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Experimental investigation of long-throated the accuracy of flow discharge measurement in trapezoidal canals

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Abstract
Discharge measurement is the basis of accurate water distribution and proper management of Irrigation networks operation. In order to exploit Irrigation networks properly, it is required to measure water discharge in different points of network. Long-throated flumes are hydraulic structures that measure the flow enjoying low sensitivity to submergence, high accuracy, and low costs. One of important issue in the design of long-throated flumes is determination of sill height and downstream slope. The hydraulic of a long-throated flume is similar to a Broad-crested weir. In this research, the effect of geometric factors on the structure measured discharge has been investigated. Eight physical model of long-throated flume with constant upstream slope, four different downstream slopes and with two sill heights of 10 and 20 cm were examined. The dimensions of long-throated physical models were designed by WinFlume Software and built from PVC. The models were installed within a flume with 60cm wide, followed by discharge measurement. The comparison of measured discharge using triangular weir with the results of WinFlume indicated the accuracy of this model in discharge measurement. The percentage of error average in measured discharge and theoretical discharge is 2.4 in a 20-cm step and 8.2 in a 10-cm step.

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1. Introduction

Volumetric distribution of water is one of the essential needs of irrigation and draining systems. There are various methods to measuring water. One structure that can be used to install and measure discharge in irrigation and drainage systems is long-throated weirs. This paper deals with long-throated flumes with a trapezoidal control section. These flumes can be applied in covered canals.

In open channels where it is required to measure a wide range of discharges, another instrument called H flume (long throated) is used. This structure has a V-shape output. This V-shaped structure is advantageous since it has a wide opening for high discharges (Since it is V-shaped then as the discharge increases, so does the width of flume output mouth) reducing the effect of back water. On the other hand, in low discharges as the output of this flume tightens, the accuracy still remains at an acceptable limit. In general, technically long-throated flumes act as Broad-crested weir and this bulge creates a flow at the critical depth in turn generating a connection between rates and ratios of the flow.

Experimental investigation is done to investigate the effect of sill height and downstream slope of a long-throated weir on the accuracy of flow discharge coefficient and energy depreciation in trapezoidal canals.

2. Long-throated flumes

Generally, long-throated flumes consist of the following(Fig1.):

1. The structure input canal
2. Input convertor
3. Throat with sufficient length to create hydrostatic flow
4. Output convertor

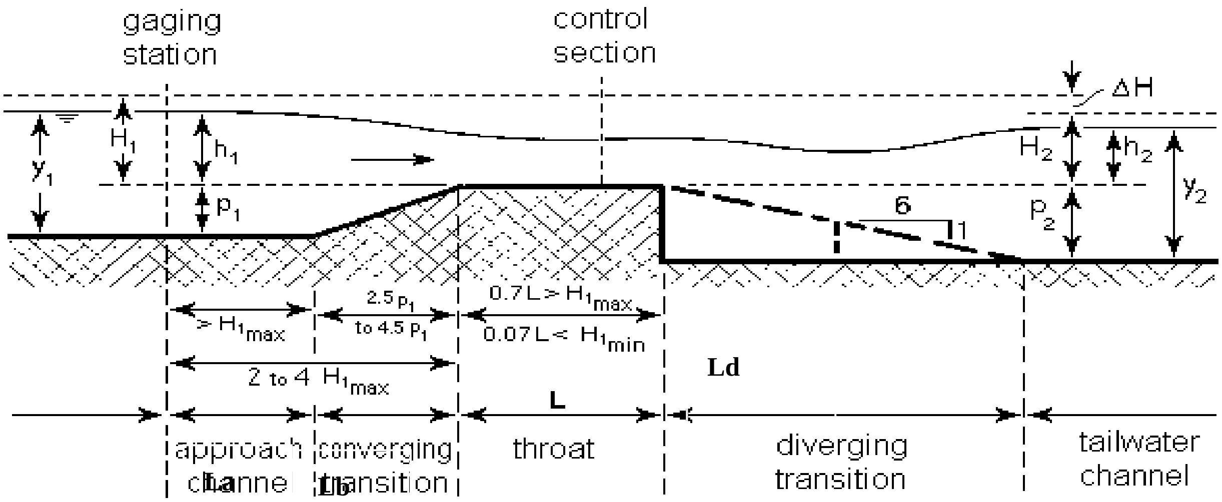


Fig 1. Sideview of a long through flume

The throat length in long-throated flumes should be at least two times the height of water in the flume to allow hydrostatic pressure distribution in the control section. This property results in generation of a specific equation between discharge and water height in flumes.

