ISSN 1023-1072

Pak. J. Agri., Agril. Engg., Vet. Sci., 2012, 28 (2): 177-185

CALIBRATION OF ADJUSTABLE ORIFICE SEMI-MODULES AT BULGAI DISTRIBUTARY

I. A. Shaikh[1], A. S. Chandio[1], M. A. Mangrio[1], N. Faryad[1]

[1]Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam, Pakistan

ABSTRACT

Prudent distribution of irrigation water at the farm gate is essential which is a responsibility of both the public sector and the water user association. The Adjustable Orifice Semi-Module (AOSM) is commonly used to divert the irrigation water from distributaries to the watercourses. An attempt was made to calibrate AOSM in the field and develop a relationship among the watercourse flow rates for different depths of flow. Three watercourses (1BL, 3R and 6R) off taking from Bulgai Distributary in District Tando Allahyar, Sindh, Pakistan were selected for this study. The geometric parameters of selected watercourses and their discharges were measured using AOSM and Global water flow probe. The Global water flow probe was calibrated in the laboratory of Irrigation and Drainage, Sindh Agriculture University Tandojam. The values of coefficient of discharge were computed using actual and theoretical discharge data for the calibration of AOSM under existing field conditions. It was observed that the average values of coefficient of discharge (C_d) varied between 0.503 and 0.574. The rating curves for flow depth and flow rates of selected watercourses were established from the computed C_d values. These curves facilitate to measure discharge of watercourses of different ranges directly from the upstream depth of flow above the roof block.

Keywords: Adjustable orifice semi-module, calibration of AOSM, coefficient of discharge, stage discharge curves, global water flow probe.

INTRODUCTION

The countries in arid and semi arid regions where temperature is high and rainfall is meager, erratic and poorly distributed hence it does not fulfill the agricultural water demands. Additional amount of irrigation water is needed to satisfy the crop water requirements (Ji *et al.,* 2007; Singh *et al.,* 2010). In Pakistan, the availability of the surface water is insufficient to irrigate the available cultivable lands and fluctuates throughout the year (Khan *et al.,* 2008; Qureshi *et al*., 2008; Zardari and Cordery, 2009). The rigid irrigation water allocation system known as *warabandi*, based on farm size instead of crop type and growth stage, has been practiced and in many instances failed to satisfy the crop's water requirements (Kahlown *et al.,* 2007; Qureshi *et al.,* 2008; Zardari and Cordery, 2009; Singh, 2011). The *warabandi* system is designed on the concept of equal distribution of water and the farmer is responsible to manage agricultural activities on his farm according to the available water. Ghumman *et al.* (2010) pointed out that the optimal use and effective management of water resources at farm level may lead to a significant increase in food production.

Management of irrigation water is dependent on the reliable measurements of flow rates and judicious distribution of the water at the farm level. Many structures are used to diverge water from main distributary to the watercourses. However, adjustable orifice semi module (AOSM) that is improved shape of the Crump's adjustable proportional module (APM) is commonly used (Ali, 2007). Tariq (2010) recommended that AOSM modules should be installed at the upper reaches of the distributaries, while open type flumes are recommended for middle and tail reaches.

Corresponding address: chandioas3@yahoo.com

The discharge in canals, distributaries and watercourses can be measured directly by the flumes, orifices and current meters of different types and sizes. However, use of these portal type devices is time consuming, cumbersome process and laborious job that needs the regular monitoring and calibration of the instrument. While, stage-discharge rating curve of a channel cross section explains a relationship between the water level (stage) and discharge at the section. It alleviates the need for costly and time consuming discharge measurement job (Westphal *et al.,* 1999; Punmia and Lal, 1992). Rahimpour and Maghrebi (2006) pointed out the advantage of this method is that the discharge can be estimated automatically at a fixed measurement location in the channel section or on the water surface, which is associated with minimum energy and cost consumptions. Thus, distributary outlets are calibrated so that discharge measurement can be made only by measuring upstream head of water. The outlet is a sort of head regulator for the field channel delivering irrigation water to the watercourses. However, the silt distribution proportionality between the off taking outlets and the parent distributaries is also considered in the design of the outlet (Ali, 2007).

The calibration of outlet structure involves the measurement of actual discharge over a wide range of flows and corresponding heads at upstream and downstream sides (or both). The coefficient of discharge C_d is calculated for each set of measurement and multiplied to theoretical discharge so that the results are match with the measured discharge (IIMI, 1998). 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. This study was aimed develop guidelines to calibrate AOSM type outlets which are commonly used in Asian countries like Pakistan.

