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CALIBRATION OF DIFFERENT WATER COURSE OUTLETS AT RAHUKI DISTRIBUTARY

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ABSTRACT

The calibration of various types of outlets plays pivotal role in ensuring accurate and equitable distribution of water. A study was conducted to calibrate three different types of outlets including orifice type semi module (OSM), pipe outlet and open flume (OF) off taking from Rahuki distributary. These types of outlets are commonly found in the irrigation system of Pakistan, particularly in Sindh. In this study theortical discharge was computed from geometrical parameters of outlets, actual discharge was measured through cut-throat flume. The values of coefficient of discharge (C_d) for all the outlets were calculated from minimum and maximum heads of the selected outlets. The results showed that the open flume outlet and adjustable proportional module produced higher C_d values as compared to pipe outlet. Hence open flume and adjustable proportional outlets could be used for higher accuracy. It was found that C_d values have direct relationship with upstream head at outlet as head increased, C_d values of all types of outlets increased. This study also developed an explicit empirical equation for all the outlets and rating curves on the basis of C_d values. The results of this study can be used as guidelines for agriculture engineers as well as Farmer's Organizations (FOs) for proper operation of watercourses.

Keywords: calibration of outlets, coefficient of discharge and Stage discharge ratings

INTRODUCTION

Pakistan's irrigation system is one of the biggest irrigation systems in the World. Its irrigated area has been increased from 9 million hectares (Mha) in 1950 to about 18 Mha (total irrigated area not Basin area) in 2006 (Government of Pakistan, 2006). Despite having the world's biggest irrigation system, huge amount of water is lost in the conveyance system. According to estimates only 30% of water diverted into the canal system reaches at the farmers' fields

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(Kahlown and Kemper, 2004). This is attributable to the uncertainty and inequity of water distribution at the head reaches of watercourses. In addition, farmers at the head reaches get more water, which results in the unavailability of water at the tail reaches (Bhutta *et al*., 1992; Latif and Pomee, 2003).

Outlet, also known as farm turnouts in some countries, is a device constructed at the head of a watercourses, which admits designed discharge of water from government own distributary or minor to public owned watercourses (Sharma and Sharma, 2008). Common types of outlets found in the irrigation system of Pakistan, particularly in Sindh are: orifice type semi module (OSM), pipe outlet and open flume (OF). There are several other structures like orifices, weirs, and flumes (Spitzer, 1991, Gertrudys, 2006, Chin, 2007) are used to measure irrigation water directly by making a reading on scale in an open channel or closed conduit (Bos, 1978; Tollner, 2002). However, outlet partially restricts the flow in an open channel and supplies irrigation water judicially on the basis of their rights and needs (Adkins, 2006). The accuracy in the measurement of designed discharge is crucial for equitable distribution of water (Pomee *et al.,* 2005, Bureau of Reclamation. 2001). This is consistent with Thandaveswara (2007), who stated that the success of any irrigation enterprise depends on the accuracy in the distribution of water.

Hence, calibration of various types of outlets plays pivotal role in ensuring accurate and equitable distribution of water to the watercourses. Once a structure is properly calibrated for immoveable channel regime, it provides accurate data so that the relationship among discharge and depth of flow can be established (Shaikh *et al.,* 2012). Therefore a study was carried out at three types of outlets off taking from Rahuki distributary.

MATERIALS AND METHODS

This study was carried out on the calibration of three types of outlets (orifice type Semi Module (OSM), Pipe outlet and Open Flume (OF)) off taking from Rahuki distributary. The total length of the distributary is 14.32 km, gross command area is 20880.56 hectares (ha) and cultivable command area is 20623.59 ha. The salient features of selected watercourse are depicted in Table 1.

Table 1. Salient features of selected watercourse

S.No.	Name of watercourse	Actual Dimensions		Type of outlet
		B_t/dia (m)	Y (m)	
1	8-L	0.12	0.23	OSM
2	2-CR	0.01	-	OF
3	Pipe	0.10	-	Pipe outlet

Calibration of outlet/mogha

Discharge measurement

The actual discharge of selected watercourses was measured by cutthroat flume, while the theoretical discharge was computed by empirical formulae at different heads (from minimum till maximum) (IWMI, 1998); hence four readings were taken at each location.

