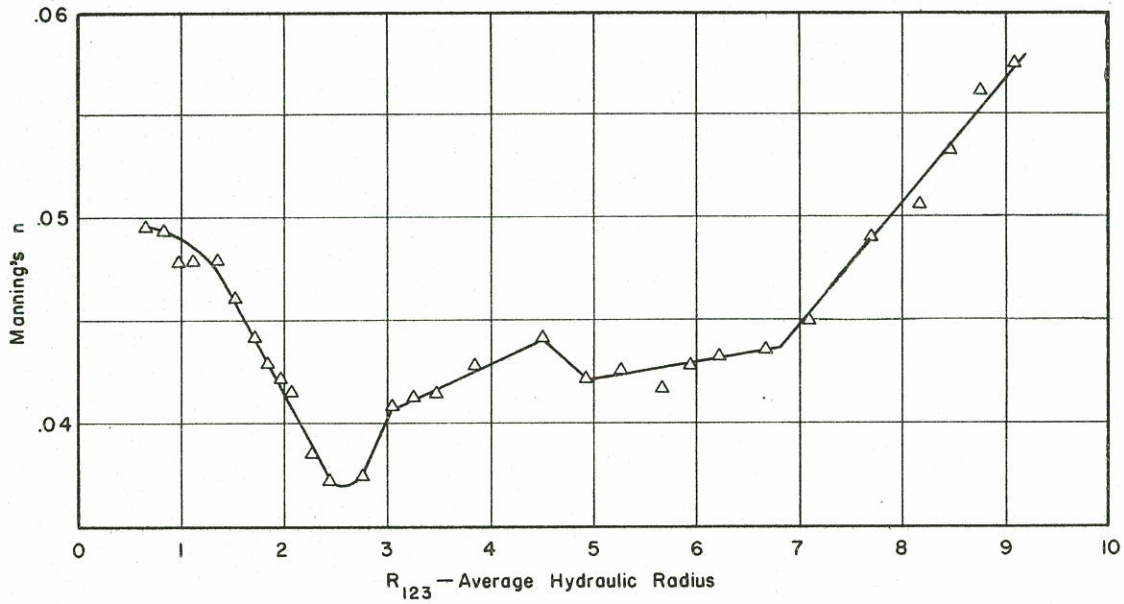

Figure 23. Prototype Values of Manning's n for 1:30 Model of Walnut Gulch Flume No. 7.

Walnut Gulch Flume No. 8

Flume 8 was constructed prior to model studies. The orientation and elevation of the flume were chosen by field engineers. The invert elevation was set too low in respect to a basalt outcrop near the flume. A low wall jetty was necessary for low-flow thalweg control. This is shown in Figure 24. The flume had a width, W, of 40 feet and a floor cross slope, S_v, of 1 on 10. The prototype structure is shown in Figure 25.

Discharge coefficients, C, are plotted against head, h_p, on Figure 26. High velocity flow produced a C value of 1.2 for h_p value of 3.5 feet. This was produced by the low invert elevation and orientation of the flume. The flume had full control of flows above an h_p value of 4.0 feet.

Three gages were used in the analysis of Manning's n. These n values expressed in prototype dimensions are plotted against the average hydraulic radius, R_{123}, on Figure 27. The sharp increase in n for hydraulic radius values less than 0.8 is produced by laminar flow occurring in the model. Therefore, these n values would not be valid for the prototype. There are no data points between hydraulic radius values of 2.0 and 2.9 . The hydraulic slope between Gage 1 and 2 was equal to or less than zero. Therefore, these data points had to be omitted from the average of Gages 1, 2, and 3. Manning's n increased linearly for hydraulic radius values greater than 2.9 feet. This increase was due to brush along the banks (see Figure 24).

Figure 24. John Pierce Points Out the Low-Flow Jetty of Walnut Gulch Flume No. 8 Model.

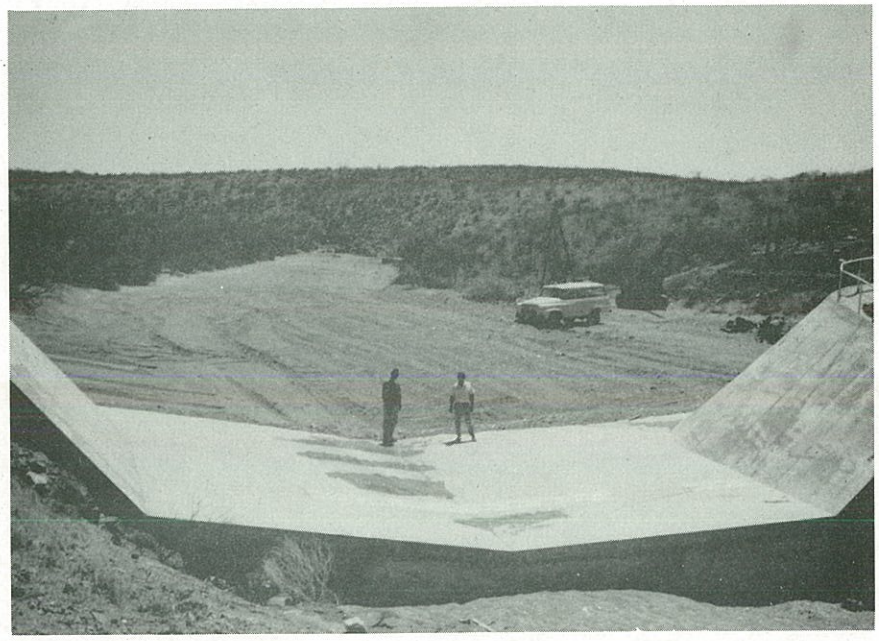

Figure 25. Walnut Gulch Flume No. 8.

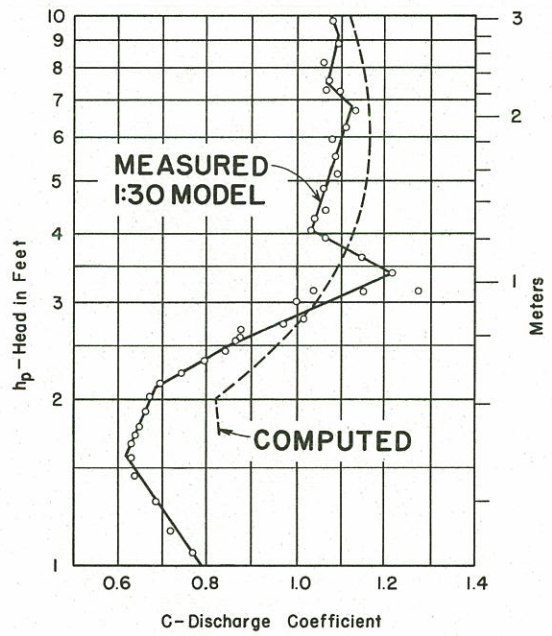

Figure 26. Discharge Coefficients for Walnut Gulch Flume No. 8.

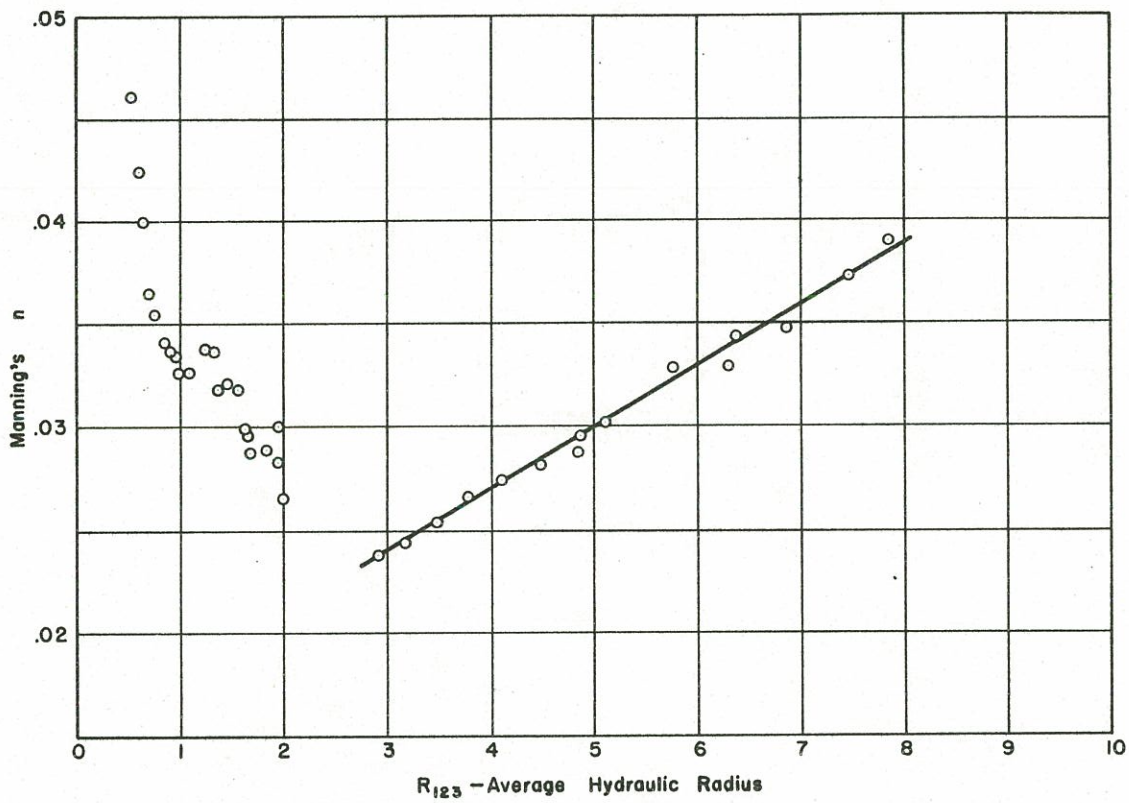

Figure 27. Prototype Values of Manning's n for 1:30 Model of Walnut Gulch Flume No. 8.

Walnut Gulch Flume No. 11

Flume No. 11 is located downstream of an S-shaped bend in the channel. This bend is shown in Figure 28. The flume had a width, W, of 30 feet and a floor cross slope, S_v, of 1:10. The prototype capacity of this flume is 6,000 cubic feet per second. The completed prototype structure is shown in Figure 29.

Measured discharge coefficients, C, are plotted against the corresponding values of head, h_p, on Figure 30. The discharge rating was excellent except for some irregularities between h_p values of 2.5 to 3.5 feet. High velocity of approach off the conglomerate point on the right bank (see Figure 28) produced these minor irregularities. There is a vertical distance of 1.5 feet from the bottom of the V to the intersection of the floor and the 1 on 1 sidewall. Therefore, there is a sharp reversal in the C curve at this point.

The measurement of Manning's n for the approach channel was difficult because of the S-shaped bend. A short reach upstream of the conglomerate point was used. The results are shown on Figure 31. Laminar flow occurs in the model for hydraulic radius values less than 0.7 foot. Therefore, these n values would not be valid for the prototype. There were some irregularities in the data as a result of the short reach and only two floor piezometers. The values of n increased generally with increase in hydraulic radius. The reach did contain secondary currents set up by the bend. Therefore, the values of Manning's n increased rapidly with hydraulic radius.

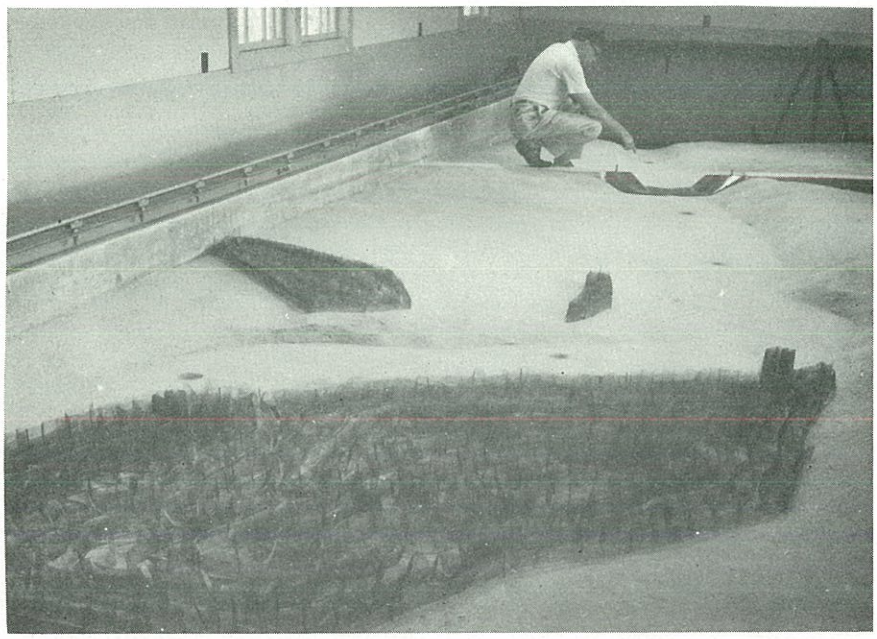

Figure 28. Approach Channel to Walnut Gulch Flume No. 11 (1:30 Model).

Figure 29. Walnut Gulch Flume No. 11 near Tombstone, Arizona.

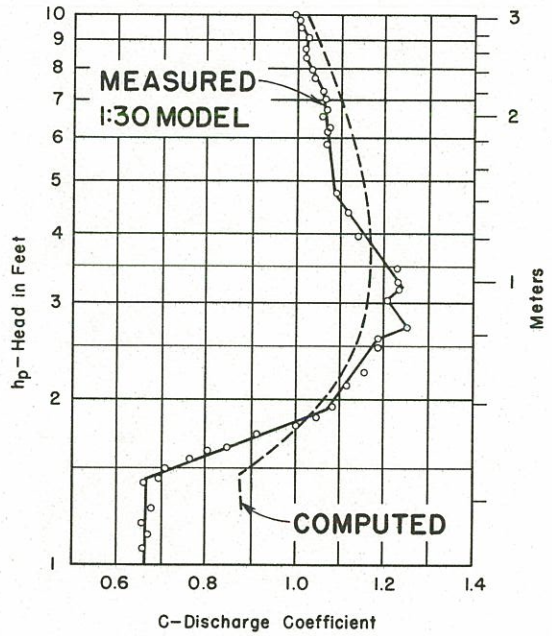

Figure 30. Discharge Coefficients for Walnut Gulch Flume No. 11.

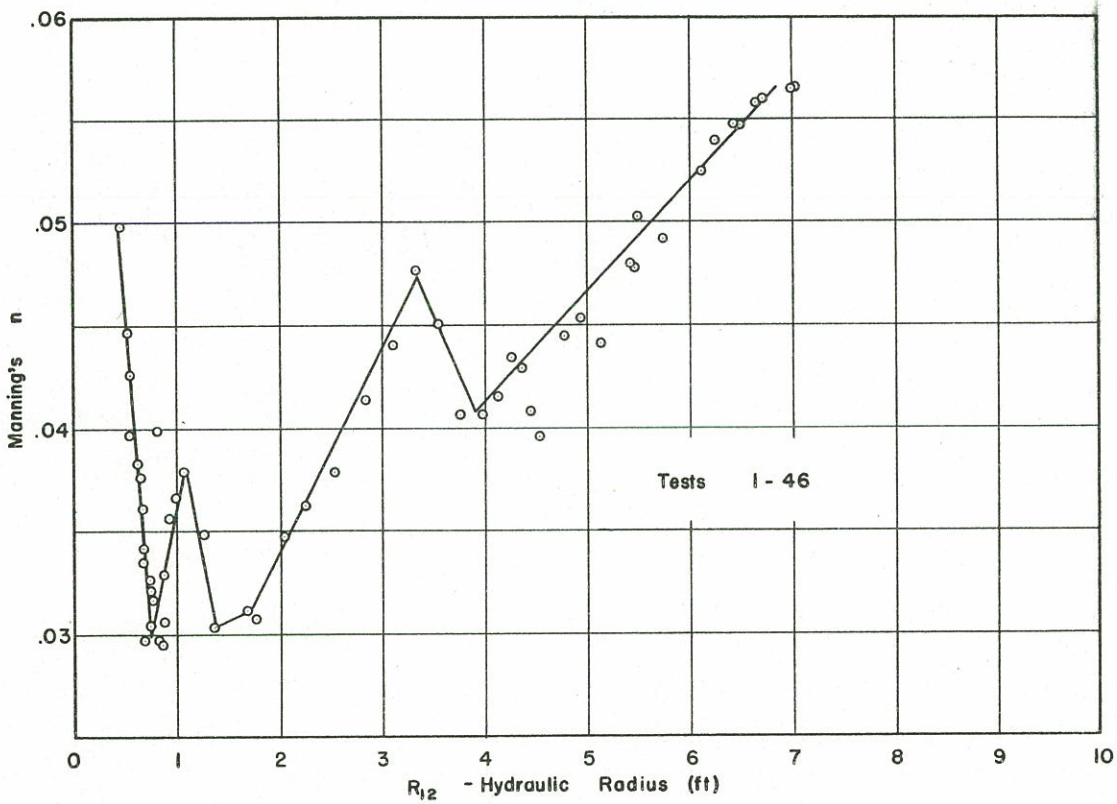

Figure 31. Prototype Values of Manning's n for 1:30 Model of Walnut Gulch Flume No. 11.

Walnut Gulch Flume No. 15

Flume No. 15 is located on a tributary to Walnut Gulch Creek some distance downstream of Flume No. 5. Flume No. 5 was too small for the design capacity of the stream. Flume No. 15 had a width, W, of 40 feet and a floor cross slope, S_v, of 1:10. The size of the flume was the same as Flumes No. 7 and 8 with a model scale of 1:30. A total of 640 feet of the approach channel was constructed in the model. This is shown in Figure 32. The completed prototype structure is shown in Figure 33.

Discharge coefficients were computed using equation (23). These C values are plotted against the corresponding values of h_p on Figure 34 and labeled "measured." Some channel control was noted for flows with h_p values less than 1.6 feet. The intersection of the floor with the 1 on 1 sidewall occurs at an h_p value of 2 feet. The rating was excellent for all h_p values greater than 1.6 feet.