A key issue in the design of long-throated flumes is determination of flow discharge coefficient. The discharge correction factor is shown by Cd parameter. Using energy and continuity equations, the flow discharge coefficient of long-throated flume structure with a rectangular control section is obtained by:

$$Q = \frac{3}{2} C_d \, b \sqrt{2g} \, H_1^{\frac{3}{2}}$$

(1)

Where b is the flume width, Q is flow rate through the flume, H1 is the water height in upstream, and Cd is flow discharge coefficient.

A thorough treatment of the computational process and several precomputed, standard-size, long-throated flumes for a variety of canals and natural channels are presented in Clemmens et al. (2001) and Bos et al. (1991). The U.S. Water Conservation Laboratory, Agriculture Research Service, U.S. Department of Agriculture, developed the first computer programs for designing and calibrating long-throated flumes.

WinFlume (Wahl et al. 2000) is the most advanced software for analysis of long-throated flumes. With the development of the WinFlume program, users are able to create possible flume situations under various conditions. The ease of use and flexibility in design are some WinFlume's advantages. Further design capabilities are discussed in the following methodologies (Wahl 2012).

Ratings are determined by numerical solution of the critical-flow equations, accounting for boundary friction and other losses. The program includes a module that simplifies and accelerates the process of developing acceptable flume designs.

Clemmens et al. (2001) and Bos et al. (1991) provides calibration tables in metric (S.I.) and English units for a set of long-throated flume dimensions that covers a discharge range from about 2.8 to 280 ft3/s for trapezoidal channel shapes with side slopes of 1:1 to 1:1.5 horizontal and with bottom widths from about 1 to 5 ft. They also provide instructions for construction and field placement. Calibration tables for long-throated rectangular flumes are also presented.

3. Flow Coefficient (Cd)

One research area that has attracted the attention of researchers and scientists is investigation of factors influencing the discharge coefficient. Regarding flow discharge coefficient (Cd), Bos et al,(1984) have conducted many research. All of these pieces of research imply excessive dependence of Cd on H1/L where H1 is the total energy in the upstream which is measured against the throat edge and L is the length of flume throat (Fig. 1).

Singer (1964) indicated that if the two following relations are true, then the discharge coefficient is almost constant and equal to 0.848.

$$0.08 \le \frac{h_1}{L} \le 0.33 \qquad \frac{h_1}{h_1 + P} \le 0.35$$

(2)

Where, h_1 is the upstream water depth, P is weir height, and L is length of weir in the flow direction.