Orifice semi module outlet (OSM)
Empirical formula of orifice semi module outlet

$$Q = Bt \times Y \times \sqrt{2gHs}$$

Where, Q is discharge (m^3/s), Bt is width of the opening (m), Y is a difference between the elevations of the roof block and the elevation of crest of the outlet (m), g is acceleration due to gravity (m/s^2), Hs is height between the upstream water level and the roof block (m) i.e. Hs = hu – Y, where, hu is upstream flow depth (m).

Pipe outlets

$$Q = C_f \times A \times \sqrt{2gH}$$

Where Q is discharge (m^3/s), C_f is coefficient, A is the inner area of pipe, g is acceleration due to gravity (m/s^2), H is height between the upstream water level and the center of pipe (m).

Open flume outlet
Free flow condition

$$Q = K \times Bt \times \left(G\right)^{3/2}$$

Where Q is discharge (m^3/s), Bt is width of the opening (m), G is height between the upstream water level and the crest of outlet (m).

Cutthroat flume
Empirical formula of cut throat flume is

For free flow formula

$$Q = C_f (h_u)^{nf}$$

Submerged flow formula

$$Q = \frac{C_s (h_u - \mathrm{h_a})^{nf}}{(-\log S)^{ns}}$$

Q = Discharge in cusec
h_u = Upstream
h_d = Downstream
S =Ration of downstream and upstream
S < 0.68 for free flow
S > 0.68 for submerged flow

Co-efficient of discharge C_d
The ratio of actual discharge to the theoretical discharge is known as Coefficient of discharge. It is unit less

$$C_d = \frac{Q_{act}}{Q_{th}}$$

Where,
C_d = Co-efficient of discharge
Q_{act} = Actual discharge in cumecs
Q_{th} = Theoretical discharge in cumecs

RESULTS AND DISCUSSION

The results of coefficient of discharge for OSM outlet are given in Table 2. The upstream head (hu) varied from 0.46 to 0.66m, while the fluctuations in the C_d values were recorded from 0.79 to 0.92 with an average value of 0.859.

Table 2. Theoretical discharge, actual discharges and values of coefficient of discharge for OSM outlet

Sr. No.	Theoretical Discharge [Outlet]			Actual Discharge [Cut-throat Flume] 12"X 3'			Coefficient Discharge
	Hs (m)	Q th (Cumecs)	Type of Flow	hu (m)	Q act (Cumecs)	Type of Flow	Cd
1	0.459	0.081	FF	0.213	0.064	FF	0.79
2	0.522	0.086	FF	0.226	0.071	FF	0.82
3	0.556	0.089	FF	0.238	0.078	FF	0.88
4	0.602	0.093	FF	0.244	0.082	FF	0.88
5	0.659	0.097	FF	0.256	0.089	FF	0.92
						Average	0.86

In pipe type of outlet upstream head (H) varied from 0.42 to 0.66m, while the fluctuations in the C_d values were recorded from 0.68 to 0.78 with average value of 0.74 as shown in Table 3. C_d values of pipe outlet were less than that of OSM. This may be due to low discharges.

Table 3. Theoretical discharge, actual discharges and values of coefficient of discharge for pipe outlet

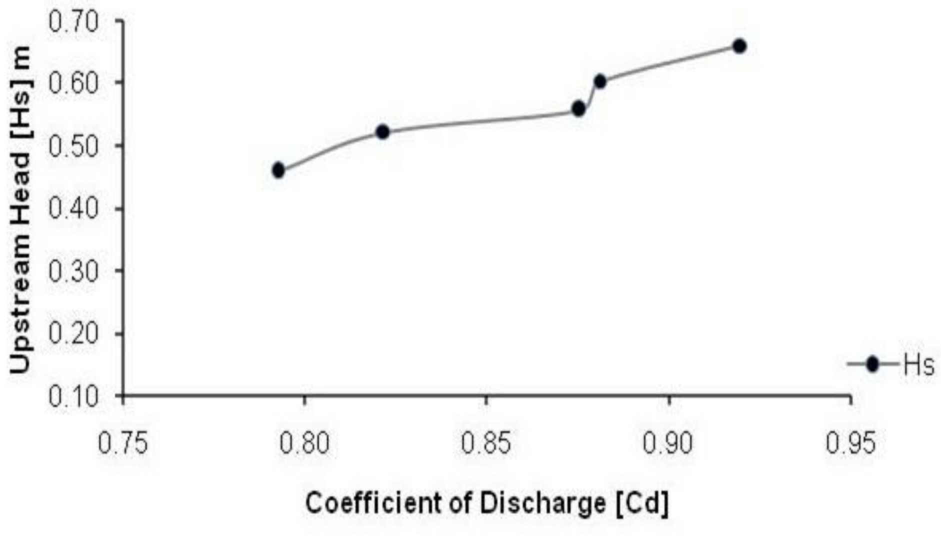
Sr. No.	Theoretical Discharge [Outlet]			Actual Discharge [Cut-throat Flume] 8"X 3'			Coefficient Discharge
	H (m)	Q th (Cumecs)	Type of Flow	hu (m)	Q act (Cumecs)	Type of Flow	Cd
1	0.419	0.023	FF	0.012	0.016	FF	0.68
2	0.496	0.025	FF	0.012	0.018	FF	0.71
3	0.534	0.026	FF	0.013	0.020	FF	0.75
4	0.573	0.027	FF	0.014	0.021	FF	0.78
5	0.659	0.029	FF	0.014	0.023	FF	0.78
						Average	0.74