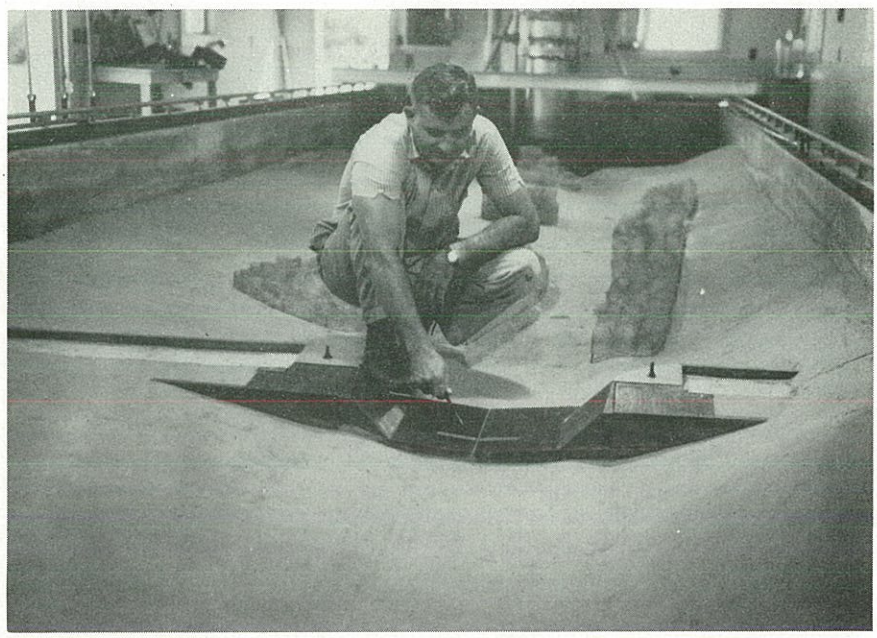

Figure 32. Upstream View of 1:30 Model of Walnut Gulch Flume No. 15. C. Rice Indicates the Head Measuring Piezometers.

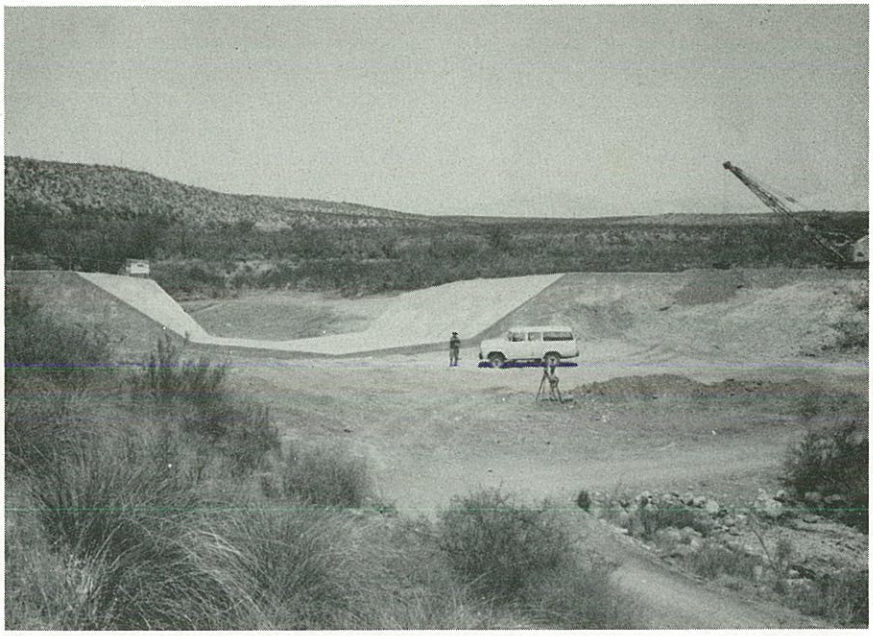

Figure 33. Downstream View of Walnut Gulch Flume No. 15 After Construction.

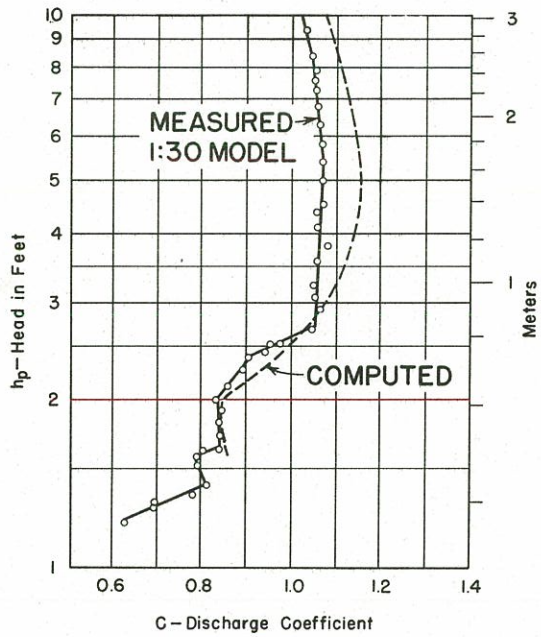

Figure 34. Discharge Coefficients for Walnut Gulch Flume No. 15.

Manning's n values were computed using equation (19). Three piezometers in the channel approach were used to measure the water surface elevation. The average values of n and hydraulic radius expressed in prototype dimensions are plotted on Figure 35. Manning's n increased from 0.035 to 0.041 as the average hydraulic radius increased from 5 to 8.5 feet. For hydraulic radius values less than 4.9 feet, the hydraulic slope using Gage 3 was equal to or less than zero. Therefore, no data points are shown for this range on Figure 35.

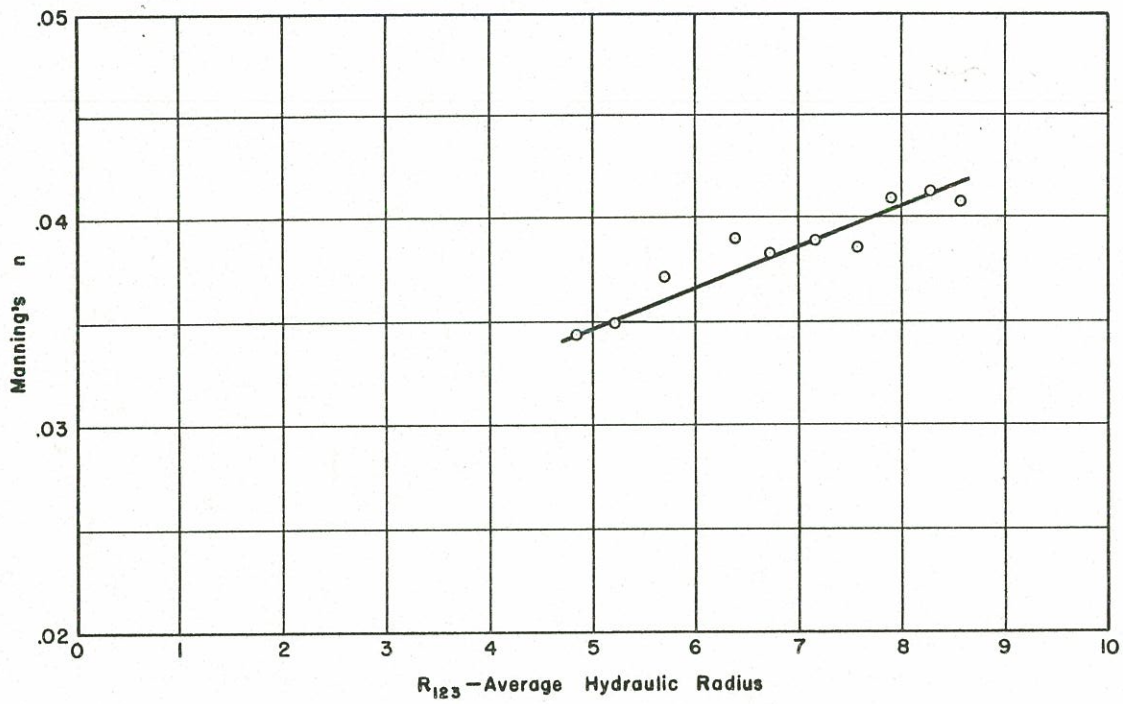

Figure 35. Prototype Values of Manning's n for 1:30 Model of Walnut Gulch Flume No. 15 Approach Channel.

Data Analysis

The horizontal length, L, between critical section and point of head measurement was computed using the following equation obtained from equation (14) (assume $\alpha = 1$):

$$L = (h_p - h_c - \frac{A_c}{2T_c} + \frac{Q^2}{2g\ A_p^{\ 2}}) \ / \ 0.03 \tag{24}$$

where

h_p = depth of flow at the point of head measurement

h_c = depth of flow at the critical section

A_c = area of critical section

T_c = width of water surface at critical section

Q = discharge

g = acceleration due to gravity

A_p = area at point of head measurement

Values of "L" were obtained for each flow solving by an iterative technique using test values for h_p and Q. The initial value of h_c was assumed to be the same as h_p (chosen low). Using the equations of the flume surfaces, A_c and T_c were computed. The critical discharge was computed using equation (8) and assuming α_c to be unity. The difference between Q_c and Q was used to add a small amount (difference/2000) to h_c. The complete process was repeated until Q_c was within one cubic foot per second (prototype) of Q. The contraction ratio, C_r, (A_p divided by the approach channel flow area) was computed at the same time. The total energy in the critical section was used to compute a backwater curve to the first gage upstream of the flume used in the channel roughness computation. The value of n obtained using this station was used in an

iterative technique to obtain the energy balance for this section. The values of L were plotted against the corresponding values of C_r on Figure 36. Flumes No. 6 and 8 were not used in the analysis. These flumes did not maintain full control of the flow for all discharges.

Both L and C_r were subject to errors of measurement. A method described by Bartlett (18) was used to obtain a linear relationship between the two variables. For the location of the fitted straight line, the pivot point used was the center of gravity of all observed points (C_r, L), that is, the point where the mean coordinates ($\bar{C}_r$, $\bar{L}$) occur. For the slope, the data points were divided into three non-overlapping groups in the C_r direction. There was an equal number of points in each of the two extreme groups. The slope of the line was computed with the following equation:

$$\text{Slope} = \frac{\bar{L}_3 - \bar{L}_1}{\bar{C}_{r3} - \bar{C}_{r1}} \tag{25}$$

where

$\bar{L}_3$ = average L for 3rd group

$\bar{L}_1$ = average L for 1st group

$\bar{C}_{r3}$ = average C_r for 3rd group

$\bar{C}_{r1}$ = average C_r for 1st group

The resulting straight line equation fitted by this method was

$$L = 0.88 + 14\ C_r \tag{26}$$

This is shown as a solid line on Figure 36.

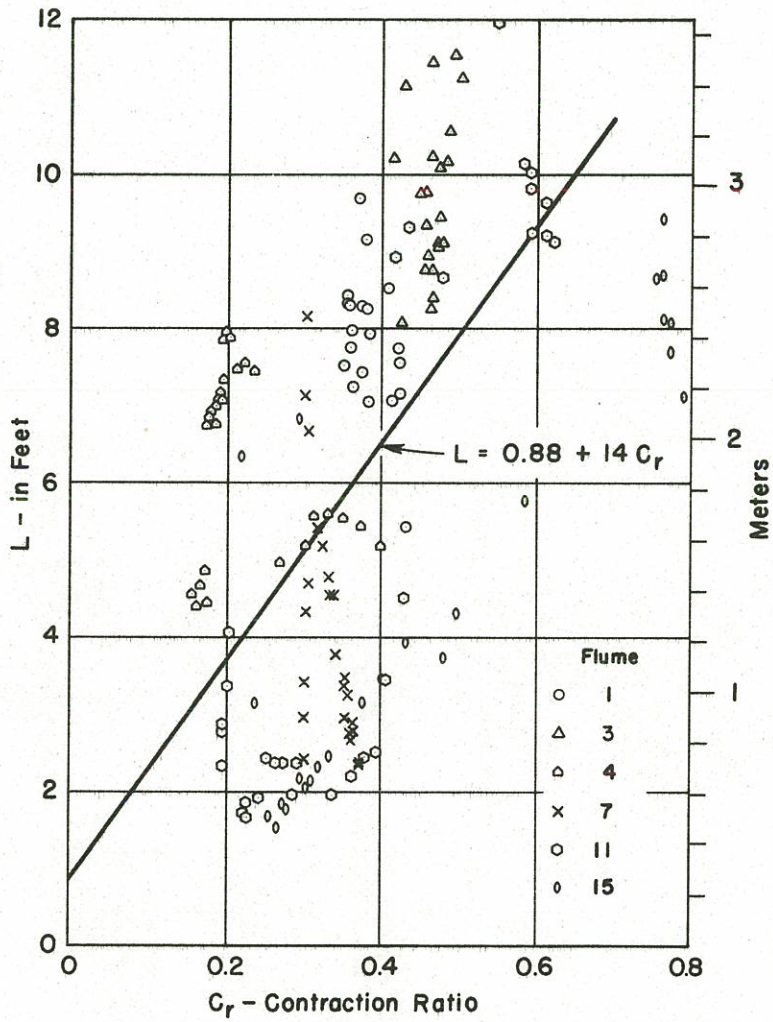

Figure 36. Computed Contraction Ratio, C_r, and Horizontal Length, L, Between Critical Section and Point of Head Measurement for Model Ratings of Walnut Gulch Flumes.

Computed Ratings

Using equations (14) and (26), a computed rating, h_p versus Q, was obtained for each flume. An initial value of h_c was selected and the area of the critical section, A_c, and the width of water surface, T_c, were computed using the surface equations of the flume. The value of discharge was then computed using equation (8) and assuming α_c to be unity. A value of L is assumed and h_p is calculated from equation (14) (assuming α_p to be unity) by iteration. A backwater computation was made from the point of head measurement to a point approximately 100 feet upstream of the flume to a known cross section. This estimates the water surface elevation and the area of the flow of the approach channel. The contraction ratio C_r was calculated and used to compute the value of L in equation (26). If L did not agree with the initially assumed value for L, the calculation was repeated. This complete iteration was continued until a balance was obtained. The C values computed from the calculated Q and h_p values are plotted as dashed lines on Figures 7, 11, 15, 17, 22, 26, 30, and 34 and labeled "computed."

Discussion of Ratings

An examination of the C versus h_p curves shows good agreement between the measured values and the computed curves. These curves can only be used for the h_p values where the sidewalls are exerting control over the flow, that is, above the reversal point of the computed "C" curves. This point on the computed C curve corresponds to the head at which contractions begin within the flume. This head is equal to the

vertical distance from the flume zero to the point of intersection at the wall with the floor of the flume. For example, Flume 7 (Figure 22) has a half width of 20 feet and a floor cross slope of 1 on 10. Therefore, there is a rise of 2 feet from the bottom of the V to the intersection of the floor and the wall. This rise corresponds to the value of h_p at the reversal of direction of the computed C line.

The measured C values for Flume 6 (Figure 17) show the greatest departure from the computed values, with a maximum deviation occurring at a head of about 4.5 feet. This is caused by wave formation in the approach because of an S-shaped bend located upstream of the flume. Flume 6 was constructed before the model studies. Thus experience would indicate the desirability of a preconstruction model study for these flumes. For those flumes modeled before construction, numbers 3, 4, 7, and 11, the coefficients agree fairly close (5 percent or less) to the computed values.

For flows within the floor of the V section (lower head range), it would be desirable to make field determinations of the discharge rates. These lower flows have a combination of channel and flume control.

The field experience with the Walnut Gulch Supercritical Flow-Measuring Flume has been good and the flumes have remained free of any sediment deposits in the measuring section.

Discussion of Manning's n

One of the most widely used formulas for open-channel flow has been named after Robert Manning (19) who published one similar to it in 1891. The original formula contained a "C_2" instead of 1/n. The formula was given as:

$$V = C_2 \, S^{1/2} \, R^{2/3} \tag{27}$$

The reciprocal of 1/n was used to correspond closely with Kutter's n. According to Rouse (20), the Manning formula is applicable only when flow is in the zone of fully developed roughness action and cannot be applied to conditions in which viscous action is appreciable. Roughness can begin to have an effect only after the laminar sublayer has become sufficiently thin to be disrupted by the surface irregularities. Despite the shortcomings of the coefficient of roughness n, Manning's is still considered to be the best suited of all formulas for estimating channel resistance.

Manning's n was developed empirically by considering that n remain a constant for a given boundary condition. However, in open-channel flow many factors are present to produce variation in "n" with depth of flow. Some of these are:

1. Secondary currents produced by bends in channel.
2. The variation of boundary shear stress around the wetted perimeter.
3. Large form elements in the channel.
4. Vegetation along the banks of a channel.
5. The cross-sectional shape of a channel is not uniquely defined by hydraulic radius.

6. The existence of suspended sediment load.

7. The bending of vegetation when depth is increased.

If a channel is infinitely wide, the hydraulic radius is equal to the depth of the flow. At smaller widths, the hydraulic radius could be correlated with depth. The Manning's n data were plotted against hydraulic radius to show the change in n with depth. Manning's n was not a constant for any of the models. However, portions of the curves for Flumes No. 6 and 7 (See Figures 20 and 23) were approximately flat for the middle range of hydraulic radius. These two flumes had a sharp bend located upstream of the reach used to measure Manning's n. Secondary currents produced by the bends could have been present in the test reach.

Flumes No. 1, 7, 8, and 11 (see Figures 8, 23, 27, and 31) showed Manning's n decreasing between hydraulic radius values of 1 and 2. The flow in the model was in a transition zone between laminar flow and complete turbulence. This would lead to the conclusion that all values of "n" with corresponding values of "R" less than 2 should be eliminated or ignored for comparison with the prototype. Manning's n, in general, increased with increasing depth of flow for all flumes.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

A new type of flow meter that will accurately and reliably measure flows that are infrequent, flashy, and heavily laden with sediment was developed in the hydraulic laboratory. The control of the flow is obtained by contracting the stream from the sides using a flume that has an 0.03 slope to maintain sediment free conditions in the throat of the flume. Eight individual models were tested in the laboratory for use in the Walnut Gulch Watershed near Tombstone, Arizona. A curved approach with a cylindroid surface was used to provide a smooth transition from the approach channel to the straight portion of the flume. The head is measured at the midpoint of the straight portion where the velocities are supercritical. This section remains free of sediment in the field.

Model ratings are portrayed in relationships of discharge coefficients to piezometric head in the supercritical flow section of the flume. Manning's n values were computed for the approach channel for each model except Flume No. 4. The contraction ratio (area of flow in flume divided by the area of the flow in the approach channel) for Flume No. 4 was small. These "n" values were plotted versus hydraulic radius to show the effect of depth of flow.

Conclusions

1. Model tests are helpful in determining flume alignment if the flume is to be placed downstream of a sharp bend in the channel.
2. Discharge ratings can be estimated for the higher flow ranges, but model and field tests are required in the lower flow ranges.
3. The location of critical depth within the flume can be predicted using the contraction ratio.
4. Discharge coefficients computed using the contraction ratio relationship for the location of critical depth satisfactorily predicted the shape of the discharge coefficient versus piezometric head curve for flows controlled by the sides of the flume.
5. The contraction ratio of the flume should be less than 0.5 for all discharge rates.
6. Manning's n increased with depth of flow.