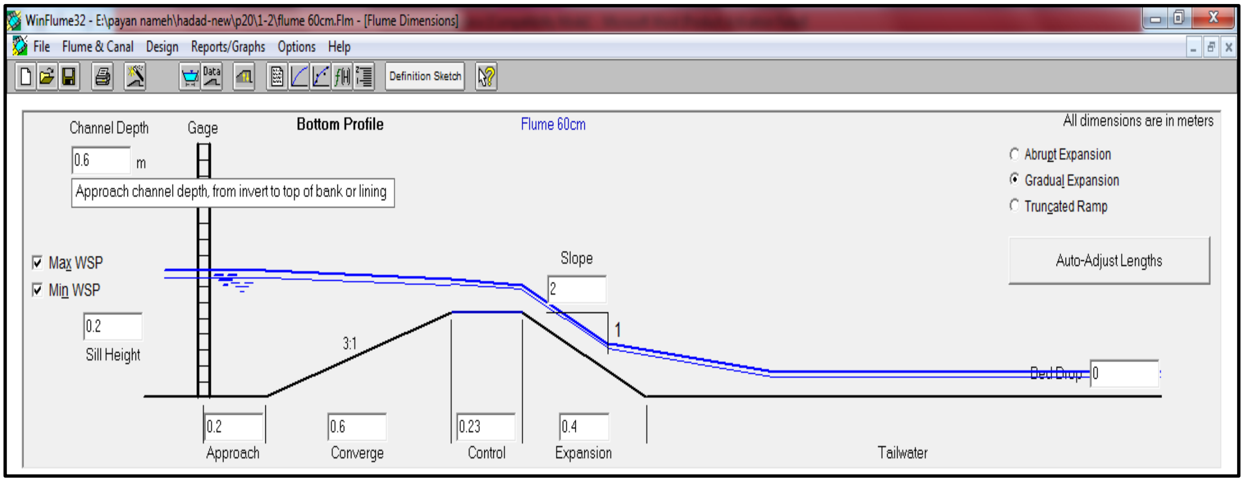
Colmans et al revealed that Cd is dependent upon H1/L. it lies within the range of 0.1 and 1 with a confidence level of 95% and error of ± 5%. Through several experiemtns they concluded that Cd is dependent on H1/L based on the following equation.

$$C_d = \left(\frac{H_1}{L} - 0.07\right)^{0.018} \qquad (3)$$

The design by John Replogel is also relevant here. The Replogel flume belongs to long-throated flumes family with a trapezoidal section. This design has been used for more than 20 years in the center of irrigation research and development of Cal Poly 7. Similar studies were conducted by Bas et al on determination of flow discharge coefficient in these flumes.

4. Material and methods

To perform this research, the flume of sedimentation laboratory in Khuzestan water and power organization was used. The flume has an open rectangular input and output canal with a glass wall, where the length of input canals at the beginning of flume and output ones at the end of flume are 6 and 4 m, respectively. The width and height of flume are 60 cm, the flume floor is in the form of fixed bed with no slope and at executive accuracy level (the slope is almost zero) horizontally. To measure discharge, a triangular weir was designed at the beginning of flume with its floor around 70 cm above the flume floor. It was then used to measure the discharge along with a vent at the end to adjust the water surface made from metal sheets. The long-throated weir was designed by WinFlume and used to measure the volumetric amount of water as well as to measure the amount of energy loss with a zero floor slope. Using this software, the structure was designed and built with two sill heights of 10 and 20 cm and in each height four downstream slope with slopes of 1:0, 1:1, 1:2, and 1:3. Fig. 2 and 3 present a sample of the model designed in WinFlume and the built model.



Flume 60cm

All dimensions are in meters

Channel Depth 0.6 m

Approach channel depth, from invert to top of bank or lining

○ Abrupt Expansion
● Gradual Expansion
○ Truncated Ramp

☑ Max WSP
☑ Min WSP

Sill Height 0.2

Slope 2

Bed Drop 0

Approach 0.2

Converge 0.6

Control 0.23

Expansion 0.4

Fig 2. Long throat flume design with 20 cm sill height and 1:2 slope (WinFlume)

Fig 3. Built Long throat flume with 20 cm sill height and 1:2 slope (experimental)

5. result

5.1. *the accuracy of discharge measurement using a long-throated structure*

The accuracy of experimental model is tested by 11 to 15 lit/s discharge. The result are shown in table 1. This indicates high accuracy of discharge measured by the developed structure. Next, the difference between the percentages of taken discharges and theoretical discharges by the software for different slopes for the weir with sill height is shown in Fig 4 and 5.