In open flume outlet, upstream head (H) varied from 0.34 to 0.57m, while the fluctuations in the C_d values were recorded from 0.79 to 0.84 and average value of C_d was 0.81 as shown in Table 4.

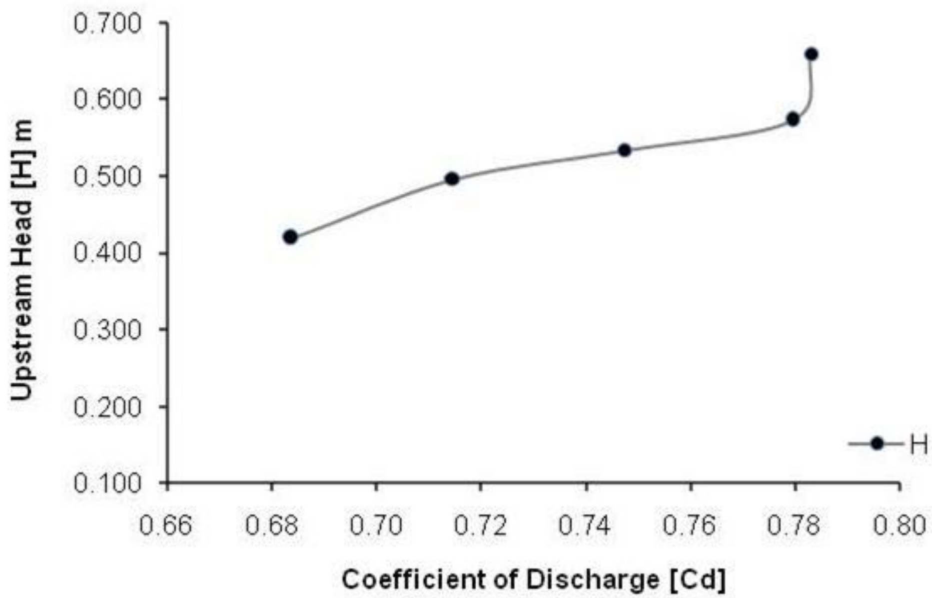
Table 4. Theoretical discharge, actual discharges and values of coefficient of discharge for open flume

Sr. No.	Theoretical Discharge [Outlet]			Actual Discharge [Cut-throat Flume] 12"X 3'			Coefficient Discharge
	H (m)	Q th (Cumecs)	Type of Flow	hu (m)	Q act (Cumecs)	Type of Flow	Cd
1	0.335	0.032	FF	0.530	0.025	FF	0.79
2	0.410	0.043	FF	0.630	0.035	FF	0.80
3	0.433	0.047	FF	0.660	0.038	FF	0.80
4	0.488	0.056	FF	0.740	0.047	FF	0.83
5	0.570	0.071	FF	0.850	0.060	FF	0.84
						Average	0.81