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APPENDIX A

EXPERIMENTAL DATA

COMPUTED L AND CONTRACTION RATIO

TABLE A-1

WALNUT GULCH FLUME NO. 1, LOCATED NEAR TOMBSTONE, ARIZONA
EXP. NO. 1, FILLED APPROACH, DISCHARGE COEFFICIENTS FOR 1 TO 40 MODEL

L IS THE HORZONTAL LENGTH BETWEEN CRITICAL
DEPTH SECTION AND POINT OF HEAD MEASUREMENT

COMPUTED APPROACH AREA

TEST NO.	PROTOTYPE DISCHARGE	FLUME HEAD	C	CONTROL AREA	APPROACH AREA	CONTRACTION RATIO	L	HYDR. RADIUS	MANNING N
	C.F.S.	FT.		SQ.FT.	SQ.FT.		FT.	FT.	
1	0.19904E 05	10.304	9.077	1033.30	2871.60	0.3598	8.304	11.028	0.0630
2	0.18351E 05	9.868	8.989	975.70	2689.73	0.3627	7.984	10.394	0.0601
3	0.16928E 05	9.500	8.827	927.36	2415.33	0.3839	7.023	9.422	0.0200
4	0.15026E 05	8.832	8.831	840.31	2198.30	0.3823	8.275	8.778	0.0200
5	0.13858E 05	8.476	8.711	794.28	2055.24	0.3865	7.938	8.398	0.0200
6	0.13384E 05	8.348	8.623	777.79	2067.07	0.3763	7.425	8.427	0.0494
7	0.12103E 05	7.872	8.579	716.75	1905.15	0.3762	8.290	7.948	0.0459
8	0.11052E 05	7.540	8.401	674.45	1767.92	0.3815	7.645	7.467	0.0449
9	0.10060E 05	6.988	8.645	604.60	1667.89	0.3625	12.215	7.100	0.0443
10	0.85812E 04	6.256	8.808	512.91	1516.02	0.3383	18.461	6.526	0.0453
11	0.94059E 04	6.660	8.733	563.39	1603.74	0.3513	14.900	6.859	0.0451
12	0.87542E 04	6.304	8.876	518.89	1543.09	0.3363	19.012	6.629	0.0455
13	0.81177E 04	6.140	8.586	498.48	1445.29	0.3449	16.470	6.254	0.0464
14	0.73699E 04	5.972	8.148	477.63	1331.02	0.3588	12.584	5.811	0.0492
15	0.70015E 04	5.884	7.926	466.73	1274.71	0.3661	10.854	5.592	0.0512
16	0.61637E 04	5.580	7.593	429.19	1153.60	0.3720	9.709	5.115	0.0517
17	0.54675E 04	5.300	7.309	394.77	1037.90	0.3804	9.163	4.658	0.0484
18	0.47783E 04	5.068	6.857	366.38	881.37	0.4157	7.071	4.054	0.0369
19	0.39607E 04	4.744	6.309	326.90	755.82	0.4325	5.430	3.561	0.0390
20	0.22531E 05	11.096	9.087	1139.00	3156.20	0.3609	7.511	12.005	0.0666
21	0.24376E 05	11.544	9.203	1199.30	3353.76	0.3576	8.318	12.672	0.0678
22	0.26172E 05	12.012	9.245	1262.70	3535.76	0.3571	8.440	13.280	0.0693
23	0.20145E 05	10.440	8.990	1051.40	2892.44	0.3635	7.263	11.100	0.0635
24	0.21432E 05	10.772	9.080	1095.60	3039.25	0.3605	7.757	11.606	0.0654
25	0.36743E 04	4.488	6.388	295.86	720.77	0.4105	8.527	3.418	0.0373
26	0.34051E 04	4.396	6.116	284.74	670.01	0.4250	7.171	3.204	0.0369
27	0.30601E 04	4.204	5.895	261.57	616.57	0.4242	7.561	2.967	0.0375
28	0.27383E 04	4.024	5.689	239.94	567.90	0.4225	7.766	2.748	0.0376
29	0.24357E 04	3.836	5.704	218.05	522.85	0.4170	8.130	2.544	0.0393
30	0.19672E 04	3.476	5.893	179.04	440.22	0.4067	9.528	2.163	0.0367
31	0.15999E 04	3.124	6.259	144.61	386.88	0.3738	12.072	1.916	0.0384
32	0.13519E 04	2.908	6.327	125.30	330.30	0.3794	11.908	1.650	0.0359
33	0.17962E 04	3.284	6.203	159.80	418.05	0.3823	12.062	2.061	0.0369
34	0.12963E 04	2.820	6.551	117.83	323.43	0.3643	13.782	1.617	0.0357
35	0.11546E 04	2.728	6.340	110.27	287.42	0.3837	11.275	1.445	0.0351
36	0.10003E 04	2.568	6.388	97.71	256.18	0.3814	11.052	1.295	0.0352
37	0.87491E 03	2.428	6.428	87.35	223.86	0.3902	10.796	1.227	0.0345
38	0.78728E 03	2.316	6.509	79.48	205.19	0.3873	10.976	1.141	0.0345
39	0.63296E 03	2.044	7.152	61.90	191.34	0.3235	15.044	1.076	0.0402
40	0.49848E 03	1.824	7.488	49.29	159.80	0.3085	16.326	1.017	0.0424
41	0.44454E 03	1.724	7.689	44.04	136.49	0.3226	17.169	1.206	0.0439
42	0.40760E 03	1.684	7.476	42.02	128.39	0.3272	14.992	1.154	0.0455
43	0.35863E 03	1.604	7.429	38.12	117.37	0.3248	13.909	1.080	0.0465
44	0.29994E 03	1.456	7.915	31.41	107.05	0.2934	16.290	1.008	0.0486
45	0.25359E 03	1.324	8.487	25.97	98.30	0.2642	19.212	0.944	0.0505
46	0.20846E 03	1.172	9.463	20.35	92.55	0.2199	24.760	0.897	0.0546
47	0.18427E 03	1.084	10.168	17.41	88.31	0.1971	28.828	0.862	0.0554
48	0.14471E 03	0.924	11.904	12.65	84.52	0.1496	39.333	0.830	0.0605
49	0.99169E 02	0.712	15.654	7.51	89.51	0.0839	63.214	0.872	0.0700

TABLE A-2

WALNUT GULCH FLUME NO. 3, LOCATED NEAR TOMBSTONE, ARIZONA
DISCHARGE COEFICIENTS FOR 1 TO 32 MODEL

L IS THE HORZONTAL LENGTH BETWEEN CRITICAL
DEPTH SECTION AND POINT OF HEAD MEASUREMENT

COMPUTED APPROACH AREA

TEST NO.	PROTOTYPE DISCHARGE	FLUME HEAD	C	CONTROL AREA	APPROACH AREA	CONTRACTION RATIO	L	HYDR. RADIUS	MANNING N
	C.F.S.	FT.		SQ.FT.	SQ.FT.		FT.	FT.	
1	0.76804E 04	11.203	8.559	385.10	764.00	0.5041	11.245	9.529	0.0389
2	0.69899E 04	10.602	8.680	356.67	718.96	0.4961	11.542	9.168	0.0373
3	0.57312E 04	9.514	8.783	307.10	628.20	0.4889	10.577	8.389	0.0335
4	0.46109E 04	8.426	8.915	259.90	544.93	0.4769	10.081	7.607	0.0333
5	0.53402E 04	9.159	8.805	291.43	599.64	0.4860	10.175	8.128	0.0333
6	0.49413E 04	8.778	8.838	274.91	569.87	0.4824	9.842	7.848	0.0334
7	0.45315E 04	8.394	8.825	258.54	538.33	0.4803	9.103	7.542	0.0340
8	0.40849E 04	7.914	8.892	238.50	503.12	0.4740	9.054	7.187	0.0345
9	0.35850E 04	7.379	8.898	216.74	463.10	0.4680	8.395	6.766	0.0367
10	0.29905E 04	6.666	8.965	188.56	404.86	0.4657	8.253	6.118	0.0333
11	0.24062E 04	5.866	9.115	158.19	342.34	0.4621	8.966	5.372	0.0285
12	0.19648E 04	5.245	9.107	135.50	295.33	0.4588	8.767	4.771	0.0289
13	0.20865E 04	5.367	9.281	139.89	335.98	0.4164	10.200	5.292	0.0487
15	0.17687E 04	4.976	9.006	125.92	294.29	0.4279	8.084	4.758	0.0461
16	0.15748E 04	4.608	9.190	113.03	250.64	0.4510	9.727	4.167	0.0285
17	0.13948E 04	4.327	9.095	103.35	226.68	0.4559	9.336	3.828	0.0276
18	0.11773E 04	3.850	9.410	87.34	196.64	0.4442	12.772	3.388	0.0228
19	0.95479E 03	3.434	9.293	73.73	167.17	0.4411	13.327	2.938	0.0235
20	0.78408E 03	3.146	8.862	64.51	138.33	0.4664	11.466	2.481	0.0221
21	0.75112E 03	3.130	8.563	64.01	134.22	0.4769	9.420	2.414	0.0243
22	0.69244E 03	2.986	8.550	59.46	127.41	0.4667	10.223	2.302	0.0252
25	0.57080E 03	2.746	8.116	51.99	109.65	0.4741	9.104	2.007	0.0267
26	0.49857E 03	2.586	7.839	47.07	100.78	0.4670	8.749	1.856	0.0287
27	0.41602E 03	2.362	7.605	40.26	87.62	0.4595	9.784	1.629	0.0284
28	0.33973E 03	2.141	7.302	33.66	78.21	0.4303	11.153	1.464	0.0308
29	0.27543E 03	1.914	7.372	27.01	67.60	0.3995	14.926	1.275	0.0297
30	0.25070E 03	1.802	7.802	23.94	65.39	0.3661	18.325	1.236	0.0306
31	0.23512E 03	1.751	7.863	22.60	62.58	0.3611	18.598	1.185	0.0307
32	0.21507E 03	1.706	7.675	21.46	59.46	0.3608	16.659	1.129	0.0324
33	0.19428E 03	1.642	7.628	19.88	54.27	0.3663	15.843	1.034	0.0316
34	0.17041E 03	1.578	7.390	18.36	49.21	0.3730	13.484	0.941	0.0320
35	0.14139E 03	1.514	6.801	16.90	41.70	0.4052	9.034	0.802	0.0313
36	0.11585E 03	1.450	6.207	15.50			5.570		
37	0.94998E 02	1.386	5.698	14.16			3.338		
38	0.76404E 02	1.322	5.158	12.88			1.676		
39	0.57462E 02	1.242	4.535	11.37			0.649		
40	0.47036E 02	1.162	4.384	9.95			0.554		

TABLE A-3

WALNUT GULCH FLUME NO. 4, LOCATED NEAR TOMBSTONE, ARIZONA
EXP. NO. 2, PREDICTED FILL, DISCHARGE COEFFICIENTS FOR 1 TO 30 MODEL

L IS THE HORZONTAL LENGTH BETWEEN CRITICAL
DEPTH SECTION AND POINT OF HEAD MEASUREMENT

COMPUTED APPROACH AREA

TEST NO.	PROTOTYPE DISCHARGE	FLUME HEAD	C	CONTROL AREA	APPROACH AREA	CONTRACTION RATIO	L	HYDR. RADIUS	MANNING N
	C.F.S.	FT.		SQ.FT.	SQ.FT.		FT.	FT.	
34	0.15479E 03	2.349	9.283	15.64	51.55	0.3035	5.164	1.166	0.0200
35	0.14133E 03	2.214	9.537	14.41	45.78	0.3148	5.559	1.052	0.0200
36	0.12698E 03	2.079	9.704	13.21	39.73	0.3326	5.579	0.928	0.0200
37	0.11367E 03	1.950	9.849	12.11	34.27	0.3533	5.516	0.813	0.0200
38	0.10041E 03	1.815	10.003	10.98	29.26	0.3752	5.423	0.704	0.0200
39	0.85133E 02	1.653	10.151	9.68	24.07	0.4019	5.181	0.588	0.0200
40	0.65415E 02	1.419	10.416	7.88			5.004		
41	0.49837E 02	1.209	10.685	6.37			4.929		
42	0.21389E 04	9.591	6.121	134.37	856.71	0.1568	4.545	5.649	0.0200
43	0.18910E 04	9.039	6.201	121.69	750.61	0.1621	4.401	5.100	0.0200
44	0.16750E 04	8.499	6.324	109.85	655.17	0.1677	4.649	4.554	0.0200
45	0.14729E 04	7.989	6.403	99.21	558.83	0.1775	4.414	3.959	0.0200
46	0.15074E 04	8.049	6.443	100.44	577.30	0.1740	4.851	4.075	0.0200
47	0.12822E 04	7.308	6.820	85.79	488.21	0.1757	6.738	4.668	0.0200
48	0.11653E 04	6.954	6.932	79.18	443.44	0.1786	6.850	4.602	0.0200
49	0.10741E 04	6.666	7.025	73.98	409.28	0.1808	6.907	4.537	0.0200
50	0.99822E 03	6.408	7.131	69.46	381.64	0.1820	7.132	4.441	0.0200
51	0.87696E 03	6.009	7.228	62.73	336.54	0.1864	6.738	4.348	0.0200
52	0.79907E 03	5.712	7.368	57.93	309.29	0.1873	6.994	4.271	0.0200
53	0.69161E 03	5.289	7.553	51.38	271.62	0.1892	7.068	4.057	0.0200
54	0.57478E 03	4.785	7.810	44.05	229.48	0.1920	7.183	3.645	0.0200
55	0.50133E 03	4.449	7.974	39.43	201.80	0.1954	7.063	3.363	0.0200
56	0.19787E 03	2.715	8.861	19.16	71.12	0.2695	4.950	1.532	0.0200
57	0.45509E 03	4.209	8.154	36.28	184.35	0.1968	7.320	3.168	0.0200
58	0.41945E 03	4.005	8.357	33.68	171.08	0.1969	7.828	3.011	0.0200
59	0.38213E 03	3.798	8.522	31.13	156.17	0.1993	7.962	2.824	0.0200
60	0.34526E 03	3.591	8.666	28.66	140.73	0.2037	7.889	2.617	0.0200
61	0.30114E 03	3.339	8.804	25.78	121.19	0.2127	7.474	2.339	0.0200
62	0.25540E 03	3.039	9.077	22.50	100.88	0.2230	7.538	2.030	0.0200
63	0.22173E 03	2.805	9.290	20.07	85.21	0.2355	7.426	1.775	0.0200

TABLE A-4

WALNUT GULCH FLUME NO. 6 , LOCATED NEAR TOMBSTONE, ARIZONA
DISCHARGE COEFICIENTS FOR 1 TO 30 MODEL

L IS THE HORZONTAL LENGTH BETWEEN CRITICAL
DEPTH SECTION AND POINT OF HEAD MEASUREMENT

COMPUTED APPROACH AREA

TEST NO.	PROTOTYPE DISCHARGE	FLUME HEAD	C	CONTROL AREA	APPROACH AREA	CONTRACTION RATIO	L	HYDR. RADIUS	MANNING N
	C.F.S.	FT.		SQ.FT.	SQ.FT.		FT.	FT.	
139	0.73301E 03	2.808	5.475	79.89	148.64	0.5375	4.760	1.646	0.0272
140	0.65512E 03	2.703	5.382	74.03	135.69	0.5456	4.064	1.512	0.0274
143	0.63836E 03	2.628	5.627	69.98	134.04	0.5221	5.406	1.495	0.0271
144	0.58956E 03	2.571	5.490	66.98	120.50	0.5558	4.455	1.354	0.0246
145	0.54125E 03	2.487	5.476	62.67	117.47	0.5335	4.256	1.322	0.0277
146	0.48654E 03	2.397	5.398	58.22	108.40	0.5371	3.699	1.227	0.0282
147	0.44335E 03	2.277	5.592	52.54	97.62	0.5382	4.510	1.112	0.0257
148	0.39938E 03	2.157	5.768	47.14	90.83	0.5191	5.245	1.038	0.0260
149	0.37868E 03	2.097	5.868	44.56	88.05	0.5061	5.672	1.008	0.0264
150	0.34905E 03	1.992	6.150	40.21	79.79	0.5039	7.076	0.918	0.0238
151	0.32416E 03	1.914	6.312	37.12	75.65	0.4907	7.801	0.873	0.0237
152	0.28694E 03	1.743	7.059	30.79	67.20	0.4582	12.176	0.779	0.0206
153	0.26160E 03	1.635	7.552	27.09	64.94	0.4172	15.206	0.754	0.0212
154	0.23336E 03	1.518	8.110	23.35	62.65	0.3727	18.650	0.728	0.0222
155	0.63836E 03	2.640	5.563	70.62	133.58	0.5287	5.025	1.490	0.0271
156	0.46682E 03	2.340	5.500	55.48	100.65	0.5512	4.132	1.144	0.0252
157	0.48481E 03	2.367	5.551	56.77	103.71	0.5474	4.447	1.177	0.0251
158	0.21463E 03	1.407	9.018	20.06	62.05	0.3233	25.287	0.722	0.0213
159	0.19925E 03	1.347	9.336	18.39	60.47	0.3041	27.217	0.704	0.0219
160	0.18327E 03	1.311	9.189	17.42	55.86	0.3118	25.122	0.652	0.0227
161	0.16434E 03	1.236	9.547	15.48	48.36	0.3202	26.899	0.568	0.0191
162	0.15054E 03	1.197	9.475	14.52	49.22	0.2950	25.443	0.577	0.0238
163	0.13787E 03	1.167	9.246	13.80	45.43	0.3038	22.875	0.535	0.0245
164	0.12121E 03	1.137	8.675	13.10			17.962		
165	0.11007E 03	1.110	8.366	12.49			15.406		
166	0.97751E 02	1.095	7.686	12.15			11.088		
167	0.89026E 02	1.077	7.296	11.76			8.854		
168	0.79611E 02	1.047	7.002	11.11			7.251		
169	0.64872E 02	0.990	6.562	9.93			5.167		
170	0.43921E 02	0.889	6.523	7.31			5.770		
171	0.14601E 03	1.227	8.638	15.26			19.047		

TABLE A-4 (Continued)