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Table 1. Result of Long throat flume design with 20 cm sill height and 1:2 slope

Head at gage h1	Head teoritical h1	Measured discharge	Theoretical discharge	Discharge Difference	Discharge Difference	Froude Number	Required Head Loss	H1/L Ratio	Upstream Energy Head	Upstream Depth	Upstream Velocity
m		L/S	liters/s	liters/s	%	m	m		m	m	m/s
0.084	0.082	11	11.47	-0.47	-4.1	0.063	0.018	0.42	0.084	0.284	0.091
0.087	0.086	12	12.15	-0.15	-1.21	0.065	0.019	0.38	0.087	0.287	0.095
0.088	0.091	13	12.38	0.62	5.05	0.066	0.019	0.385	0.088	0.288	0.097
0.092	0.095	14	13.31	0.69	5.18	0.07	0.019	0.402	0.093	0.292	0.102
0.096	0.099	15	14.28	0.72	5.08	0.073	0.02	0.42	0.097	0.296	0.108

Measured discharge	Allowable Tailwater h2	Tailwater Head,h2	Tailwater Depth,y2	Modular Limit	Tailwater Depth measurment,y2	down stream Velocity	E_2	ΔE	$\Delta E/E_1$
L/S	m	m	m		m	m/s			
11	0.066	-0.151	0.049	0.784	0.05	0.367	0.057	0.027	32.319
12	0.068	-0.149	0.051	0.787	0.051	0.392	0.059	0.028	32.370
13	0.069	-0.149	0.051	0.787	0.053	0.409	0.062	0.026	30.093
14	0.073	-0.146	0.054	0.791	0.055	0.424	0.064	0.029	30.996
15	0.076	-0.144	0.056	0.794	0.058	0.431	0.067	0.030	30.444