Adjustable Orifice Semi-Module (AOSM)

In India and Pakistan, the adjustable orifice semi-module outlets are widely used that is modified shape of Crurnp's Adjustable Proportional Module (APM). Crump's module was incapable to draw its fair share of silt, which was an essential requirement for the irrigation systems which draw their supplies from rivers (Singh *et al.,* 2010; Tariq, 2010). Thus, the APM has now been replaced in India and Pakistan by the AOSM which is neither proportional nor fully modular, however it ensures to pass on a fair proportion of silt from the parent distributaries (Ali, 2007; Tariq, 2010).

The AOSM has a along throat flume with a roof block at the upstream end of a parallel throat. The roof block is adjustable and is attached with the flume by bolts. To prevent it from tampering, the bolts are secured by a masonry work. The governing discharge formula is as follows:

$$Q_{th} = B_t \times Y \sqrt{2g\, H_s} \qquad (1)$$

Where Q_{th} is discharge (m^3/s), B_t 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), H_s is height between the upstream water level and the suffit of the roof block (m) *i.e*. $H_s = h_u - Y$, where, hu is upstream flow depth (m).

MATERIALS AND METHODS

Description of study area and sample watercourses

This study was carried out in Tando Allahyar district of Sindh province. Three watercourses were selected that are off taking from Bulgai Distributary. The total length of Bulgai Distributary is 23.774 km that commands about 9603 hectares. The particulars of selected watercourses with regard to outlets obtained from Irrigation Department of Sindh are given in the Table 1.

Discharge measurement for calibration

The discharge of watercourses under the study was measured by Area x Velocity method. All the watercourses are lined with rectangular shape. The channel width and depth of flow was measured at different sections in each watercourse. The average values of watercourse geometric parameters (channel bottom width and depth of flow) were used in discharge computation.

The global water flow probe was used according to the manufacturer's guidelines (Global Water, 1997) to estimate flow velocity (Principe *et al*., 2008; Soupir *et al.,* 2009; Sarukkalige, 2011). The Global water flow probe was initially calibrated and verified in the laboratory of Irrigation and Drainage, Sindh Agriculture University Tandojam. The application of the probe in the field is involved to measure flow velocity of the watercourse section. To obtain the reliable data of average velocity, the flow probe was dipped in water at least for 60 seconds and the procedure was repeated at least 25 times at each watercourse. The resulting velocity was multiplied by the cross sectional area to determine the watercourse discharge. Finally, the discharge in watercourses was calculated by following mathematical equation:

$$Q_{ac} = A * V = b * d * V \qquad (2)$$

Where, Q_{ac} is actual discharge (m^3/sec), A is flow area (m^2), V is flow velocity (m/sec), b is channel bottom width (m) and d is depth of flow (m) of the watercourse.

Measurement of geometrical parameters

For AOSM type outlets, geometrical parameters include outlet width (B_t) and outlet opening (Y). The measurement of outlet's geometrical parameters is difficult during canal flowing conditions. The inaccurate measurement of B_t and Y leads to error in computation of C_d value. Thus, geometrical parameters of selected watercourses were measured during closure. H_s is the depth of water above the lower tip of the roof block. H_s, Full Supply Level (FSL) in minor and crest of mogha were measured with the help of engineer's level and staff rod.

Calibration of Adjustable Orifice Semi-Module (AOSM)

Outlet calibration is a process of computing coefficient of discharge (ratio of actual discharge to theoretical discharge) for prevailing flow condition in conjunction with outlet geometrical parameters. This constant accounts the contraction and frictional losses and used to determine actual discharge through hydraulic structures. For this study, the C_d for selected AOSM type outlet was computed by standard equation which is written as:

$$C_d = \frac{Q_{ac}}{Q_{th}} = \frac{Q_{ac}}{B_t \times Y \sqrt{2gH_s}} \qquad (3)$$

Where, C_d is coefficient of discharge, Q_{ac} is actual discharge in m^3/sec (cumecs) which is practically measured using Global water flow probe. Q_{th} is theoretical discharge which is determined using outlet geometrical parameters B_t and Y for AOSM type outlet and H_s which is upstream head of water above roof block.

RESULTS AND DISCUSSION

Measured discharge for selected watercourses

Velocity of all considered watercourses was measured with Global water flow probe for three consecutive days and three alternate days. The results of measured velocity, area and discharge for selected watercourses are presented in Tables 2 and 3. The stage discharge curves were established for wide range of flow rates (varying between 0.12 and 0.184 m^3/s). From Table 3 it is observed that the change in depth of flow tended to be most pronounced impacts on the shape of the flow and hydraulic resistance offered by channel.