WALNUT GULCH FLUME NO. 6 , LOCATED NEAR TOMBSTONE, ARIZONA
DISCHARGE COEFICIENTS FOR 1 TO 30 MODEL

L IS THE HORZONTAL LENGTH BETWEEN CRITICAL
DEPTH SECTION AND POINT OF HEAD MEASUREMENT

COMPUTED APPROACH AREA

TEST NO.	PROTOTYPE DISCHARGE	FLUME HEAD	C	CONTROL AREA	APPROACH AREA	CONTRACTION RATIO	L	HYDR. RADIUS	MANNING N
	C.F.S.	FT.		SQ.FT.	SQ.FT.		FT.	FT.	
222	0.10597E 05	9.267	9.176	562.66	1218.24	0.4619	11.219	9.464	0.0260
223	0.98816E 04	9.021	8.963	542.58	1144.65	0.4740	9.076	9.140	0.0245
224	0.90278E 04	8.568	8.947	505.92	1066.61	0.4743	9.335	8.723	0.0236
225	0.81740E 04	8.073	8.969	466.34	992.09	0.4701	10.149	8.280	0.0251
226	0.73907E 04	7.653	8.881	433.15	917.11	0.4723	9.917	7.817	0.0251
227	0.68781E 04	7.395	8.759	412.93	863.45	0.4782	9.217	7.474	0.0236
228	0.63753E 04	7.107	8.682	390.52	815.18	0.4791	9.106	7.155	0.0247
229	0.59149E 04	6.861	8.547	371.52	767.23	0.4842	8.427	6.831	0.0247
230	0.54165E 04	6.582	8.391	350.11	714.71	0.4899	7.802	6.466	0.0247
231	0.49497E 04	6.276	8.303	326.81	665.52	0.4911	7.967	6.117	0.0238
232	0.44040E 04	5.781	8.468	289.53	615.07	0.4707	11.377	5.748	0.0221
233	0.46840E 04	6.006	8.454	306.41	642.84	0.4766	10.269	5.952	0.0228
234	0.57083E 04	6.750	8.478	362.98	745.37	0.4870	8.097	6.680	0.0247
235	0.45671E 04	5.913	8.459	299.42	630.21	0.4751	10.703	5.860	0.0217
236	0.42137E 04	5.520	8.745	270.06	607.09	0.4448	15.748	5.688	0.0223
237	0.36803E 04	5.082	8.751	237.72	554.99	0.4283	18.918	5.293	0.0211
238	0.33264E 04	4.683	9.041	208.58	537.25	0.3882	26.934	5.156	0.0218
239	0.29912E 04	4.416	8.944	189.27	500.63	0.3781	29.156	4.864	0.0191
240	0.27260E 04	4.437	8.089	190.78	434.21	0.4394	17.318	4.316	0.0181
241	0.28847E 04	4.398	8.683	187.97	476.59	0.3944	25.583	4.669	0.0181
242	0.26096E 04	4.314	8.105	181.93	425.53	0.4275	19.043	4.243	0.0191
243	0.22655E 04	4.200	7.348	173.75	365.22	0.4757	12.017	3.715	0.0202
244	0.19910E 04	4.011	6.957	160.25	327.82	0.4888	10.421	3.378	0.0217
245	0.31627E 04	4.554	8.996	199.23	519.59	0.3834	27.935	5.017	0.0208
246	0.17549E 04	3.687	7.022	137.27	302.94	0.4531	15.891	3.151	0.0171
247	0.15828E 04	3.567	6.679	128.81	274.40	0.4694	14.244	2.885	0.0166
248	0.13797E 04	3.420	6.295	118.51	244.86	0.4840	12.192	2.604	0.0195
249	0.11909E 04	3.207	6.382	104.21	214.29	0.4863	13.141	2.307	0.0164
250	0.10455E 04	3.117	6.016	98.44	184.63	0.5332	9.498	2.012	0.0164
251	0.92181E 03	3.000	5.836	91.19	165.74	0.5502	7.762	1.821	0.0182
252	0.79907E 03	2.886	5.573	84.39	146.87	0.5746	5.547	1.628	0.0200
253	0.18953E 05	12.234	10.081	814.48	2403.60	0.3389	25.785	9.948	0.0200
256	0.16116E 05	11.385	9.738	740.60	2003.61	0.3696	18.880	8.466	0.0308
257	0.15091E 05	10.950	9.768	703.32	1857.90	0.3786	19.065	7.909	0.0287
258	0.14334E 05	10.614	9.800	674.78	1751.73	0.3852	19.447	7.502	0.0279
259	0.13248E 05	10.125	9.836	633.65	1597.82	0.3966	19.901	6.905	0.0273
260	0.12054E 05	9.447	10.096	577.43	1438.20	0.4015	24.070	7.558	0.0251
261	0.11175E 05	8.853	10.470	528.94	1356.82	0.3898	30.746	8.076	0.0230
262	0.10124E 05	8.088	11.074	467.53	1294.64	0.3611	42.953	8.396	0.0258
263	0.89381E 04	8.502	8.976	500.62	1061.51	0.4716	9.702	8.693	0.0251
264	0.95045E 04	8.850	8.910	528.69	1110.73	0.4760	8.688	8.963	0.0257
265	0.10131E 05	9.135	8.993	551.87	1169.23	0.4720	9.292	9.266	0.0255
266	0.11100E 05	9.423	9.338	575.46	1273.10	0.4520	13.047	8.936	0.0255

TABLE A-5

WALNUT GULCH FLUME NO. 7, LOCATED NEAR TOMBSTONE, ARIZONA
EXP. NO. 4, PREDICTED FILL, DISCHARGE COEFFICIENTS FOR 1 TO 30 MODEL

L IS THE HORZONTAL LENGTH BETWEEN CRITICAL
DEPTH SECTION AND POINT OF HEAD MEASUREMENT

COMPUTED APPROACH AREA

TEST NO.	PROTOTYPE DISCHARGE	FLUME HEAD	C	CONTROL AREA	APPROACH AREA	CONTRACTION RATIO	L	HYDR. RADIUS	MANNING N
	C.F.S.	FT.		SQ.FT.	SQ.FT.		FT.	FT.	
80	0.90801E 04	11.279	8.257	495.10	1643.82	0.3012	2.419	8.996	0.0576
81	0.84698E 04	10.772	8.394	465.91	1545.36	0.3015	2.950	8.513	0.0562
82	0.74701E 04	9.887	8.679	416.15	1374.51	0.3028	4.309	8.104	0.0507
83	0.80089E 04	10.382	8.501	443.80	1466.71	0.3026	3.407	8.122	0.0533
84	0.65887E 04	9.164	8.801	376.62	1226.43	0.3071	4.701	7.756	0.0491
85	0.60144E 04	8.522	9.169	342.37	1137.14	0.3011	7.132	7.503	0.0450
86	0.50566E 04	7.646	9.372	296.92	980.27	0.3029	8.171	6.881	0.0433
87	0.55180E 04	8.135	9.150	322.11	1051.76	0.3063	6.665	7.194	0.0436
88	0.45124E 04	7.319	9.042	280.34	877.56	0.3195	5.415	6.443	0.0428
89	0.39997E 04	6.845	9.026	256.66	788.42	0.3255	5.183	6.065	0.0417
90	0.34718E 04	6.341	8.963	231.97	696.51	0.3330	4.786	5.942	0.0426
91	0.30696E 04	5.930	8.909	212.19	629.25	0.3372	4.552	5.710	0.0423
92	0.25924E 04	5.390	8.877	186.70	552.41	0.3380	4.655	5.334	0.0442
93	0.19994E 04	4.781	8.407	158.64	447.53	0.3545	2.946	4.630	0.0428
94	0.17154E 04	4.409	8.276	141.85	396.78	0.3575	2.888	4.279	0.0415
95	0.15296E 04	4.163	8.129	130.89	363.05	0.3605	2.728	3.998	0.0413
96	0.13541E 04	3.911	7.991	119.79	330.46	0.3625	2.678	3.716	0.0409
97	0.12023E 04	3.674	7.875	109.46	299.54	0.3654	2.789	3.470	0.0374
98	0.10021E 04	3.383	7.527	96.93	259.62	0.3733	2.351	3.122	0.0372
99	0.80646E 03	3.047	7.195	82.66	221.34	0.3734	2.374	2.750	0.0385
100	0.63491E 03	2.687	6.955	67.61	188.52	0.3587	3.258	2.405	0.0415
101	0.57132E 03	2.555	6.792	62.16	175.47	0.3542	3.475	2.262	0.0422
102	0.50034E 03	2.417	6.507	56.49	159.53	0.3541	3.392	2.079	0.0429
103	0.41678E 03	2.228	6.179	48.79	141.29	0.3453	3.777	1.864	0.0442
104	0.32263E 03	1.997	5.782	39.49	119.65	0.3300	4.466	1.603	0.0461
105	0.24972E 03	1.733	6.379	29.74	104.78	0.2838	7.466	1.419	0.0479
106	0.20013E 03	1.472	7.688	21.45	98.49	0.2178	14.732	1.340	0.0474
107	0.17578E 03	1.364	8.170	18.42	93.80	0.1964	17.258	1.281	0.0479
108	0.14029E 03	1.220	8.617	14.74	82.38	0.1789	18.785	1.136	0.0479
109	0.99477E 02	1.079	8.306	11.53	61.35	0.1879	14.627	0.860	0.0494
110	0.68421E 02	0.977	7.323	9.45	42.68	0.2215	8.206	0.608	0.0496
111	0.50675E 02	0.887	6.905	7.79	36.22	0.2151	5.914	0.519	0.0574

TABLE A-6

WALNUT GULCH FLUME NO. 8, LOCATED NEAR TOMBSTONE, ARIZONA
DISCHARGE COEFICIENTS FOR 1 TO 30 MODEL

L IS THE HORZONTAL LENGTH BETWEEN CRITICAL
DEPTH SECTION AND POINT OF HEAD MEASUREMENT

COMPUTED APPROACH AREA

TEST NO.	PROTOTYPE DISCHARGE	FLUME HEAD	C	CONTROL AREA	APPROACH AREA	CONTRACTION RATIO	L	HYDR. RADIUS	MANNING N
	C.F.S.	FT.		SQ.FT.	SQ.FT.		FT.	FT.	
51	0.17785E 04	4.429	8.526	142.11	225.21	0.6310	4.168	3.758	0.0211
52	0.16405E 04	4.279	8.337	135.42	211.12	0.6414	3.544	3.556	0.0217
53	0.14926E 04	4.069	8.257	126.13	196.10	0.6432	3.583	3.336	0.0221
54	0.13137E 04	3.415	9.738	97.75	191.65	0.5100	16.149	3.271	0.0225
55	0.10958E 04	3.163	9.221	87.04	163.27	0.5331	13.512	2.841	0.0225
56	0.88287E 03	3.019	8.021	80.98	139.69	0.5797	6.365	2.471	0.0283
57	0.60337E 03	2.599	7.001	63.53	105.14	0.6042	4.194	1.907	0.0296
58	0.13856E 04	3.649	9.200	107.81	191.51	0.5630	10.493	3.268	0.0214
59	0.73597E 03	2.749	7.794	69.72	123.19	0.5659	7.045	2.205	0.0290
60	0.14601E 04	3.940	8.527	120.46	193.28	0.6232	5.234	3.295	0.0213
61	0.12136E 04	3.160	10.228	86.91	186.67	0.4656	22.853	3.196	0.0215
62	0.98984E 03	3.166	8.316	87.17	150.58	0.5789	7.151	2.643	0.0266
63	0.80400E 03	2.824	8.149	72.83	134.31	0.5423	8.575	2.385	0.0301
64	0.10782E 05	12.040	8.627	540.13	1103.15	0.4896	6.435	9.070	0.0390
65	0.96839E 04	11.410	8.577	502.82	998.40	0.5036	5.263	8.381	0.0373
66	0.86138E 04	10.780	8.489	466.31	889.80	0.5241	3.983	7.970	0.0347
67	0.73686E 04	9.814	8.648	411.85	772.92	0.5329	4.415	7.396	0.0329
68	0.62461E 04	8.905	8.766	362.28	638.76	0.5672	4.660	6.301	0.0200
69	0.52341E 04	8.227	8.485	326.38	566.29	0.5763	2.605	5.682	0.0328
70	0.43488E 04	7.279	8.787	277.71	467.59	0.5939	4.058	6.360	0.0288
71	0.62397E 04	8.896	8.774	361.80	672.60	0.5379	4.704	6.584	0.0344
72	0.46214E 04	7.627	8.588	295.37	491.48	0.6010	2.993	6.484	0.0301
73	0.42802E 04	7.327	8.547	280.13	461.09	0.6075	2.740	6.321	0.0296
74	0.38933E 04	6.715	9.079	249.60	430.22	0.5802	5.845	6.133	0.0281
75	0.33781E 04	6.268	8.895	227.77	383.35	0.5942	4.660	5.805	0.0274
76	0.30030E 04	5.956	8.647	212.76	348.28	0.6109	3.365	5.383	0.0267
77	0.26826E 04	5.560	8.707	194.00	318.41	0.6093	3.864	5.010	0.0254
78	0.23755E 04	5.176	8.725	176.10	288.99	0.6094	4.229	4.630	0.0244
79	0.20763E 04	4.861	8.494	161.63	258.37	0.6256	3.417	4.220	0.0238
80	0.63935E 03	2.692	7.006	67.36	108.31	0.6219	3.574	1.960	0.0288
81	0.58562E 03	2.569	6.925	62.29	103.16	0.6039	4.086	1.874	0.0299
82	0.53189E 03	2.464	6.730	57.99	98.57	0.5884	4.090	1.796	0.0318
83	0.46790E 03	2.359	6.352	53.71	89.94	0.5972	3.377	1.650	0.0322
84	0.40269E 03	2.242	5.934	48.97	80.24	0.6103	2.789	1.482	0.0319
85	0.35171E 03	2.146	5.560	45.10	74.64	0.6042	2.320	1.385	0.0336
86	0.31001E 03	2.032	5.378	40.53	68.63	0.5905	2.685	1.279	0.0338
87	0.26185E 03	1.909	5.298	35.77	60.02	0.5960	2.545	1.126	0.0326
88	0.21808E 03	1.789	5.189	31.42	53.01	0.5926	2.104	1.000	0.0327
89	0.19831E 03	1.732	5.117	29.45			1.821		
90	0.17844E 03	1.669	5.051	27.34			1.602		
91	0.15527E 03	1.579	5.049	24.47			1.522		
92	0.12895E 03	1.459	5.109	20.90			1.597		
93	0.10568E 03	1.309	5.491	16.82			2.473		
94	0.81484E 02	1.159	5.739	13.19			2.933		
95	0.69949E 02	1.060	6.158	11.03			4.032		
96	0.52597E 02	0.919	6.615	8.29			5.058		

TABLE A-7

WALNUT GULCH FLUME NO. 11, LOCATED NEAR TOMBSTONE, ARIZONA
EXP. NO. 1, FILLED APPROACH,DISCHARGE COEFFICIENTS FOR 1 TO 30 MODEL

L IS THE HORZONTAL LENGTH BETWEEN CRITICAL
DEPTH SECTION AND POINT OF HEAD MEASUREMENT

COMPUTED APPROACH AREA

TEST NO.	PROTOTYPE DISCHARGE C.F.S.	FLUME HEAD FT.	C	CONTROL AREA SQ.FT.	APPROACH AREA SQ.FT.	CONTRACTION RATIO	L FT.	HYDR. RADIUS FT.	MANNING N
1	0.59484E 04	9.859	8.186	344.54	1757.45	0.1960	2.763	7.258	0.0801
2	0.63226E 04	10.264	8.050	363.72	1864.27	0.1951	2.322	7.629	0.0800
3	0.56635E 04	9.574	8.246	331.24	1659.50	0.1996	2.878	6.912	0.0694
4	0.53993E 04	9.265	8.371	317.01	1573.99	0.2014	3.372	6.605	0.0625
5	0.50892E 04	8.890	8.537	300.00	1476.40	0.2032	4.063	6.248	0.0579
6	0.46160E 04	8.650	8.156	289.26	1307.35	0.2213	1.722	5.594	0.0562
7	0.43429E 04	8.362	8.181	276.53	1212.37	0.2281	1.669	5.220	0.0525
8	0.39870E 04	7.942	8.274	258.27	1092.22	0.2365	1.846	4.737	0.0511
9	0.37671E 04	7.678	8.328	246.98	1013.90	0.2436	1.910	4.418	0.0489
10	0.34792E 04	7.282	8.488	230.30	912.35	0.2524	2.415	4.203	0.0468
18	0.17805E 04	4.963	8.703	139.02	365.71	0.3801	2.460	3.093	0.0200
19	0.16509E 04	4.750	8.720	131.19	332.38	0.3947	2.510	2.896	0.0200
20	0.14715E 04	4.387	8.936	118.04	289.00	0.4084	3.459	2.616	0.0200
21	0.12639E 04	3.970	9.132	103.28	239.46	0.4313	4.499	2.300	0.0200
22	0.10835E 04	3.472	9.856	86.10	205.42	0.4191	8.914	2.076	0.0200
23	0.98689E 03	3.283	9.875	79.72	182.41	0.4370	9.311	1.907	0.0200
24	0.85379E 03	3.049	9.682	71.91	149.77	0.4801	8.648	1.652	0.0200
25	0.72710E 03	2.713	10.030	60.90	110.28	0.5522	11.981	1.282	0.0102
26	0.28680E 04	6.565	8.470	200.91	700.81	0.2867	1.962	3.992	0.0409
27	0.30238E 04	6.721	8.553	207.22	752.79	0.2753	2.381	4.100	0.0423
28	0.32658E 04	7.024	8.518	219.60	835.33	0.2629	2.385	4.226	0.0449
29	0.26752E 04	6.268	8.597	189.04	644.16	0.2935	2.357	3.779	0.0410
30	0.25579E 04	6.133	8.552	183.71	605.45	0.3034	2.115	3.612	0.0394
31	0.23183E 04	5.815	8.536	171.29	506.11	0.3384	1.959	3.499	0.0200
32	0.19989E 04	5.323	8.625	152.48	421.88	0.3614	2.194	3.392	0.0200
33	0.63886E 03	2.593	9.503	57.02	95.69	0.5959	9.253	1.150	0.0150
34	0.59647E 03	2.488	9.503	53.65	90.47	0.5930	9.821	1.101	0.0162
35	0.54027E 03	2.356	9.420	49.45	84.62	0.5843	10.154	1.041	0.0183
36	0.49182E 03	2.248	9.264	46.03	77.63	0.5930	10.034	0.968	0.0192
37	0.43242E 03	2.125	8.934	42.17	68.74	0.6135	9.210	0.872	0.0201
38	0.36597E 03	1.951	8.693	36.77	59.95	0.6133	9.651	0.795	0.0211
39	0.32619E 03	1.858	8.388	33.90	54.39	0.6234	9.133	0.730	0.0217
40	0.29528E 03	1.798	8.008	32.06			7.899		
41	0.25486E 03	1.738	7.302	30.23			5.355		
42	0.21645E 03	1.645	6.777	27.41			4.383		
43	0.19964E 03	1.618	6.419	26.59			3.400		
44	0.17840E 03	1.558	6.095	24.78			3.025		
45	0.15627E 03	1.501	5.667	23.07			2.373		
46	0.14187E 03	1.441	5.553	21.28			2.567		
47	0.12960E 03	1.417	5.290	20.58			1.889		
48	0.11348E 03	1.342	5.307	18.46			1.949		
49	0.10007E 03	1.267	5.403	16.45			2.143		
50	0.84738E 02	1.198	5.263	14.71			1.721		
51	0.75569E 02	1.138	5.336	13.27			1.831		
52	0.64626E 02	1.075	5.262	11.84			1.615		
53	0.48408E 02	0.955	5.298	9.35			1.585		
54	0.40964E 02	0.877	5.547	7.88			2.007		
55	0.25436E 02	0.688	6.318	4.85			3.322		
56	0.32732E 02	0.787	5.810	6.35			2.428		