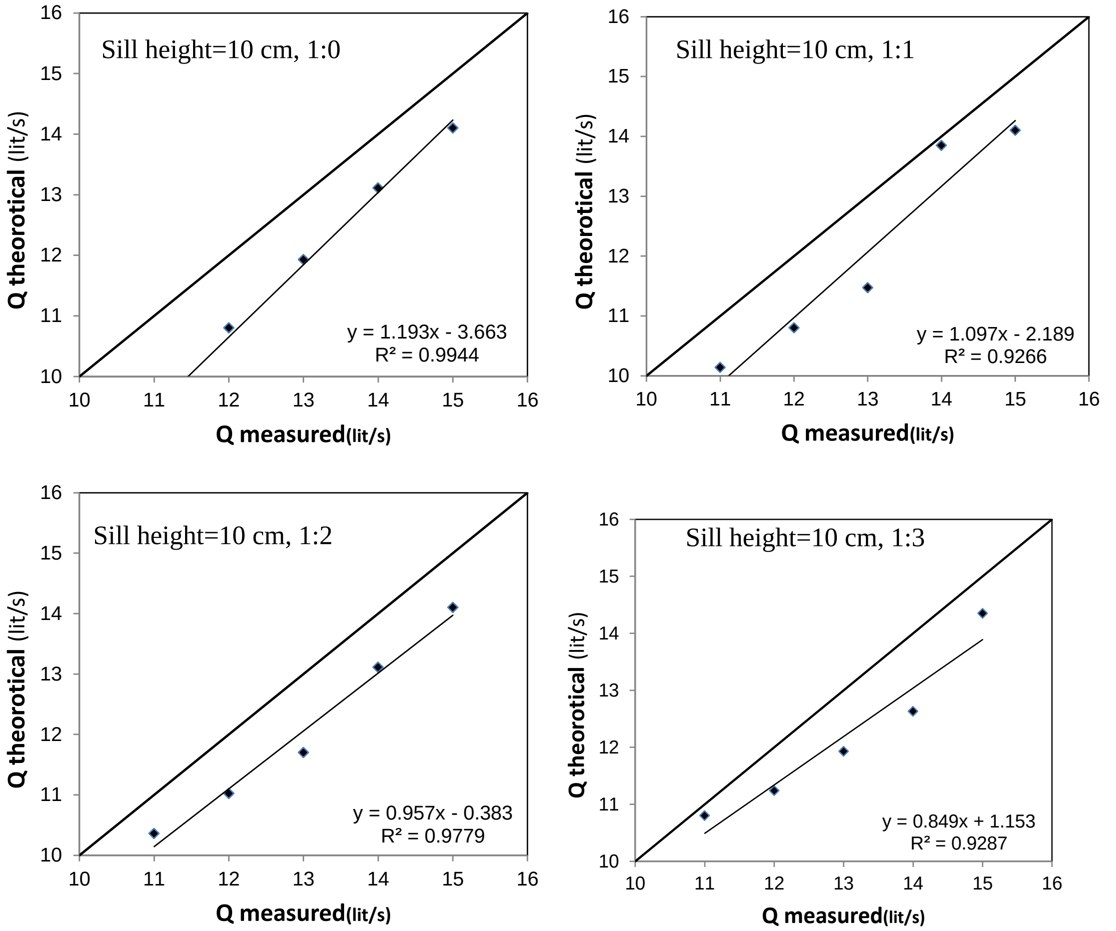

Fig 4. Q-theoretical and Q-measured relationship in long throat flume with 10 cm sill height

With regard to the accuracy of experimental model in estimation of discharge(table1), water Head at gage h_1 reveal that for a weir with a height of 20 cm, Q measured read in the triangular weir at the beginning of obtained canal and at the weir input with certain figures read from the scale with Q theoretical obtained from the relation of discharge at the scale proposed by WinFlume Software are not significantly different.