Table 1. Particulars of selected watercourses with regard to diverging structure.

S. No.	W/C No.	Length (m)	Command Area (hectares)	Module Type	Flow Type	Geometrical Parameters	
						Bt (m)	Y (m)
1	1BL	1800	146	AOSM	Modular/ Free flow	0.20	0.60
2	3R	1800	146	AOSM	Modular/ Free flow	0.15	0.57
3	6R	2500	346	AOSM	Modular/ Free flow	0.20	0.52

Source: Irrigation and Power Department, Government of Sindh

Table 2. Average watercourses X-sectional area and velocity determined by Global water flow probe.

Day	W/C No. 1BL			W/C No. 3R			W/C No. 6R		
	$A(m^2)$	V (m/sec)	Q (m^3/sec)	$A(m^2)$	V (m/sec)	Q (m^3/sec)	$A(m^2)$	V (m/sec)	Q (m^3/sec)
1	0.360	0.510	0.184	0.348	0.460	0.160	0.459	0.360	0.165
2	0.324	0.540	0.175	0.318	0.460	0.146	0.422	0.390	0.165
3	0.306	0.530	0.162	0.296	0.480	0.142	0.400	0.400	0.160
5	0.288	0.530	0.153	0.289	0.470	0.136	0.355	0.440	0.156
7	0.264	0.560	0.148	0.244	0.550	0.134	0.326	0.430	0.140
9	0.246	0.570	0.140	0.222	0.540	0.120	0.303	0.440	0.133

Table 3. Geometric parameters of AOSM and coefficient of discharge for selected watercourses.

Day	B_t (m)	Y(m)	H_s (m)	Q_{th} (cumecs)	Q_{ac} (cumecs)	$C_d = Q_{ac} / Q_{th}$
Water course 1BL						
1	0.2	0.6	0.44	0.353	0.184	0.521
2	0.2	0.6	0.41	0.340	0.175	0.514
3	0.2	0.6	0.37	0.323	0.162	0.502
4	0.2	0.6	0.34	0.310	0.153	0.492
5	0.2	0.6	0.31	0.296	0.148	0.500
6	0.2	0.6	0.29	0.286	0.140	0.490
Average				0.318	0.160	0.503
Watercourse 3R						
1	0.15	0.575	0.48	0.265	0.160	0.608
2	0.15	0.575	0.44	0.253	0.146	0.580
3	0.15	0.575	0.43	0.251	0.142	0.571
4	0.15	0.575	0.40	0.242	0.136	0.571
5	0.15	0.575	0.39	0.239	0.134	0.562
6	0.15	0.575	0.33	0.219	0.120	0.551
Average				0.245	0.141	0.574
Watercourse 6R						

1	0.2	0.52	0.43	0.302	0.165	0.550
2	0.2	0.52	0.43	0.302	0.165	0.540
3	0.2	0.52	0.42	0.299	0.160	0.539
4	0.2	0.52	0.40	0.291	0.156	0.539
5	0.2	0.52	0.37	0.280	0.140	0.507
6	0.2	0.52	0.35	0.273	0.133	0.499
Average				0.291	0.153	0.529

Coefficient of discharge and rating curves for watercourses

The values of coefficient of discharge C_d for different flow rates measured in the selected watercourses were calculated and are portrayed in Table 3. It can be seen from the table that the value of C_d is varying between 0.490 and 0.608 for different watercourses. Hence, the values of C_d were averaged and used in developing rating curves based on the flowing expression as shown in Figure 1.

$$Q_{ac} = C_d \times B_t \times Y \sqrt{2g\ H_s} \qquad (4)$$

These curves can be used to determine flow rate of watercourses under the study. In the same way, rating curve or table for any AOSM can be prepared and utilized for discharge measurement of watercourses.