TABLE A-8

WALNUT GULCH FLUME NO. 15, LOCATED NEAR TOMBSTONE, ARIZONA
EXPERIMENT NO. 2, FILLED APPROACH DISCHARGE COEFFICIENTS FOR 1 TO 30 MODEL

L IS THE HORZONTAL LENGTH BETWEEN CRITICAL
DEPTH SECTION AND POINT OF HEAD MEASUREMENT

COMPUTED APPROACH AREA

TEST NO.	PROTOTYPE DISCHARGE	FLUME HEAD	C	CONTROL AREA	APPROACH AREA	CONTRACTION RATIO	L	HYDR. RADIUS	MANNING N
	C.F.S.	FT.		SQ.FT.	SQ.FT.		FT.	FT.	
50	0.10545E 05	11.622	9.040	515.53	2501.04	0.2061	10.081	8.193	0.0625
51	0.97411E 04	11.349	8.733	499.52	2270.34	0.2200	6.339	7.496	0.0629
52	0.87897E 04	10.983	8.380	478.30	2002.83	0.2388	3.143	6.702	0.0635
53	0.79833E 04	10.581	8.161	455.29	1773.67	0.2567	1.681	6.519	0.0627
54	0.72705E 04	10.059	8.165	425.88	1603.60	0.2656	1.520	6.122	0.0652
55	0.65389E 04	9.423	8.284	390.78	1431.21	0.2730	1.833	5.590	0.0663
56	0.60637E 04	9.036	8.296	369.80	1323.69	0.2794	1.779	5.244	0.0683
57	0.53978E 04	8.427	8.386	337.39	1168.75	0.2887	2.016	4.719	0.0690
58	0.49319E 04	7.989	8.438	314.53	1059.37	0.2969	2.170	4.321	0.0687
59	0.45538E 04	7.653	8.417	297.25	975.80	0.3046	2.029	4.012	0.0696
60	0.42640E 04	7.359	8.454	282.31	909.76	0.3103	2.148	3.804	0.0697
61	0.37893E 04	6.870	8.490	257.83	805.17	0.3202	2.317	3.398	0.0694
62	0.33377E 04	6.384	8.512	233.97	702.99	0.3328	2.458	3.029	0.0684
63	0.29069E 04	5.877	8.568	209.57	591.09	0.3546	2.852	2.851	0.0661
64	0.25465E 04	5.439	8.585	188.90	500.03	0.3778	3.169	2.656	0.0626
65	0.22394E 04	5.049	8.581	170.81	422.14	0.4046	3.450	2.438	0.0580
66	0.19560E 04	4.662	8.589	153.15	354.62	0.4319	3.927	2.311	0.0549
67	0.17593E 04	4.416	8.470	142.08	295.15	0.4814	3.736	2.391	0.0510
68	0.15877E 04	4.149	8.493	130.20	260.69	0.4994	4.331	2.346	0.0496
69	0.14310E 04	3.852	8.671	117.14			6.033		
70	0.12550E 04	3.609	8.478	106.59	181.07	0.5887	5.780	2.104	0.0390
71	0.10623E 04	3.279	8.412	92.45	311.50	0.2968	6.829	2.460	0.1200
72	0.90456E 03	2.946	8.542	78.40			9.783		
73	0.77836E 03	2.715	8.399	68.77			10.935		
74	0.65710E 03	2.559	7.806	62.34	82.38	0.7567	8.657	1.971	0.0304
75	0.99920E 03	3.150	8.454	86.98			7.783		
76	0.64231E 03	2.556	7.645	62.21	80.47	0.7731	7.692	1.948	0.0304
77	0.60189E 03	2.472	7.562	58.76	76.95	0.7636	8.117	1.906	0.0307
78	0.55506E 03	2.409	7.271	56.19	71.11	0.7902	7.126	1.832	0.0301
79	0.50083E 03	2.283	7.155	51.06	66.08	0.7727	8.078	1.767	0.0303
80	0.43414E 03	2.139	6.886	45.24	59.21	0.7639	8.701	1.687	0.0304
81	0.38169E 03	2.019	6.681	40.42	52.83	0.7650	9.428	1.609	0.0295
82	0.34748E 03	1.929	6.781	36.90	46.03	0.8015	10.412	1.485	0.0258
83	0.30582E 03	1.839	6.725	33.53	40.79	0.8222	9.946	1.382	0.0246
84	0.26737E 03	1.740	6.752	30.02	37.50	0.8006	9.840	1.313	0.0253
85	0.22932E 03	1.638	6.735	26.60	32.89	0.8089	9.267	1.206	0.0245
86	0.21620E 03	1.629	6.438	26.31	31.39	0.8384	7.413	1.157	0.0245
87	0.20038E 03	1.593	6.309	25.16			6.549		
88	0.18204E 03	1.530	6.340	23.21			6.473		
89	0.15478E 03	1.419	6.508	19.97			6.867		
90	0.13354E 03	1.359	6.255	18.31			5.398		
91	0.11180E 03	1.326	5.568	17.43			2.722		
92	0.10342E 03	1.287	5.550	16.42			2.603		
93	0.79759E 02	1.209	5.004	14.49			1.224		
94	0.65759E 02	1.149	4.686	13.09			0.725		
95	0.49787E 02	1.059	4.350	11.12			0.467		

APPENDIX B

LISTING OF COMPUTER PROGRAMS

TABLE B-1

```
CARD
0001  //WRG1    JOB (10268,251-42-4902,03,4),'W.R.GWINN',CLASS=A,MSGLEVEL=1
0002  // EXEC FORTGCL
0003  //FORT.SYSIN DD *
0004  C      PROGRAM TO COMPUTE MANNINGS N
0005  C          BY WENDELL R GWINN
0006  C
0007  C    DELTX =DISTANCE BETWEEN READINGS ACROSS CHANNEL
0008  C    SCALE = MODEL LENGTH SCALE
0009  C    NGT = TOTAL NUMBER OF GAGES
0010  C    NT = TOTAL NUMBER OF TESTS
0011  C    VISNUE(I) = KINEMATIC VISCOSITY (FT2/SEC) (I=1 FOR 33 DEGREES F )
0012  C    STAU = UPSTREAM STATION DISTANCE IN FEET
0013  C    NYU = NUMBER OF UY READINGS,UPSTREAM (EQUAL OR LESS THAN 100)
0014  C    NOGAU  = UPSTREAM GAGE NUMBER (0 TO 9 ONLY)
0015  C    ZEROU = UPSTREAM GAGE ZERO (PROTO FEET)(SHOULD BE THE SAME FOR
0016  C              BOTTOM READINGS AND WATER SURFACE ELEVATION)
0017  C    UY = ELEVATION OF GROUND SURFACE ACROSS  SECTION,UPSTREAM SECTION
0018  C      NOTE, UY AND DY , MAINCHANNEL READ IN FIRST WITH PEAKS FOLLOWING
0019  C                          MAIN CHANNEL
0020  C    STAD = DOWNSTREAM STATION DISTANCE IN FEET ( SHOULD BE GREATER THAN
0021  C           STAU)
0022  C    NYD = NUMBER OF DY READINGS,DOWNSTREAM (EQUAL OR LESS THAN 100)
0023  C    NOGAD = DOWNSTREAM GAGE NUMBER ( 0 TO 9 ONLY)
0024  C    ZEROD = DOWNSTREAM GAGE ZERO  ETC.
0025  C    DY = ELEVATION OF GROUND SURFACE ACROSS  SECTION, DOWNSTREAM SECTION
0026  C    STA3 = THIRD STATION DOWNSTREAM (PROTOTYPE FEET)
0027  C    NY3 = NUMBER OF Y3 READINGS
0028  C    NOGA3 = THIRD GAGE DOWNSTREAM NUMBER (0 TO 9 ONLY)
0029  C    ZERO3 = THIRD GAGE DOWNSTREAM ZERO  ETC.
0030  C    Y3(I) = ELEVATION OF GROUND SURFACE ACROSS SECTION, THIRD GAGE DOWNS
0031  C    NOTEST = TEST NUMBER
0032  C    NEX = EXPERIMENT NUMBER
0033  C    MO = MONTH
0034  C    DAY =  DAY OF MONTH
0035  C    YEAR = LAST TWO DIGITS OF YEAR
0036  C    QM = MODEL DISCHARGE (C.F.S.)
0037  C    TEMP = WATER TEMPERATURE (DEGREES F )
0038  C    UELEVM = UPSTREAM WATER SURFACE ELEVATION (MODEL FEET)
0039  C    DELEVM = DOWNSTREAM WATER SURFACE ELEVATION (MODEL FEET)
0040  C    ELEVM3 = WATER SURFACE ELEVATION THIRD STATION DOWNSTREAM (MODEL FT)
0041  C    TIMEFA = TIME FACTOR (BETWEEN 0 AND 1)( 0 = BEFORE READINGS,
0042  C             1 = AFTER TEST BOTTOM READINGS USED)
0043  C    DURFLO = DURATION OF FLOW (MIN.)
0044  C    IDENT = IDENTIFICATION (13SPACES)
0045  C    NREACH = REACH NUMBER (COMPOSED OF GAGE NUMBERS)
0046  C    QP = PROTOTYPE DISCHARGE (C.F.S.)
0047  C    AVHYRP = AVERAGE HYDRAULIC RADIUS (PROTOTYPE)
0048  C    AVVEL = AVERAGE VELOCITY
0049  C    AVVR = AVERAGE VELOCITY TIMES THE HYDRAULIC RADIUS
0050  C    AVAREA = AVERAGE AREA
0051  C    CHEZY = CHEZY C
0052  C    ROUGHN = MANNINGS N (PROTOTYPE)
0053  C    WETPER = WETTED PERIMETER
0054  C    CENDEP = CENTER DEPTH ( FEET )
0055  C    SCOUR = RATE OF SCOUR (IN/HR )
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TABLE B-1 (Continued)

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CARD
0056  C    KN = KUTTERS N
0057  C    AVHYRM = AVERAGE HYDRAULIC RADIUS (MODEL)
0058  C    RENOLD = REYNOLDS NUMBER
0059  C    F = DARCY-WEISBACH RESISTANCE COEFFICIENT
0060  C    ROUGNM = MANNINGS N (MODEL)
0061  C              PRINT CARDS WITH PAGE SKIP SUPPRESSED
0062         REAL  KN,MAXD3,MAXDU,MAXDD,MAXD3E,MAXDUE,MAXDDE,IDENT1,IDENT2,
0063        1IDENT3 ,IDENT4
0064         INTEGER DAY,YEAR,TEMP,BRYU,ERYU,BRYD,ERYD,BRY3,ERY3,DURFLO
0065         DIMENSION UY(100),VISNUE(68),Y3(100),DY(100),ALIST(20)
0066    90   FORMAT (14X,F8.2,24X,I5,12X,I3,5X,F9.3/(9F8.3))
0067    91   FORMAT (7X,F6.2,13X,F7.2,17X,I2,20X,I4)
0068    92   FORMAT (I3,4I2,E10.5,I3,   3(I2,E10.5),F4.2,I3,3A4  ,A1)
0069    93   FORMAT ( /  19X,8HCHANNEL ,3A4  ,A1,17H   EXPERIMENT NO.,I3,20X)
0070   110   FORMAT ( /  22X,8HCHANNEL ,3A4  ,A1,17H   EXPERIMENT NO.,I3,17X)
0071   103   FORMAT (/ /                                                  80HTEST
0072        1 REACH   PROTO.   HYD.   MEAN    MEAN  CENTER            CHEZY MANNI
0073        2NG  MEAN  /80H NO.  NO.  DISCHARGE RADIUS  VEL.    AREA  DEPTH   S
0074        3LOPE     C       N       VR   ///13X,6HC.F.S.,4X,3HFT.,2X,20HF.P.S.
0075        4 SQ.FT.   FT.,24X,8HF.S.P.S.   /  )
0076    94   FORMAT (I3,I6,F10.1,F8.3,F7.3,F8.2,F6.2,F8.5,F8.2,F7.4,F9.3)
0077    95   FORMAT (80X)
0078    96   FORMAT (1H1  /46X,8HCHANNEL ,3A4  ,A1,16H  EXPERIMENT NO.,I3)
0079   106   FORMAT (/19X,4HDATE,14X,27HMEAN    MEAN   WETTED  HYD.,17X,4HDUR.,
0080        17X,4HRATE,27X,5HVALUE/ 5X,122HTEST  REACH    OF    DISCHARGE  AREA
0081        2    VEL.   PERIM. RADIUS  SLOPE  CENTER  OF  WATER  OF    CHEZY  M
0082        3ANNING KUTTER     OF / 6X,                                  19HNO.
0083        4  NO.   TESTING,13X,1HA,7X,1HV,7X,1HP,6X,1HR,12X,28HDEPTH  FLOW TE
0084        5MP. SCOUR    C,7X,1HN,7X,1HN,7X,  2HVR,// 7X,1H1,5X,1H2,7X,1H3,8X,
0085        61H4,7X,1H5,7X,1H6,7X,1H7,6X,1H8,7X,1H9,6X,2H10,4X,2H11,3X,2H12,4X,
0086        72H13,5X,2H14,6X,2H15,6X,2H16,7X,2H17///28X,35HC.F.S.  SQ.FT.  F.P.
0087        8S.   FT.    FT.,13X,21HFT.  MIN. DEG.F IN/HR/)
0088    97   FORMAT ( 6X,I3,I6,1X,3I3,F9.2,F8.2,F7.2,F8.2,F8.3,F8.5,F6.2,2I5,
0089        1F8.2,F7.2,F8.4,F7.4,F9.3)
0090    98   FORMAT (5X,I4,1X,3I3,I6,F10.5,F8.4,F13.0,2F11.5,2X)
0091   100   FORMAT (/////)
0092   101   FORMAT(1H1)
0093   107   FORMAT(//T14,'DATE', T30,'MODEL', T39,'HYD.',T58,'DARCY-WEISBACH'/
0094        1 T7,'TEST',            T15,'OF', T22,'REACH', T28,'DISCHARGE RADIUS
0095        2', T49,'MODEL', T62,'MODEL', T73,'MANNING' /            T8,'NO.',
0096        3 T13,'TESTING', T23,'NO.',T32,'Q', T40,'R', T46,'REYNOLDS NO.',T64
0097        4,'F', T76,'N'// T30,'C.F.S.   FT.'/)
0098   108   FORMAT (20A4)
0099   109   FORMAT (27X,20A4)
0100         DEFINE FILE 8(2000,80,E,LOC),9(2000,80,E,LOD)
0101         VISNUE ( 1) = 0.1891E-04
0102         VISNUE ( 2) = 0.1858E-04
0103         VISNUE ( 3) = 0.1824E-04
0104         VISNUE ( 4) = 0.1791E-04
0105         VISNUE ( 5) = 0.1759E-04
0106         VISNUE ( 6) = 0.1727E-04
0107         VISNUE ( 7) = 0.1696E-04
0108         VISNUE ( 8) = 0.1667E-04
0109         VISNUE ( 9) = 0.1638E-04
0110         VISNUE (10) = 0.1611E-04
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TABLE B-1 (Continued)

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CARD
0111        VISNUE (11) = 0.1584E-04
0112        VISNUE (12) = 0.1558E-04
0113        VISNUE (13) = 0.1532E-04
0114        VISNUE (14) = 0.1507E-04
0115        VISNUE (15) = 0.1482E-04
0116        VISNUE (16) = 0.1457E-04
0117        VISNUE (17) = 0.1433E-04
0118        VISNUE (18) = 0.1410E-04
0119        VISNUE (19) = 0.1388E-04
0120        VISNUE (20) = 0.1366E-04
0121        VISNUE (21) = 0.1345E-04
0122        VISNUE (22) = 0.1325E-04
0123        VISNUE (23) = 0.1305E-04
0124        VISNUE (24) = 0.1286E-04
0125        VISNUE (25) = 0.1266E-04
0126        VISNUE (26) = 0.1247E-04
0127        VISNUE (27) = 0.1228E-04
0128        VISNUE (28) = 0.1210E-04
0129        VISNUE (29) = 0.1193E-04
0130        VISNUE (30) = 0.1177E-04
0131        VISNUE (31) = 0.1160E-04
0132        VISNUE (32) = 0.1145E-04
0133        VISNUE (33) = 0.1129E-04
0134        VISNUE (34) = 0.1114E-04
0135        VISNUE (35) = 0.1099E-04
0136        VISNUE (36) = 0.1085E-04
0137        VISNUE (37) = 0.1070E-04
0138        VISNUE (38) = 0.1056E-04
0139        VISNUE (39) = 0.1041E-04
0140        VISNUE (40) = 0.1028E-04
0141        VISNUE (41) = 0.1015E-04
0142        VISNUE (42) = 0.1002E-04
0143        VISNUE (43) = 0.0990E-04
0144        VISNUE (44) = 0.0978E-04
0145        VISNUE (45) = 0.0967E-04
0146        VISNUE (46) = 0.0954E-04
0147        VISNUE (47) = 0.0942E-04
0148        VISNUE (48) = 0.0931E-04
0149        VISNUE (49) = 0.0920E-04
0150        VISNUE (50) = 0.0909E-04
0151        VISNUE (51) = 0.0898E-04
0152        VISNUE (52) = 0.0887E-04
0153        VISNUE (53) = 0.0877E-04
0154        VISNUE (54) = 0.0866E-04
0155        VISNUE (55) = 0.0855E-04
0156        VISNUE (56) = 0.0844E-04
0157        VISNUE (57) = 0.0833E-04
0158        VISNUE (58) = 0.0823E-04
0159        VISNUE (59) = 0.0814E-04
0160        VISNUE (60) = 0.0805E-04
0161        VISNUE (61) = 0.0796E-04
0162        VISNUE (62) = 0.0787E-04
0163        VISNUE (63) = 0.0779E-04
0164        VISNUE (64) = 0.0770E-04
0165        VISNUE (65) = 0.0761E-04
```