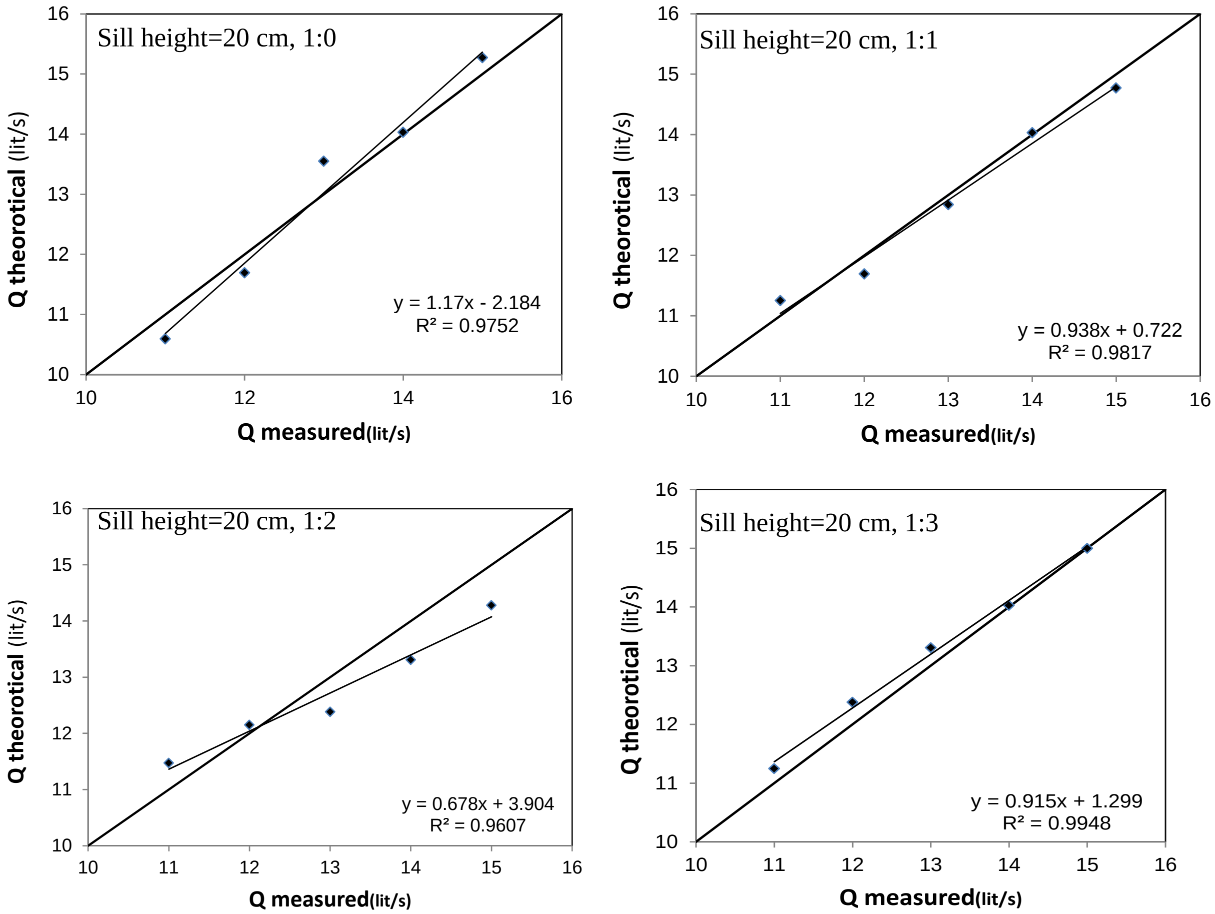

Fig 5. Q-theoretical and Q-measured relationship in long throat flume with 20 cm sill height

The difference between measured discharges and theoretical discharges at different slopes is shown in Fig. 1 and 2 for the weir with heights of 10 and 20 cm.

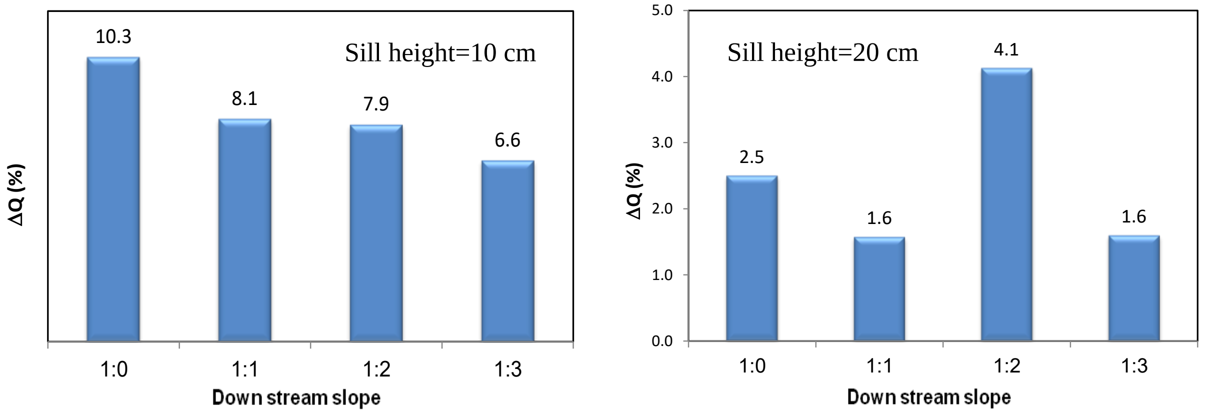

Fig 4. Difference between measured discharges and theoretical discharges

5.2. *Energy dissipation*

The results of energy depreciation measurement in the long-throated weir structure with step heights of 10 and 20 cm are demonstrated in the figures.