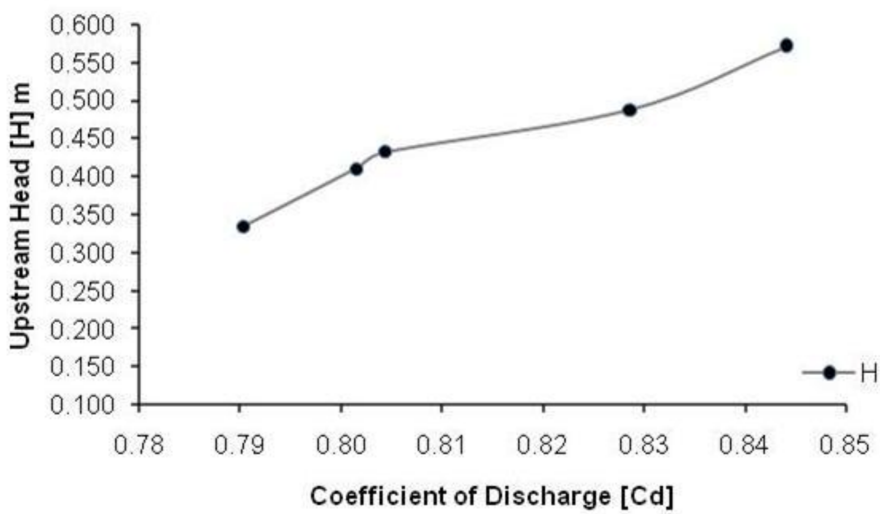
The results also showed that the coefficient of discharge is directly proportional to the upstream head of all the outlets in free flow state. As upstream head increased Cd values also increased. Similar trend was found in all three types of outlet as shown in Figure 1.



a) Orifice Semi Module



b) Pipe Outlet



c) Open Flume Outlet

Figure 1. Relationship between upstream head and co-efficient of discharge

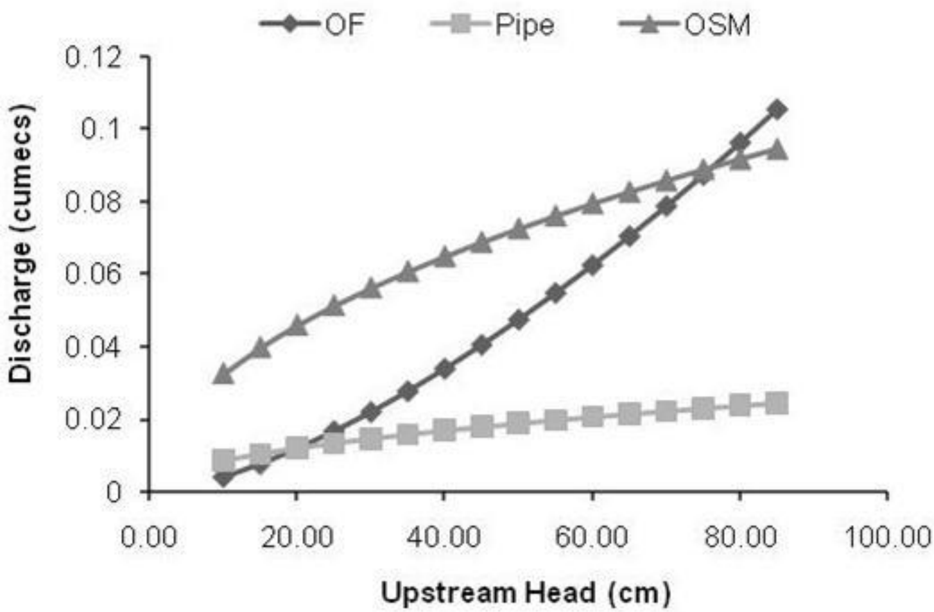


Figure 2. Stage discharge (rating) curves of OSM, OF and Pipe Outlts

The results of this experiment are in resemblance with Arjen (1997), who found that coefficient of discharge for Orifice type Semi Module (OSM) outlets ranged from 0.89 to 1.04 (average 0.97). However IWMI (1997), found coefficient of discharge for Orifice type Semi Module is 0.81 and 0.91 for Open Flume outlet. Iqbal (1994) states that there is a clear distinction between Cd values of OFRB and AOSM. This is probably due to the difference in the upstream face of the orifice.

Pomee *et al.* (2005) conducted a study to calculate the coefficient of discharge for commonly used outlets in Indus Basin Irrigation System (IBIS) under real field conditions. The results of calibration outlets of Hakra 4-R distributary showed that coefficient of discharge for Orifice Semi Module (OSM) type outlets ranged from 0.89 to 1.04 (average 0.97), while for Open Flume (OF) and Open Flume with roof Block (OFRB) type outlets ranged from 0.62 to 0.86 (average 0.73) and 0.99 to 1.19 (average 1.10) were observed, respectively (Arjen, 1997).