TABLE B-1 (Continued)

```
CARD
0166          VISNUE (66) = 0.0753E-04
0167          VISNUE (67) = 0.0745E-04
0168          VISNUE (68) = 0.0736E-04
0169      200 WRITE(6,101)
0170          LOC= 1
0171           LOD=1
0172          READ(5,91,END=500)  DELTX,SCALE,NGT,NT
0173       23 NOT=NT
0174          NOL = 40
0175          READ (5,90)STAU,NYU,NOGAU,ZEROU,(UY(I),I=1,NYU)
0176          DO 301 I = 1,NYU
0177      301 UY(I) = UY(I) + ZEROU
0178          READ (5,90) STAD,NYD,NOGAD,ZEROD,(DY(I),I=1,NYD)
0179          DO 302 I = 1,NYD
0180      302 DY(I) = DY(I) + ZEROD
0181          IF (NGT.LT.3)GO TO 21
0182          READ (5,90) STA3,NY3,NOGA3,ZERO3,(Y3(I),I=1,NY3)
0183          DO 303 I = 1,NY3
0184      303 Y3(I) = Y3(I) + ZERO3
0185       21 K=1
0186          INDEX = 0
0187       11 READ (5,92) NOTEST,NEX,MO, DAY,YEAR  ,QM, TEMP,NOGAU,UELEVM,NOGAD,
0188         1DELEVM,NOGA3,ELEVM3,TIMEFA,DURFLO,IDENT1,IDENT2,IDENT3 ,IDENT4
0189          IF (ELEVM3.LT.0.0001) GO TO 13
0190          ELEV3P=(ELEVM3*SCALE)+ZERO3
0191          CALL AREAHR(ELEV3P,AREA3,HYRAD3,Y3,DELTX       ,NY3,MAXD3)
0192       13 NREACH=(NOGAU*10)+NOGAD
0193          QP= QM*(SCALE**2.5)
0194          UELEVP=(UELEVM*SCALE)+ZEROU
0195          DELEVP=(DELEVM*SCALE)+ZEROD
0196          CALL AREAHR(UELEVP,UAREA,UHYRAD,UY,DELTX       ,NYU,MAXDU)
0197          CALL AREAHR(DELEVP,DAREA,DHYRAD,DY,DELTX       ,NYD,MAXDD)
0198          IF (TIMEFA.GT.0.0001) GO TO 24
0199          SCOURD = 0.0
0200          SCOURU = 0.0
0201          SCOUR3 = 0.0
0202          SCOURA = 0.0
0203       14 IF (DAREA.LT.0.0001) GO TO 5
0204          IF (UAREA.LT.0.0001) GO TO 5
0205          SLOPE=(UELEVP+(((QP*QP)/(UAREA*UAREA))/64.3)-DELEVP-(((QP*QP)/
0206         1(DAREA*DAREA))/ 64.3))/(STAD-STAU)
0207          IF(SLOPE.LE.0.0)GO TO 5
0208          AVAR23=(UAREA*(UHYRAD**.666667  )+(DAREA*(DHYRAD**.666667  )))/2.
0209          ROUGHN=(1.486/QP)*AVAR23*(SLOPE**.5)
0210          AVR16=((UHYRAD**.166667  )+(DHYRAD**.166667  ))/2.
0211          CHEZY = (1.486/ROUGHN)*AVR16
0212          AVAREA=AVAR23/(AVR16**4.0)
0213          AVVEL = QP/AVAREA
0214          AVHYRP=AVR16**6.0
0215          C=41.65 +(.00281/SLOPE)
0216          KN=(((((C-CHEZY)*(C-CHEZY))+(7.244*CHEZY*C/(AVHYRP**.5)))**.5)-
0217         1CHEZY+C)/((2.*CHEZY*C)/(AVHYRP**.5))
0218        6 AVVR = AVHYRP*AVVEL
0219          AVHYRM=AVHYRP/SCALE
0220          ROUGNM=ROUGHN/(SCALE**.166667)
```

TABLE B-1 (Continued)

```
CARD
0166          VISNUE (66) = 0.0753E-04
0167          VISNUE (67) = 0.0745E-04
0168          VISNUE (68) = 0.0736E-04
0169      200 WRITE(6,101)
0170          LOC= 1
0171           LOD=1
0172          READ(5,91,END=500)  DELTX,SCALE,NGT,NT
0173       23 NOT=NT
0174          NOL = 40
0175          READ (5,90)STAU,NYU,NOGAU,ZEROU,(UY(I),I=1,NYU)
0176          DO 301 I = 1,NYU
0177      301 UY(I) = UY(I) + ZEROU
0178          READ (5,90) STAD,NYD,NOGAD,ZEROD,(DY(I),I=1,NYD)
0179          DO 302 I = 1,NYD
0180      302 DY(I) = DY(I) + ZEROD
0181          IF (NGT.LT.3)GO TO 21
0182          READ (5,90) STA3,NY3,NOGA3,ZERO3,(Y3(I),I=1,NY3)
0183          DO 303 I = 1,NY3
0184      303 Y3(I) = Y3(I) + ZERO3
0185       21 K=1
0186          INDEX = 0
0187       11 READ (5,92) NOTEST,NEX,MO, DAY,YEAR  ,QM, TEMP,NOGAU,UELEVM,NOGAD,
0188         1DELEVM,NOGA3,ELEVM3,TIMEFA,DURFLO,IDENT1,IDENT2,IDENT3 ,IDENT4
0189          IF (ELEVM3.LT.0.0001) GO TO 13
0190          ELEV3P=(ELEVM3*SCALE)+ZERO3
0191          CALL AREAHR(ELEV3P,AREA3,HYRAD3,Y3,DELTX       ,NY3,MAXD3)
0192       13 NREACH=(NOGAU*10)+NOGAD
0193          QP= QM*(SCALE**2.5)
0194          UELEVP=(UELEVM*SCALE)+ZEROU
0195          DELEVP=(DELEVM*SCALE)+ZEROD
0196          CALL AREAHR(UELEVP,UAREA,UHYRAD,UY,DELTX       ,NYU,MAXDU)
0197          CALL AREAHR(DELEVP,DAREA,DHYRAD,DY,DELTX       ,NYD,MAXDD)
0198          IF (TIMEFA.GT.0.0001) GO TO 24
0199          SCOURD = 0.0
0200          SCOURU = 0.0
0201          SCOUR3 = 0.0
0202          SCOURA = 0.0
0203       14 IF (DAREA.LT.0.0001) GO TO 5
0204          IF (UAREA.LT.0.0001) GO TO 5
0205          SLOPE=(UELEVP+(((QP*QP)/(UAREA*UAREA))/64.3)-DELEVP-(((QP*QP)/
0206         1(DAREA*DAREA))/ 64.3))/(STAD-STAU)
0207          IF(SLOPE.LE.0.0)GO TO 5
0208          AVAR23=(UAREA*(UHYRAD**.666667  )+(DAREA*(DHYRAD**.666667  )))/2.
0209          ROUGHN=(1.486/QP)*AVAR23*(SLOPE**.5)
0210          AVR16=((UHYRAD**.166667  )+(DHYRAD**.166667  ))/2.
0211          CHEZY = (1.486/ROUGHN)*AVR16
0212          AVAREA=AVAR23/(AVR16**4.0)
0213          AVVEL = QP/AVAREA
0214          AVHYRP=AVR16**6.0
0215          C=41.65 +(.00281/SLOPE)
0216          KN=(((((C-CHEZY)*(C-CHEZY))+(7.244*CHEZY*C/(AVHYRP**.5)))**.5)-
0217         1CHEZY+C)/((2.*CHEZY*C)/(AVHYRP**.5))
0218        6 AVVR = AVHYRP*AVVEL
0219          AVHYRM=AVHYRP/SCALE
0220          ROUGNM=ROUGHN/(SCALE**.166667)
```

TABLE B-1 (Continued)

```
CARD
0221          SCOUR=(SCOURU+SCOURD)/2.
0222          RENOLD= AVVR/((SCALE**1.5)*(VISNUE(TEMP-32)))
0223          WETPER = 0.0
0224          IF (AVHYRP.GT.0.001)WETPER = AVAREA/AVHYRP
0225          CENDEP = (MAXDU + MAXDD)/2.
0226     18   IF (NOL.NE.40) GO TO 8
0227          WRITE (9'LOD,93) IDENT1,IDENT2,IDENT3,IDENT4,NEX
0228          WRITE (8'LOC,110)IDENT1,IDENT2,IDENT3,IDENT4,NEX
0229          WRITE (8'LOC,107)
0230          WRITE(9'LOD,103)
0231          WRITE (6,96)IDENT1,IDENT2,IDENT3,IDENT4,NEX
0232          WRITE (6,106)
0233          NOL = 0
0234      8   WRITE(9'LOD,94)NOTEST,NREACH,QP,AVHYRP,AVVEL,AVAREA,CENDEP,SLOPE,
0235         1CHEZY, ROUGHN,AVVR
0236          WRITE (6,97)NOTEST     ,NREACH,MO,DAY,YEAR,QP,AVAREA,AVVEL,WETPER,
0237         1AVHYRP,SLOPE,CENDEP,DURFLO,TEMP,SCOUR,CHEZY,ROUGHN,KN,AVVR
0238          NOL=NOL+1
0239          A=(FLOAT(NOL))/4.0
0240          B = FLOAT(NOL/4)
0241          IF (A.NE.B) GO TO 9
0242          WRITE(9'LOD,95)
0243          WRITE (6,95)
0244          IF (NOL.EQ.40) WRITE(9'LOD,100)
0245      9   IF(CHEZY.GT.0.01)F=257.2/(CHEZY*CHEZY)
0246          WRITE (8'LOC,98)NOTEST     ,MO,DAY,YEAR,NREACH,QM,AVHYRM,RENOLD,F,
0247         1 ROUGNM
0248          IF(A.EQ.B)WRITE(8'LOC,95)
0249          IF(NOL.EQ.40)WRITE(8'LOC,100)
0250          IF (ELEVM3.LT.0.0001) GO TO 19
0251          GO TO (15,16,17,19),K
0252     15   IF (ELEVM3.LT.0.0001) GO TO 19
0253          AMAXD = MAXDD
0254          ASTAD = STAD
0255          AELEVP=DELEVP
0256          AAREA =DAREA
0257          AHYRAD=DHYRAD
0258          ASCOUR=SCOURD
0259          SCOURD= SCOUR3
0260          STAD = STA3
0261          MAXDD = MAXD3
0262          DELEVP = ELEV3P
0263          DAREA = AREA3
0264          DHYRAD = HYRAD3
0265          NREACH = (NOGAU*10)+NOGA3
0266          AHRP = AVHYRP
0267          AV = AVVEL
0268          AVR = AVVR
0269          AA  = AVAREA
0270          AS = SLOPE
0271          AC = CHEZY
0272          ANP = ROUGHN
0273          ANK=KN
0274          AHRM = AVHYRM
0275          AR = RENOLD
```

TABLE B-1 (Continued)

```
CARD
0276          ANM = ROUGNM
0277          K = 2
0278          AVMAXD = CENDEP
0279          GO TO 14
0280        5 ROUGHN = 0.0
0281          INDEX = 1
0282          SLOPE = 0.0
0283          F  = 0.0
0284          CHEZY  = 0.0
0285          AVAREA = 0.0
0286          AVVEL  = 0.0
0287          AVHYRP = 0.0
0288          KN     = 0.0
0289          GO TO (6,6,6,89),K
0290       89 AVVR = 0.0
0291          AVHYRM = 0.0
0292          ROUGHM = 0.0
0293          WETPER = 0.0
0294          GO TO 18
0295       24 READ (5,90) STAU,BRYU,ERYU,ZEROU,(UY(I),I=BRYU,ERYU)
0296          READ (5,90) STAD,BRYD,ERYD,ZEROD,(DY(I),I=BRYD,ERYD)
0297          IF (NGT.LT.3) GO TO 25
0298          READ (5,90) STA3,BRY3,ERY3,ZERO3,(Y3(I),I=BRY3,ERY3)
0299          CALL AREAHR(ELEV3P,AREA3E,HYRA3E,Y3,DELTX       ,NY3,MAXD3E)
0300          IF (HYRAD3.GT.0.0001)
0301         1                    SCOUR3=(((AREA3E-AREA3)*720.)/(((AREA3/HYRAD3)+
0302         1(AREA3E/HYRA3E))/2.))/FLOAT (DURFLO)
0303          MAXD3=  (MAXD3*(1.0-TIMEFA))+(MAXD3E*TIMEFA)
0304          AREA3 = (AREA3*(1.0-TIMEFA))+(AREA3E *TIMEFA)
0305          HYRAD3= (HYRAD3*(1.0-TIMEFA))+(HYRA3E*TIMEFA)
0306          IF(HYRAD3.LT.0.0001)SCOUR3=HYRA3E* 720./ FLOAT(DURFLO)
0307       25 CALL AREAHR(UELEVP,UEAREA,UEHYRA,UY,DELTX       ,NYU,MAXDUE)
0308          IF(UHYRAD.GT.0.001)SCOURU=(((UEAREA-UAREA)*720.)/(((UAREA/UHYRAD)+
0309         1(UEAREA/UEHYRA))/2.))/FLOAT(DURFLO)
0310          MAXDU = (MAXDU*(1.0-TIMEFA))+(MAXDUE *TIMEFA)
0311          UAREA = (UAREA*(1.0-TIMEFA))+( UEAREA*TIMEFA)
0312          UHYRAD= (UHYRAD*(1.0-TIMEFA))+(UEHYRA*TIMEFA)
0313          IF (UHYRAD.LT.0.0001)SCOURU=(UEHYRA*720.)/FLOAT(DURFLO)
0314          CALL AREAHR(DELEVP,DEAREA,DEHYRA,DY,DELTX       ,NYD,MAXDDE)
0315          IF (DHYRAD.GT.0.0001)SCOURD=(((DEAREA-DAREA)*720.)/(((DAREA/DHYRAD
0316         1)+(DEAREA/DEHYRA))/2.))/FLOAT(DURFLO)
0317          IF (DHYRAD.GT.0.0001)SCOURD=(DEHYRA*720.)/FLOAT(DURFLO)
0318          DAREA= (DAREA *(1.0-TIMEFA)) + (DEAREA * TIMEFA)
0319          DHYRAD=(DHYRAD*(1.0-TIMEFA)) + (DEHYRA * TIMEFA)
0320          SCOURA = (SCOURU+SCOURD+SCOUR3)/3.0
0321          MAXDD = (MAXDD *(1.0-TIMEFA)) + (MAXDDE *TIMEFA)
0322          GO TO 14
0323       16 UELEVP= AELEVP
0324          SCOURU = ASCOUR
0325          UAREA =  AAREA
0326          MAXDU = AMAXD
0327          UHYRAD = AHYRAD
0328          BSTAD = STAU
0329          NREACH = (NOGAD*10) + NOGA3
0330          STAU = ASTAD
```

TABLE B-1 (Continued)

```
CARD
0331          K = 3
0332          AHRP = AHRP + AVHYRP
0333          AV = AV + AVVEL
0334          AVR = AVR + AVVR
0335          AA = AA + AVAREA
0336          AS = AS + SLOPE
0337          AC = AC + CHEZY
0338          ANP = ANP + ROUGHN
0339          ANK=ANK+KN
0340          AHRM = AHRM + AVHYRM
0341          AR = AR + RENOLD
0342          ANM = ANM + ROUGNM
0343          AVMAXD = AVMAXD + CENDEP
0344          GO TO 14
0345     17   NREACH  = (NOGAU*100) + (NOGAD*10) + NOGA3
0346          STA3 = STAD
0347          STAD = STAU
0348          STAU = BSTAD
0349          SCOUR = SCOURA
0350          AVHYRP = (AHRP + AVHYRP)/3.
0351          AVVEL = (AV + AVVEL)/3.
0352          AVVR = (AVR + AVVR) /3.
0353          AVAREA = (AA + AVAREA)/3.
0354          SLOPE = (AS + SLOPE)/3.
0355          CHEZY = (AC + CHEZY)/3.
0356          ROUGHN = (ANP + ROUGHN)/3.
0357          KN=(ANK+KN)/3.
0358          AVHYRM = (AHRM + AVHYRM)/3.
0359          RENOLD = (AR + RENOLD)/3.
0360          ROUGNM = (ANM + ROUGNM)/3.
0361          CENDEP= (AVMAXD + CENDEP)/3.
0362          WETPER= AVAREA/AVHYRP
0363          K = 4
0364          IF (INDEX.EQ.1) GO TO 5
0365          GO TO 18
0366     19   NOT=NOT-1
0367          IF(NOT.NE.0) GO TO 21
0368          NOL = 40 - NOL
0369          D = FLOAT(NOL/4)
0370          E = FLOAT(NOL)/4.0
0371          IF (E.EQ.D) NOL = NOL - 1
0372          NOL = (IFIX(D)) + NOL + 6
0373          DO 22  I =1,NOL
0374          WRITE(8'LOC,95)
0375     22   WRITE(9'LOD,95)
0376          NGT = NGT - 1
0377          IF(NGT.GT.2) GO TO 23
0378          END FILE 9
0379          REWIND 9
0380          WRITE (6,101)
0381          LODE=LOD -1
0382           LOD=1
0383          DO 600 I=1,LODE
0384          READ(9'LOD,108          )ALIST
0385     600  WRITE(6,109,END=601)ALIST
```

TABLE B-1 (Continued)

```
CARD
0386    601 REWIND 9
0387        END FILE 8
0388        REWIND 8
0389        WRITE(6,101)
0390        LOCE=LOC - 1
0391        LOC= 1
0392        DO 400 I=1,LOCE
0393        READ(8'LOC,108          )ALIST
0394    400 WRITE (6,109,END=401)ALIST
0395    401 REWIND 8
0396        WRITE(6,101)
0397        GO TO 200
0398    500 STOP
0399        END
0400        SUBROUTINE AREAHR(ELEV,AREA,HYRAD,Y    ,DELTX      ,NY,CENDEP)
0401        DIMENSION Y(100)
0402        CENDEP = 0.0
0403        I = 0
0404        AREA = 0.0
0405        HYRAD = 0.0
0406        WTPER = 0.0
0407        DELTXS  = DELTX *DELTX
0408      5 NUMB = 0
0409      1 I = I + 1
0410        IF (I.EQ.NY) GO TO 100
0411        Y1 = ELEV - Y(I)
0412        Y2 = ELEV - Y(I+1)
0413        IF (Y2.GE.Y1) CENDEP = AMAX1(CENDEP,Y2)
0414        IF (Y2.GE.0.0) GO TO 2
0415        IF (NUMB.EQ.0  ) GO TO 1
0416        GO TO 4
0417      2 IF (Y1.LT.0.0) GO TO 3
0418        AREA = AREA + (((Y1 + Y2)*DELTX)/2.0)
0419        WTPER=WTPER+(((Y2-Y1)*(Y2-Y1))+DELTXS)**.5
0420        NUMB = 1
0421        GO TO 1
0422      3 X = (Y2/(Y2 - Y1))*DELTX
0423        AREA = AREA + ((Y2 * X)/2.0)
0424        WTPER = WTPER + (((X * X)+(Y2 *Y2))**.5)
0425        NUMB = 1
0426        GO TO 1
0427      4 X = (Y1/(Y1 - Y2))*DELTX
0428        AREA  = AREA + ((Y1*X)/2.0)
0429        WTPER = WTPER + (((X*X) + (Y1*Y1))**.5)
0430        IF(WTPER.GT.0.01) HYRAD = AREA/WTPER
0431        GO TO 5
0432    100 CONTINUE
0433        RETURN
0434        END
0435  //LKED.SYSLMOD DD DSNAME=OSU.DEPT2111.PRN50004.GWINNLIB,DISP=SHR
0436  //LKED.SYSIN DD *,DCB=BLKSIZE=80
0437   NAME CHROUGHN(R)
0438  //
```