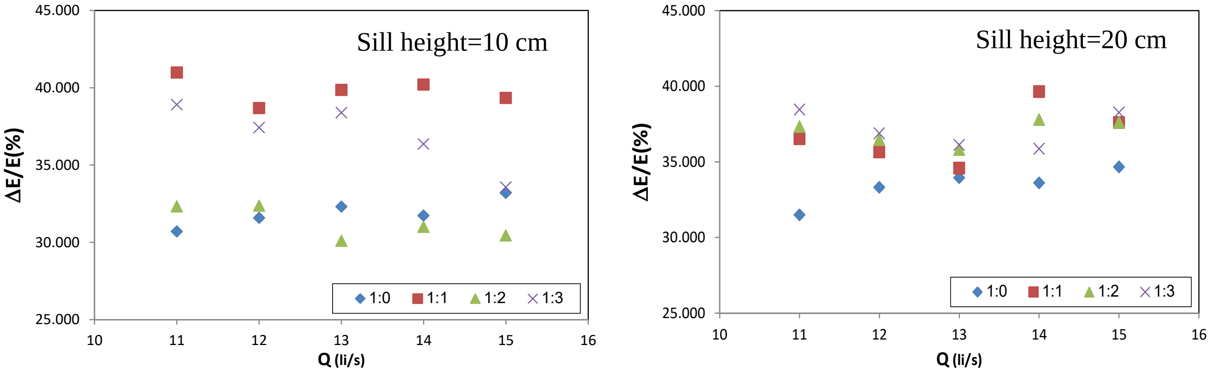

Fig 6.energy depreciation in Different sill height and slope

5.3. *Q-h1 relationship*

This form is used to generate a power-curve equation that approximates the Q vs. h1 rating curve of the flume. This equation can be programmed into a data logger for automating the measurement storage of discharge data. WinFlume determines a curve-fit equation of the form:

$$Q = K_1 .(h_1+K_2)^u \quad (4)$$

You may also force $K_2 = 0$ when performing the curve-fit calculations. The resulting simplified equation form may be more easily programmed into some data loggers. The curve-fitting routine uses a rating table generated by WinFlume. The user specifies the type of rating table (range of heads vs. range of discharges) and the range and increment for the rating table on the Options tab. The second and third tabs of the form allow the user to review the rating table and curve-fitting results in tabular and graphical form.

Table 2. K1 and U coefficient in different scenarios

sill hight	upstream slope	K1	U	Coefficient of determination	Discharge Difference %	$\Delta E/E_1$ (%)
20	1:0	642.69	1.62	0.9999	2.5	31.90
20	1:1				1.6	39.81
20	1:2				4.1	31.24
20	1:3				1.6	36.93
10	1:0	678.75	1.63	0.9998	10.3	33.39
10	1:1				8.1	36.80
10	1:2				7.9	36.99
10	1:3				6.6	37.10

The results reveal that the measurement accuracy of discharge in long-throated flumes with a 10-cm step height and at the experimented discharges (11, 12, 13, 14, and 15 L/s) was lower than the case for the long-throated flume with a height of 20 cm. This is because of hydraulic conditions of the flow in downstream. At the 10-cm step height, the measurement accuracy is compromised because the flow conditions are affected by the conditions at downstream (submergence).

Reference

［1］. Bos, M.G., 1989, Discharge Measurement Structures, 3rd ed., ILRI Publication 20, International Institute for LandReclamation and Improvement, The Netherlands.

［2］. Bos, M.G., J.A. Replogle, and A.J. Clemmens, 1984, Flow Measuring Flumes for Open Channel Systems, JohnWiley & Sons, New York, NY.

Note: The 1984 printing is no longer available, but this book has been republished as: Bos, M.G., J.A. Replogle, and A.J. Clemmens, 1991, Flow Measuring Flumes for Open Channel Systems,

［3］. American Society of Agricultural Engineers, St. Joseph, Michigan, USA.

［4］. Clemmens, Albert J., Tony L. Wahl, Marinus G. Bos, and John A. Replogle, 2001, *Water Measurement with Flumes and Weirs*, ILRI Publication 58, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.

［5］. WinFlume (Wahl et al. 2000) is the most advanced software for analysis of long-throated flumes. The program is Windows-based and can be downloaded from http://www.usbr.gov/pmts/hydraulics_lab/winflume.

［6］. Wahl, L. T., A. J. Clemmens, M. G. Bos, J. A. Replogle. 2012. The WinFlume Home Page. US Department of the Interior, USBR.

［7］. Clemmens A.J , Bos,M.G , Replogle. J.A , Wahl,2001,T.L. Water Measurement with Flumes and Weirs, International Institute for Land Reclamation and Improvement / ILRI ,Wageningen, The Netherlands.

［8］. 5-Bos,M.G.,J.A.Replogle,and A.J.Clemmens,1984,Flow Measuring Flumes for Open Channel Systems.John Wiley,NewYork, 321p.

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