Stage discharge curves were developed for all three outlets (OSM, OF and Pipe) on the basis of average Cd values as shown in Figure 2. The curves showed that maximum fluctuation occurs in Open flume outlet, followed by orifice semi module and pipe outlets with respect to water level in the distributary.

CONCLUSION

The selected outlets were calibrated against the cut throat flume and the corresponding values of coefficient of discharge Cd were 0.859, 0.814 and 0.74

for OSM, OF and pipe outlets, respectively. The open flume outlet and adjustable proportional module produced higher Cd values as compared pipe outlet. Hence open flume and adjustable proportional outlets could be used for higher accuracy. It was also found that Cd values had direct relationship with upstream head. As head increased, Cd values increased.

REFERENCES

Adkins, G. B. 2006. Flow Measurement Devices, Report published by Ph.D. Division of Water Rights.

Arjen, A. 1997. During an evaluation of outlet calibration method a contribution study on collective action for water management below Hakra 6-R distributaries Report No R-32, Pakistan National Program International Irrigation Management Institute Lahore.

Bhutta, M. N. and E. J. V. Velde. 1992. Equity of Water Distribution along secondry canals in Punjab. Irrigation and Drainage Systems, 6: 161-177.

Bos, M. G. 1978. Discharge Measurement Structures. 2nd Ed. International Institute for Land Reclamation and Improvement/ILRI Wageningen, Netherlands

Bureau of Reclamation. 2001. Water Measurement Manual. 3rd Ed. Revised reprint, U. S. Government Printing Office, Washington DC, 20402.

Chin, D. A. 2007. 2nd Ed. Water Resources Engineering. Publisher: Pearson Education, Inc., Upper Saddle River, NJ 07458. pp. 750.

Gertrudys, B. A. 2006. Flow Measurement Devices. Publisher: Division of Water Rights.

Government of Pakistan. 2006. Agriculture Statistics of Pakistan. Economic Wing of the Ministry of Food, Agriculture and Livestock, Government of Pakistan.

IWMI. 1997. An Evaluation of outlet Calibration Methods, collective action for Water Management below the outlets Hakra 6-R Distributary, Punjab, Pakistan. Report. No. R-32.

IWMI. 1998. Field discharge calibration of head regulators, Mirpurkhas sub-division, Jamrao Canal, Nara Circle, Sindh Province, Pakistan. Report. No. R-62.

Iqbal, A. 1994. 1st Ed. Irrigation and Hydraulic Structures Theory Design and Practices, Institute of Environmental Engineering and Research, NED University of Engineering and Technology, Karachi, Pakistan.

Kahlown, M. A. and W. D. Kemper. 2004. Seepage losses as affected by condition and composition of channel banks. Agricultural Water Management, 65 (2): 145-153.

Latif, M. and M. S. Pomee. 2003. Impacts of institutional reforms on irrigated agriculture in Pakistan. Irrigation and Drainage Systems, 17 (3): 195-212.

Pomee, M. S., M. A. Khan, M. Z. Ikram, I. Ali and A. Wahab. 2005. Guidelines for Field Calibration of Irrigation Outlets commonly used in Indus Basin Irrigation System. Pak. J. Water Resou., 9 (1): 9-16.

Shaikh, I. A., A. S. Chandio, M. A. Mangrio and N. Faryad. 2012. Calibration of Adjustable Orifice Semi-modules at Bulgai Distributary. Pak. J. Agric., Agril. Engg., Vet. Sci., 28 (2): 177-185.

Sharma, R. K. and T. K Sharma. 2008. Irrigation Engineering. Publisher: S. Chand and company Pvt. Ltd. Ram Nagar, New Delhi.

Spitzer, D. W. 1991. Flow Measurement: Practical Guides for Measurement and Control. Publisher: Research Triangle part, NC. ISA.

Thandaveswra, B. S. 2007. 12^{th} Ed. Hydraulics. Indian Institute of Madras. pp. 135-140

Tollner, E. W. 2002. Natural Resources Engineering. Publisher: Iowa State Press, Ames. pp. 576.

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