TABLE B-2

```
CARD
0001  //WRG2    JOB (10268,251-42-4902,03,4),'W.R.GWINN',CLASS=A,MSGLEVEL=1
0002  // EXEC FORTGCL
0003  //FORT.SYSIN DD *
0004  C      WALNUT GULCH FLUME COEFFICIENT  BY W.R. GWINN  IBM360
0005  C      SCALE=MODEL LENGTH SCALE
0006  C      EXNO = EXPERIMENT NUMBER
0007  C      NOT = NUMBER OF TEST
0008  C      TEST = TEST NUMBER
0009  C      Q = DISCHARGE (MODEL CFS)
0010  C      ELEVHL = ELEVATION OF HEAD WATER ON LEFT SIDE OF FLUME (MODEL FT)
0011  C      ELEVHR = ELEVATION OF HEAD WATER ON RIGHT SIDE OF FLUME (MODEL FT)
0012  C      DISCHARGE COEFFICIENTS FOR WALNUT GULCH FLUMES
0013  C            BY W.R.GWINN, STILLWATER, OKLA.
0014  C
0015  C      A1L,B1L, ETC. = SURFACE EQUATION COEFFICIENTS FOR A STRAIGHT LINE
0016  C                WHERE X = ELEVATION AND Y = SCALE WITH ZERO ON LEFT SIDE
0017        INTEGER TEST, EXNO, PAGE
0018        DIMENSION IDENT(40)
0019   200  FORMAT (20A4/ 20A4/ 2E12.6/2E12.6/2E12.6/
0020       1                                    14X, E11.6, 8X, I3, 14X, I4)
0021   201  FORMAT ( 4X, I4, 4X, E10.5, 6X, E10.5, 6X, E10.5,20X,F6.4)
0022   202  FORMAT (1H1,95X, 4HPAGE,I3//27X,20A4/27X, 20A4/31X, 71H(C=Q/(AREA*
0023       1(H**.5),C1=Q/((W/2)*(H**1.5)), WHERE Q=DISCHARGE AND H=HEAD),//30X
0024       2, 4HTEST, 2X, 9HPROTOTYPE,5X, 7HCONTROL, 2X, 9HHEADWATER, 1X, 9HHE
0025       3ADWATER, 2X, 9HDISCHARGE, 4X, 9HDISCHARGE/31X, 3HNO., 2X, 9HDISCHA
0026       4RGE, 6X, 4HAREA, 6X, 4HLEFT, 6X, 5HRIGHT, 5X, 7HCOEF. C, 5X, 8HCOE
0027       5F. C1,//38X, 5H(CFS), 7X, 7H(SQ FT), 4X, 4H(FT), 6X, 4H(FT)/)
0028   203  FORMAT (    68X, 4HPAGE,I3//    20A4/     20A4/ 4X, 71H%C#Q/%AREA*
0029       1%H**.5<,C1#Q/%%W/2<*%H**1.5<<, WHERE Q#DISCHARGE AND H#HEAD< // 3X
0030       2, 4HTEST, 2X, 9HPROTOTYPE,5X, 7HCONTROL, 2X, 9HHEADWATER, 1X, 9HHE
0031       3ADWATER, 2X, 9HDISCHARGE, 4X, 9HDISCHARGE/ 4X, 3HNO., 2X, 9HDISCHA
0032       4RGE, 6X, 4HAREA, 6X, 4HLEFT, 6X, 5HRIGHT, 5X, 7HCOEF. C, 5X, 8HCOE
0033       5F. C1,//11X, 5H%CFS<, 7X, 7H%SQ FT<, 4X, 4H%FT<, 6X, 4H%FT</)
0034   204  FORMAT ( 3X, I3, 1X, 2E12.5, F8.3,  10X,1X, 2F12.4)
0035   205  FORMAT ( 3X, I3, 1X, 2E12.5,  8X, F10.3,1X, 2F12.4)
0036   206  FORMAT (30X, I3, 1X, 2E12.5, F8.3,  10X,1X, 2F12.4)
0037   207  FORMAT (30X, I3, 1X, 2E12.5,  8X, F10.3,1X, 2F12.4)
0038   208  FORMAT (80X)
0039   209  FORMAT(1H1)
0040   210  FORMAT(//////////)
0041        NR=5
0042        NW=6
0043        NP=7
0044      1 READ(NR,200,END=300) IDENT,A1L,B1L,A2L,B2L,A1R,B1R,A2R,B2R,SCALE,
0045       1EXNO, NOT
0046        PAGE = 1
0047        NOL = 36
0048        ZERO = (A1L- A1R)/(B1R-B1L)
0049        CROSR = (A1R-A2R)/(B2R-B1R)
0050        CROSL = (A1L-A2L)/(B2L-B1L)
0051        SC=A1R+(B1R*ZERO)
0052        SR=A1R+(B1R*CROSR)
0053        SL=A1L+(B1L*CROSL)
0054        AREA1=(SC+SR)/2.*(CROSR-ZERO)
0055        AREA2=(SC+SL)/2.*(CROSL-ZERO)
```

TABLE B-2 (Continued)

```
CARD
0056          IF (CROSL.EQ.CROSR) GO TO 28
0057          IF (CROSL.LT.CROSR) GO TO 20
0058          SRL2=A2R+(B2R*CROSL)
0059          AREA3=(SR+SRL2)/2.*(CROSL-CROSR)
0060          SLR1=A1L+(B1L*CROSR)
0061          AREA4=(SLR1+SL)/2.*(CROSL-CROSR)
0062          AREA9=AREA1-AREA2+AREA4
0063          ARE10=AREA9+AREA3-AREA4
0064          GO TO 30
0065     20   SRL1=A1R+(B1R*CROSL)
0066          AREA5=(SRL1+SR)/2.*(CROSR-CROSL)
0067          SLR2=A2L+(B2L*CROSR)
0068          AREA6=(SL+SLR2)/2.*(CROSR-CROSL)
0069          AREA7=AREA1-AREA2-AREA5
0070          AREA8=AREA7+AREA5-AREA6
0071          GO TO 30
0072     28   ARE10=AREA1-AREA2
0073     30   READ(NR,201) TEST, Q, ELEVHL, ELEVHR
0074         1,CORZER
0075          K = 1
0076          IF (ELEVHL.NE.0.0) ELEVHL= ELEVHL+CORZER
0077          IF (ELEVHR.NE.0.0) ELEVHR= ELEVHR+CORZER
0078          IF (ELEVHL.NE.0.0) ELEVH = ELEVHL
0079          IF (ELEVHL.EQ.0.0) GO TO 129
0080     34   IF (CROSL.LT.CROSR) GO TO 60
0081          IF (CROSL.EQ.ELEVH) GO TO 40
0082          IF (CROSL.GT.ELEVH) GO TO 42
0083          SR2=A2R+(B2R*ELEVH)
0084          SL2=A2L+(B2L*ELEVH)
0085          ARE11=((SRL2+SR2)/2.)*(ELEVH-CROSL)
0086          ARE12=((SL+SL2)/2.)*(ELEVH-   CROSL)
0087          AREA=ARE10+ARE11-ARE12
0088          GO TO 80
0089     40   AREA=ARE10
0090          GO TO 80
0091     42   IF (CROSR.EQ.ELEVH) GO TO 47
0092          IF (CROSR.GT.ELEVH) GO TO 50
0093          SR2=A2R+(B2R*ELEVH)
0094          SL1=A1L+(B1L*ELEVH)
0095          ARE13=((SR2+SR)/2.)*(ELEVH-CROSR)
0096          ARE14=((SLR1+SL1)/2.)*(ELEVH-CROSR)
0097          AREA=AREA9+ARE13-ARE14
0098          GO TO 80
0099     47   AREA=AREA9
0100          GO TO 80
0101     50   SR1=A1R+(B1R*ELEVH)
0102          SL1=A1L+(B1L*ELEVH)
0103          ARE15=((SC+SR1)/2.)*(ELEVH- ZERO)
0104          ARE16=((SC+SL1)/2.)*(ELEVH-ZERO)
0105          AREA=ARE15-ARE16
0106          GO TO 80
0107     60   IF (CROSR.EQ.ELEVH) GO TO 70
0108          IF (CROSR.GT.ELEVH) GO TO 72
0109          SL2=A2L+(B2L*ELEVH)
0110          SR2=A2R+(B2R*ELEVH)
```

TABLE B-2 (Continued)

```
CARD
0111          ARE17=((SR2+SR)/2.)*(ELEVH-CROSR)
0112          ARE18=((SL2+SLR2)/2.)*(ELEVH- CROSR)
0113          AREA=AREA8+ARE17-ARE18
0114          GO TO 80
0115     70   AREA=AREA8
0116          GO TO 80
0117     72   IF (CROSL.EQ.ELEVH) GO TO 77
0118          IF (CROSL.GT.ELEVH) GO TO 50
0119          SR1=A1R+(B1R*ELEVH)
0120          SL2=A2L+(B2L*ELEVH)
0121          ARE19=((SR1+SR)/2.)*(CROSR- ELEVH)
0122          ARE20=((SL2+SLR2)/2.)*(CROSR- ELEVH)
0123          AREA=AREA8-ARE19+ARE20
0124          GO TO 80
0125     77   AREA=AREA7
0126     80   FH=ELEVH-ZERO
0127          C=Q/(AREA*(FH**.5))
0128          FHP=FH*SCALE
0129          QP=Q*(SCALE**2.5)
0130          IF (CROSR.LE.ELEVH) GO TO 109
0131          WR=A1R+(B1R*ELEVH)
0132          GO TO 110
0133    109   WR=A2R+(B2R*ELEVH)
0134    110   IF (CROSL.LE.ELEVH) GO TO 113
0135          WL=A1L+(B1L*ELEVH)
0136          GO TO 114
0137    113   WL=A2L+(B2L*ELEVH)
0138    114   W=WR-WL
0139          C1=(2.*Q)/(W*(FH**1.5))
0140          AREAP = AREA*(SCALE*SCALE)
0141          IF (NOL.NE.36) GO TO 117
0142          WRITE(NW,202) PAGE, IDENT
0143          WRITE(NP,203) PAGE, IDENT
0144          PAGE = PAGE + 1
0145          NOL = 0
0146    117   IF (K.EQ.2) GO TO 120
0147          WRITE(NP,204) TEST, QP, AREAP, FHP , C, C1
0148          WRITE(NW,206) TEST, QP, AREAP,  FHP, C, C1
0149          GO TO 122
0150    120   WRITE(NP,205) TEST, QP, AREAP,  FHP, C, C1
0151          WRITE(NW,207) TEST, QP, AREAP,  FHP, C, C1
0152    122   NOL = NOL + 1
0153          CC = (FLOAT(NOL))/4.0
0154          D = FLOAT (NOL/4)
0155          IF (CC.NE.D) GO TO 127
0156          WRITE(NW,208)
0157          WRITE(NP,208)
0158          IF(NOL.NE.36) GO TO 127
0159          WRITE(NP,210)
0160    127   IF (K.NE.2) GO TO 129
0161          NOT = NOT-1
0162          IF(NOT.NE.0) GO TO 30
0163          WRITE(NP,210)
0164          WRITE(NW,209)
0165          GO TO 1
```

TABLE B-2 (Continued)

```
CARD
0166   129  IF(ELEVHR.EQ.0.0) GO TO 30
0167        ELEVH = ELEVHR
0168        K = 2
0169        GO TO 34
0170    300 STOP
0171        END
0172  //LKED.SYSLMOD DD DSNAME=OSU.DEPT2111.PRN50004.GWINNLIB,DISP=SHR
0173  //LKED.SYSIN DD *,DCB=BLKSIZE=80
0174   NAME WGFLUMEC(R)
0175  //
```

TABLE B-3

```
CARD
0001  //WRG3   JOB (10268,251-42-4902,03,4),'W.R.GWINN',CLASS=A,MSGLEVEL=1
0002  // EXEC FORTGCLG,TIME.GO=03
0003  //FORT.SYSIN DD *
0004  C      WALNUT GULCH FLUMES
0005  C      COMPUTED DISCHARGE COEFFICIENTS
0006  C            BY W.R.GWINN, STILLWATER, OKLA.
0007  C                 SEPTEMBER, 1969
0008  C
0009  C      CONTL = HORZONTAL LENGTH BETWEEN CRITICAL DEPTH SECTION AND POINT
0010  C                OF HEAD MEASUREMENT
0011  C      BO,B1 = COEFFICIENTS FOR A LINEAR EQUATION
0012  C              WHERE X = CONTRACTION RATIO
0013  C                    Y = CONTL
0014  C      BNO, BN1 = COEFFICIENT FOR LINEAR EQUATION
0015  C                 WHERE X = HYDRAULIC RADIUS
0016  C                       Y = MANNING'S N
0017  C      A1L,B1L, ETC. = SURFACE EQUATION COEFFICIENTS FOR A STRAIGHT LINE
0018  C                 WHERE X = ELEVATION AND Y = SCALE WITH ZERO ON LEFT SIDE
0019  C      Q = DISCHARGE (MODEL CFS)
0020  C      SCALE = MODEL SCALE
0021  C      BEGIN = ASSUMED FLUME HEAD(PROTOTYPE DIMENSIONS) AT CRITICAL
0022  C              DEPTH SECTION
0023  C      BEGFH = BEGINNING FLUME HEAD (PROTOTYPE DIMENSIONS)
0024  C      ENDHD = ENDING HEAD (PROTOTYPE DIMENSIONS)
0025         DIMENSION IDENT(40),Y(100)
0026         INTEGER              PAGE
0027      90 FORMAT(14X,F8.2,24X,I5,12X,I3,5X,F9.3/(9F8.3))
0028      91 FORMAT (14X,F8.2)
0029      92 FORMAT (5X,F8.5,5X,F8.4,6X,F9.6,6X,F9.6)
0030     202 FORMAT(1H1,99X,4HPAGE,I3/27X,20A4/ 27X,20A4/
0031        135X,62HCOMPUTED DISCHARGE COEFFICIENTS ASSUMING CRITICAL DEPTH AT
0032        2THE/44X,46HDISTANCE L FROM THE POINT OF HEAD MEASUREMENT /
0033        3 35X,64H(C=Q/A*H**0.5, C1=Q/(W/2)*H**1.5,TC=C/SQRT(2G), TC1=C1/SQR
0034        4T(2G))  // 29X, 5HMODEL,3X, 9HPROTOTYPE,2X, 5HFLUME,48X, 6HCONTR.
0035        5 ,10H  CRITICAL /
0036        627X,25HDISCHARGE DISCHARGE  HEAD,7X, 1HC, 7X,2HTC, 7X, 2HC1,6X,
0037        73HTC1, 7X, 2HL , 5X,5HRATIO ,16H     HEAD      N /29X,6HC.F.S.,4X,
0038        86HC.F.S.,4X,3HFT.,41X,3HFT.,16X,3HFT./)
0039    208  FORMAT (80X)
0040    400 FORMAT (20A4/ 20A4/ 2E12.6/2E12.6/2E12.6/2E12.6/14X,E11.6)
0041    401 FORMAT(   27X,F8.4  ,F10.0,F7.3,7F9.3, F9.4)
0042    402 FORMAT(4(6X,E12.6))
0043         NR=5
0044         NW=6
0045         NP=7
0046       1 READ(NR,92,END=300) BO,B1,BNO,BN1
0047         READ(NR,91)STAMS
0048         READ(NR,90)STA,NY,NOGA,ZEROU,(Y(J),J=1,NY)
0049         DO 10 J=1,NY
0050      10 Y(J)=Y(J)+ZEROU
0051          CONTR = 0.0
0052         M = 0
0053         ELOSS= (STAMS- STA)*0.01
0054         READ(NR,400,END=300) IDENT,A1L,B1L,A2L,B2L,A1R,B1R,A2R,B2R,SCALE
0055         READ(NR,402)BEGIN,BEGFH,ENDHD ,CONTL
```

TABLE B-3 (Continued)

```
CARD
0056          PAGE = 1
0057          NOL = 40
0058          ZERO = (A1L- A1R)/(B1R-B1L)
0059          CROSR = (A1R-A2R)/(B2R-B1R)
0060          CROSL = (A1L-A2L)/(B2L-B1L)
0061          SC=A1R+(B1R*ZERO)
0062          SR=A1R+(B1R*CROSR)
0063          SL=A1L+(B1L*CROSL)
0064          AREA1=(SC+SR)/2.*(CROSR-ZERO)
0065          AREA2=(SC+SL)/2.*(CROSL-ZERO)
0066          IF (CROSL.EQ.CROSR) GO TO 28
0067          IF (CROSL.LT.CROSR) GO TO 20
0068          SRL2=A2R+(B2R*CROSL)
0069          AREA3=(SR+SRL2)/2.*(CROSL-CROSR)
0070          SLR1=A1L+(B1L*CROSR)
0071          AREA4=(SLR1+SL)/2.*(CROSL-CROSR)
0072          AREA9=AREA1-AREA2+AREA4
0073          ARE10=AREA9+AREA3-AREA4
0074          GO TO 30
0075       20 SRL1=A1R+(B1R*CROSL)
0076          AREA5=(SRL1+SR)/2.*(CROSR-CROSL)
0077          SLR2=A2L+(B2L*CROSR)
0078          AREA6=(SL+SLR2)/2.*(CROSR-CROSL)
0079          AREA7=AREA1-AREA2-AREA5
0080          AREA8=AREA7+AREA5-AREA6
0081          GO TO 30
0082       28 ARE10=AREA1-AREA2
0083       30 ASFH=ZERO+(BEGIN/SCALE)
0084          K = 1
0085       32 ELEVH = ASFH
0086       33 IF(CROSL-CROSR)60,34,34
0087       34 IF(CROSL-ELEVH)35,40,42
0088       35 SR2=A2R+(B2R*ELEVH)
0089          SL2=A2L+(B2L*ELEVH)
0090          ARE11=((SRL2+SR2)/2.)*(ELEVH-CROSL)
0091          ARE12=((SL+SL2)/2.)*(ELEVH-CROSL)
0092          AREA=ARE10+ARE11-ARE12
0093          GO TO 80
0094       40 AREA=ARE10
0095          GO TO 80
0096       42 IF(CROSR-ELEVH)43,47,50
0097       43 SR2=A2R+(B2R*ELEVH)
0098          SL1=A1L+(B1L*ELEVH)
0099          ARE13=((SR2+SR)/2.)*(ELEVH-CROSR)
0100          ARE14=((SLR1+SL1)/2.)*(ELEVH-CROSR)
0101          AREA=AREA9+ARE13-ARE14
0102          GO TO 80
0103       47 AREA=AREA9
0104          GO TO 80
0105       50 SR1=A1R+(B1R*ELEVH)
0106          SL1=A1L+(B1L*ELEVH)
0107          ARE15=((SC+SR1)/2.)*(ELEVH-ZERO)
0108          ARE16=((SC+SL1)/2.)*(ELEVH-ZERO)
0109          AREA=ARE15-ARE16
0110          GO TO 80
```

TABLE B-3 (Continued)

```
CARD
0111      60 IF(CROSR-ELEVH)61,70,72
0112      61 SR2=A2R+(B2R*ELEVH)
0113         SL2=A2L+(B2L*ELEVH)
0114         ARE17=((SR2+SR)/2.)*(ELEVH-CROSR)
0115         ARE18=((SL2+SLR2)/2.)*(ELEVH-CROSR)
0116         AREA=AREA8+ARE17-ARE18
0117         GO TO 80
0118      70 AREA=AREA8
0119         GO TO 80
0120      72 IF(CROSL-ELEVH)73,77,50
0121      73 SR1=A1R+(B1R*ELEVH)
0122         SL2=A2L+(B2L*ELEVH)
0123         ARE19=((SR1+SR)/2.)*(CROSR-ELEVH)
0124         ARE20=((SL2+SLR2)/2.)*(CROSR-ELEVH)
0125         AREA=AREA8-ARE19+ARE20
0126         GO TO 80
0127      77 AREA=AREA7
0128      80 A=AREA
0129         IF(CROSR-ELEVH)109,109,107
0130     107 WR=A1R+(B1R*ELEVH)
0131         GO TO 110
0132     109 WR=A2R+(B2R*ELEVH)
0133     110 IF(CROSL-ELEVH)113,113,111
0134     111 WL=A1L+(B1L*ELEVH)
0135         GO TO 114
0136     113 WL=A2L+(B2L*ELEVH)
0137     114 W=WR-WL
0138         IF(K-1)200,115,115
0139     115 VELHD=(A/W)/2.
0140         VELT=SQRT(VELHD*64.3)
0141         Q=A*VELT
0142         TOLHD=VELHD+((CONTL*0.03) /SCALE)+(ELEVH-ZERO)
0143         IF(K-1)200,120,230
0144     120 TFH=BEGFH/SCALE
0145     121 ELEVH=TFH+ZERO
0146         K = 0
0147         GO TO 33
0148     200 VELH=((Q/A)*(Q/A))/64.3
0149         NO=IFIX((TFH+VELH-TOLHD)*100000.)
0150         IF(NO)210,210,203
0151     203 TFH=TFH+(0.0010/SCALE)
0152         GO TO 121
0153     210 FH=TFH
0154         FHP=FH*SCALE
0155         QP=Q*(SCALE**2.5)
0156         VELHP = VELH*SCALE
0157         AP = A*SCALE*SCALE
0158         IF(M.GT.2) GO TO 119
0159         TOTALH = VELHP + FHP + ZERO*SCALE + ELOSS
0160         INDEX = 0
0161     116 ELEV = TOTALH
0162         CENDEP = 0.0
0163         I = 0
0164         AREAU= 0.0
0165         HYRAD = 0.0
```

TABLE B-4

```
CARD
0001  //WRG4    JOB (10268,251-42-4902,03,4),'W.R.GWINN',CLASS=A,MSGLEVEL=1
0002  // EXEC FORTGCLG,TIME.GO=03
0003  //FORT.SYSIN DD *
0004  C      WALNUT GULCH FLUMES
0005  C      COMPUTED APPROACH AREA
0006  C        COMPUTE L AND CONTRACTION RATIO
0007  C            SEPTEMBER, 1969
0008  C            BY W.R.GWINN, STILLWATER, OKLA.
0009  C
0010  C      A1L,B1L, ETC. = SURFACE EQUATION COEFFICIENTS FOR A STRAIGHT LINE
0011  C                WHERE X = ELEVATION AND Y = SCALE WITH ZERO ON LEFT SIDE
0012  C      SCALE = MODEL SCALE
0013  C
0014     90 FORMAT (14X,F8.2,24X,I5,12X,I3,5X,F9.3/(9F8.3))
0015     91 FORMAT (14X,F8.2)
0016    100 FORMAT(I6,1X,2E12.5,F19.4,2F13.5/19X,F9.4,6X,F9.3,21X,F8.5)
0017    202 FORMAT(1H1,26X,                    20A4/27X,20A4//27X,19X,42HL IS TH
0018       1E HORZONTAL LENGTH BETWEEN CRITICAL/27X,19X,43HDEPTH SECTION AND P
0019       2OINT OF HEAD MEASUREMENT // 27X,29X,22HCOMPUTED APPROACH AREA  //
0020       3                            27X,4HTEST,1X,9HPROTOTYPE, 3X, 5HFLUME
0021       4, 9X, 7HCONTROL, 1X, 8HAPPROACH, 1X, 11HCONTRACTION, 8X, 5HHYDR.,
0022       51X,7HMANNING/27X,1X,3HNO.,1X,9HDISCHARGE,4X,4HHEAD,5X,1HC,5X,4HARE
0023       6A, 4X,4HAREA, 6X, 5HRATIO, 6X, 1HL, 3X, 6HRADIUS, 4X,1HN// 27X, 7X
0024       7, 6HC.F.S., 6X,3HFT., 10X, 6HSQ.FT., 2X, 6HSQ.FT., 15X, 3HFT.,4X,
0025       83HFT./)
0026    203 FORMAT(27X,I3,E12.5,F8.3,F7.3 ,F8.2,       18X,F9.3)
0027    204 FORMAT(                            20A4/    20A4//    19X,42HL IS TH
0028       1E HORZONTAL LENGTH BETWEEN CRITICAL/    19X,43HDEPTH SECTION AND P
0029       2OINT OF HEAD MEASUREMENT //      29X,22HCOMPUTED APPROACH AREA  //
0030       3                                 4HTEST,1X,9HPROTOTYPE, 3X, 5HFLUME
0031       4, 9X, 7HCONTROL, 1X, 8HAPPROACH, 1X, 11HCONTRACTION, 8X, 5HHYDR.,
0032       51X,7HMANNING/    1X,3HNO.,1X,9HDISCHARGE,4X,4HHEAD,5X,1HC,5X,4HARE
0033       6A, 4X,4HAREA, 6X, 5HRATIO, 6X, 1HL, 3X, 6HRADIUS, 4X,1HN//      7X
0034       7, 6HC.F.S., 6X,3HFT., 10X, 6HSQ.FT., 2X, 6HSQ.FT., 15X, 3HFT.,4X,
0035       83HFT./)
0036    205 FORMAT(    I3,E12.5,F8.3,F7.3 ,F8.2,       18X,F9.3)
0037    208 FORMAT (1X)
0038    209 FORMAT (1H1,1X)
0039    400 FORMAT (20A4/ 20A4/ 2E12.6/2E12.6/2E12.6/2E12.6/14X,E11.6)
0040    401 FORMAT(27X,I3,E12.5,F8.3,F7.3, 2F8.2,F10.4,F9.3,F7.3,F7.4)
0041    402 FORMAT(    I3,E12.5,F8.3,F7.3, 2F8.2,F10.4,F9.3,F7.3,F7.4)
0042        DIMENSION IDENT(40),Y(100)
0043        INTEGER       TEST
0044        NR=5
0045        NW=6
0046        NP=7
0047      1 READ(NR,91,END=300)STAMS
0048        READ(NR,90) STA,NY,NOGA,ZEROU,(Y(I),I=1,NY)
0049         DO 10 I= 1,NY
0050     10 Y(I) = Y(I) + ZEROU
0051        READ(NR,400,END=300) IDENT,A1L,B1L,A2L,B2L,A1R,B1R,A2R,B2R,SCALE
0052        A1L = A1L*SCALE
0053        A2L = A2L*SCALE
0054        A1R = A1R*SCALE
0055        A2R = A2R*SCALE
```

TABLE B-4 (Continued)

```
CARD
0056        WRITE(NW,202)IDENT
0057        WRITE(NP,204)IDENT
0058        ZERO = (A1L- A1R)/(B1R-B1L)
0059        CROSR = (A1R-A2R)/(B2R-B1R)
0060        CROSL = (A1L-A2L)/(B2L-B1L)
0061        SC=A1R+(B1R*ZERO)
0062        SR=A1R+(B1R*CROSR)
0063        SL=A1L+(B1L*CROSL)
0064        AREA1=(SC+SR)/2.*(CROSR-ZERO)
0065        AREA2=(SC+SL)/2.*(CROSL-ZERO)
0066        IF (CROSL.EQ.CROSR) GO TO 28
0067        IF (CROSL.LT.CROSR) GO TO 20
0068        SRL2=A2R+(B2R*CROSL)
0069        AREA3=(SR+SRL2)/2.*(CROSL-CROSR)
0070        SLR1=A1L+(B1L*CROSR)
0071        AREA4=(SLR1+SL)/2.*(CROSL-CROSR)
0072        AREA9=AREA1-AREA2+AREA4
0073        ARE10=AREA9+AREA3-AREA4
0074        GO TO 30
0075     20 SRL1=A1R+(B1R*CROSL)
0076        AREA5=(SRL1+SR)/2.*(CROSR-CROSL)
0077        SLR2=A2L+(B2L*CROSR)
0078        AREA6=(SL+SLR2)/2.*(CROSR-CROSL)
0079        AREA7=AREA1-AREA2-AREA5
0080        AREA8=AREA7+AREA5-AREA6
0081        GO TO 30
0082     28 ARE10=AREA1-AREA2
0083     30 READ (NR,100,END=128) TEST,Q,AP,HP,C,C1,R,AP1,AN
0084        IF(TEST.EQ.0) GO TO 128
0085     31 HC =HP
0086     32 ELEVH = HC + ZERO
0087     33 IF(CROSL-CROSR)60,34,34
0088     34 IF(CROSL-ELEVH)35,40,42
0089     35 SR2=A2R+(B2R*ELEVH)
0090        SL2=A2L+(B2L*ELEVH)
0091        ARE11=((SRL2+SR2)/2.)*(ELEVH-CROSL)
0092        ARE12=((SL+SL2)/2.)*(ELEVH-CROSL)
0093        AREA=ARE10+ARE11-ARE12
0094        GO TO 80
0095     40 AREA=ARE10
0096        GO TO 80
0097     42 IF(CROSR-ELEVH)43,47,50
0098     43 SR2=A2R+(B2R*ELEVH)
0099        SL1=A1L+(B1L*ELEVH)
0100        ARE13=((SR2+SR)/2.)*(ELEVH-CROSR)
0101        ARE14=((SLR1+SL1)/2.)*(ELEVH-CROSR)
0102        AREA=AREA9+ARE13-ARE14
0103        GO TO 80
0104     47 AREA=AREA9
0105        GO TO 80
0106     50 SR1=A1R+(B1R*ELEVH)
0107        SL1=A1L+(B1L*ELEVH)
0108        ARE15=((SC+SR1)/2.)*(ELEVH-ZERO)
0109        ARE16=((SC+SL1)/2.)*(ELEVH-ZERO)
0110        AREA=ARE15-ARE16
```

TABLE B-4 (Continued)

```
CARD
0111          GO TO 80
0112       60 IF(CROSR-ELEVH)61,70,72
0113       61 SR2=A2R+(B2R*ELEVH)
0114          SL2=A2L+(B2L*ELEVH)
0115          ARE17=((SR2+SR)/2.)*(ELEVH-CROSR)
0116          ARE18=((SL2+SLR2)/2.)*(ELEVH-CROSR)
0117          AREA=AREA8+ARE17-ARE18
0118          GO TO 80
0119       70 AREA=AREA8
0120          GO TO 80
0121       72 IF(CROSL-ELEVH)73,77,50
0122       73 SR1=A1R+(B1R*ELEVH)
0123          SL2=A2L+(B2L*ELEVH)
0124          ARE19=((SR1+SR)/2.)*(CROSR-ELEVH)
0125          ARE20=((SL2+SLR2)/2.)*(CROSR-ELEVH)
0126          AREA=AREA8-ARE19+ARE20
0127          GO TO 80
0128       77 AREA=AREA7
0129       80 A=AREA
0130          IF(CROSR-ELEVH)109,109,107
0131      107 WR=A1R+(B1R*ELEVH)
0132          GO TO 110
0133      109 WR=A2R+(B2R*ELEVH)
0134      110 IF(CROSL-ELEVH)113,113,111
0135      111 WL=A1L+(B1L*ELEVH)
0136          GO TO 114
0137      113 WL=A2L+(B2L*ELEVH)
0138      114 W=WR-WL
0139          QC = SQRT(32.15*A*A*A/W)
0140          DELTQ = Q -QC
0141          IF(ABS(DELTQ).LT.1.0)GO TO 115
0142          HC = HC + (DELTQ/ 2000.)
0143          GO TO 32
0144      115 ELEV = 0.0
0145          VELH = Q*Q/(64.3*AP*AP)
0146          CL = (HP - HC -(A/(2.*W)) +VELH                    )/0.03
0147          INDEX = 0
0148          ELOSS= (STAMS- STA)*.01
0149          IF(AN.LT.0.0001) AN = 0.02
0150          TOTALH = VELH +HP + ZERO +ELOSS
0151      116 ELEV = TOTALH
0152          CENDEP = 0.0
0153          I = 0
0154          AREA = 0.0
0155          HYRAD = 0.0
0156          WTPER = 0.0
0157          DELTX = 0.1 * SCALE
0158          DELTXS  = DELTX *DELTX
0159        5 NUMB = 0
0160        6 I = I + 1
0161          IF (I.EQ.NY) GO TO  99
0162          Y1 = ELEV - Y(I)
0163          Y2 = ELEV - Y(I+1)
0164          IF (Y2.GE.Y1) CENDEP = AMAX1(CENDEP,Y2)
0165          IF (Y2.GE.0.0) GO TO 2
```

TABLE B-4 (Continued)

```
CARD
0166          IF (NUMB.EQ.0  ) GO TO 6
0167          GO TO 4
0168        2 IF (Y1.LT.0.0) GO TO 3
0169          AREA = AREA + (((Y1 + Y2)*DELTX)/2.0)
0170          WTPER=WTPER+(((Y2-Y1)*(Y2-Y1))+DELTXS)**.5
0171          NUMB = 1
0172          GO TO 6
0173        3 X = (Y2/(Y2 - Y1))*DELTX
0174          AREA = AREA + ((Y2 * X)/2.0)
0175          WTPER = WTPER + (((X * X)+(Y2 *Y2))**.5)
0176          NUMB = 1
0177          GO TO 6
0178        4 X = (Y1/(Y1 - Y2))*DELTX
0179          AREA  = AREA + ((Y1*X)/2.0)
0180          WTPER = WTPER + (((X*X) + (Y1*Y1))**.5)
0181          IF(WTPER.GT.0.01) HYRAD = AREA/WTPER
0182          GO TO 5
0183       99 CONTINUE
0184           IF (AREA.LT.0.01)GO TO 129
0185          IF(HYRAD.LT.0.01) GO TO 129
0186          ELOSS = (STAMS -STA)*(((Q*AN)/(1.486*AREA*(HYRAD**0.66667)))**2.0)
0187          TOTALH = VELH +HP + ZERO +ELOSS
0188          DIFF = TOTALH - ELEV
0189          TOTALH = TOTALH -(DIFF*0.7)
0190          INDEX = INDEX + 1
0191          IF(INDEX.GT.15) GO TO 129
0192          IF(ABS(DIFF).GT.0.01) GO TO 116
0193          IF(AREA.LT.0.01) GO TO 129
0194          CONTR = AP / AREA
0195          R = HYRAD
0196          AP1 = AREA
0197          WRITE(NW,401)TEST,Q,HP,C1,AP,AP1,CONTR,CL,R,AN
0198          WRITE(NP,402)TEST,Q,HP,C1,AP,AP1,CONTR,CL,R,AN
0199          GO TO 30
0200      128 WRITE(NW,209)
0201          GO TO 1
0202      129 CONTR = 0.0
0203      130 WRITE(NW,203)TEST,Q,HP,C1,AP,CL
0204          WRITE(NP,205)TEST,Q,HP,C1,AP,CL
0205          GO TO 30
0206      300 STOP
0207          END
0208    //GO.SYSIN DD *
0209    //GO.SYSPUNCH DD SYSOUT=B
0210    //
```

APPENDIX C

LIST OF SYMBOLS

List of Symbols

Symbol	Description
A	Cross-sectional area of flow, in square feet
A_c	Cross-sectional area of flow at the critical section, in square feet
A_p	Cross-sectional area of flow at the point of head measurement, in square feet
c	A subscript relating to conditions at the critical section
C	Discharge coefficient
C_r	Contraction ratio (A_p / approach cross-sectional area of flow)
E	Specific energy, in feet
E_c	Total specific energy at the critical section, in feet
E_p	Total specific energy at the point of head measurement, in feet
E_1	Elevation of water surface at upstream station
E_2	Elevation of water surface at downstream station
g	Acceleration due to gravity, in feet per second per second
h_c	Depth of flow above the V-shaped floor at the critical section, in feet
h_p	Piezometric head above the flume zero, the bottom of the V-shaped floor, in feet
L	Horizontal length between critical section and point of head measurement, in feet
n	Manning's n
p	A subscript relating to conditions at the point of head measurement
Q	Discharge, in cubic feet per second
Q_c	Critical discharge, in cubic feet per second
R	Hydraulic radius, in feet

Symbol	Description
S	Slope of the energy line
S_v	Floor cross slope
T	Top width of flow, in feet
T_c	Top width of flow at the critical section, in feet
V	Velocity, in feet per second
W	Flume width, in feet
x	Horizontal coordinate positive in the upstream direction, in feet
y	Vertical coordinate, in feet or Depth of flow, in feet
z	Horizontal coordinate normal to the centerline of the flume, in feet
α	Velocity distribution coefficient
α_c	Velocity distribution coefficient at the critical section
α_p	Velocity distribution coefficient at the point of head measurement
1	Subscript relating to the upstream station
2	Subscript relating to the downstream station

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