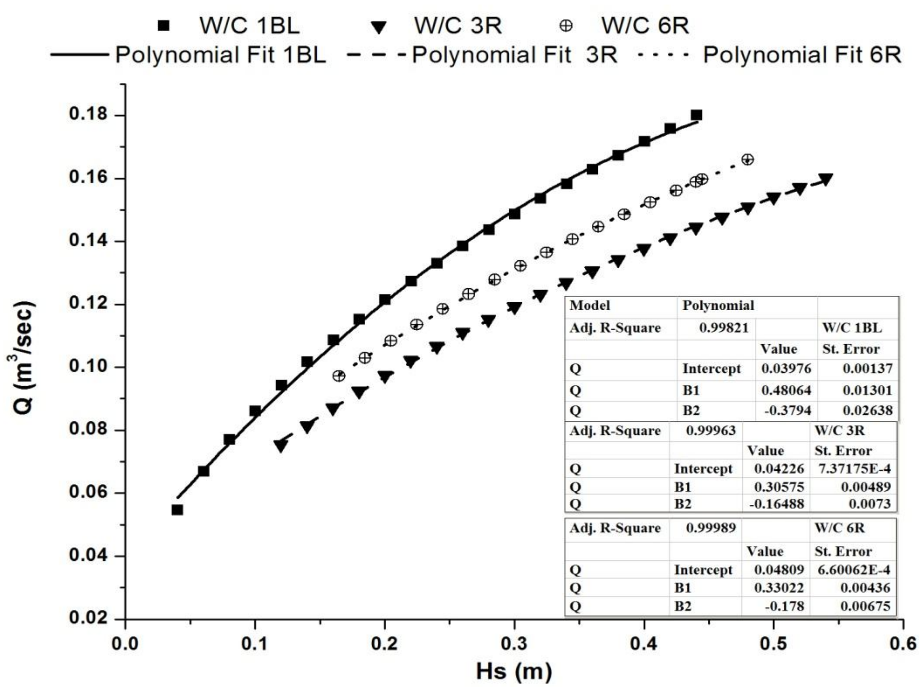

Figure 1. Stage discharge curves for different watercourses

CONCLUSION

The selected AOSM of watercourses No. 1BL, 3R and 6R were calibrated against the Global water flow probe and the corresponding average values of coefficient of discharge C_d are 0.503, 0.574 and 0.529 respectively. The calculated C_d values have been used to prepare rating curves for the watercourses under study. The relationship between channel flow and stage is established through curvilinear instead of straight line. The study is beneficial for the engineers and surveyors so they can easily measure the flow rate from the single parameter (Hs). Adopting the methodology of this study, Irrigation Engineers can develop rating curves for strategic locations and used them for discharge measurement by simply measuring the upstream head.

REFERENCES

Ali, I. 2007. Irrigation and hydraulic structures: Theory, Design and Practice. 3rd edition Allied Book Company, Lahore, Pakistan.

Ghumman, A. R., M. Z. Khan, A. H. Khan and S. Munir. 2010. Assessment of operational strategies for logical and optimal use of irrigation water in a downstream control system. Irrig. and Drain., 59: 117–128.
Global Water. 1997. Global flow probe FP101-FP201 instruction manual. Global Water, Inc., Gold River, Colorado.

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

Ji, X. B., E. S. Kang, R. S. Chen, W. Z. Zhao, Z. H. Zhang and B. W. Jin. 2007. A mathematical model for simulating water balances in cropped sandy soil with conventional flood irrigation applied. Agric. Water Manage. 87:337–346.

Kahlown, M. A., A. Raoof, M. Zubair and W. D. Kemper. 2007. Water use efficiency and economic feasibility of growing rice and wheat with sprinkler irrigation in the Indus basin of Pakistan. Agric. Water Manage, 87: 292–298.

Khan S., T. Rana, H. F. Gabriel and M. K. Ullah. 2008. Hydrogeologic assessment of escalating groundwater exploitation in the Indus Basin, Pakistan. Hydrogeol. J., 16: 1635–1654

Principe, R. E., M. F. Boccolini and M. C. Corigliano. 2008. Structure and spatial-temporal dynamics of chironomidae fauna (Diptera) in upland and lowland fluvial habitats of the Chocancharava River basin (Argentina). Int. Rev. Hydrobiol., 93: 342–357.

Punmia, B. C. and B. B. P. Lal. 1992. Irrigation and water power engineering. Twelfth Edition. Laxmi Publications Pvt. Ltd. India

Qureshi, A. S., P. G. McCornick, M. Qadir and Z. Aslam. 2008. Managing salinity and waterlogging in the Indus basin of Pakistan. Agric. Water Manage, 95: 1-10.

Rahimpour, M. and M. F. Maghrebi. 2006. Prediction of stage–discharge curves in open channels using a fixed-point velocity measurement. Flow Measurement and Instrumentation, 17: 276–281.

Sarukkalige, P. R. 2011. Characteristics of stormwater runoff in different land use areas. 2nd International Conference on Environmental Science and Development. IACSIT Press, Singapore. http://www.ipcbee.net/vol4/64-ICESD 2011D069.pdf

Singh, A. 2011. Estimating long-term regional groundwater recharge for the evaluation of potential solution alternatives to waterlogging and salinisation. J. Hydrol., 406: 245–255.

Singh, A., P. Krause, S. N. Panda and W. A. Flugel. 2010. Rising water table: a threat to sustainable agriculture in an irrigated semi-arid region of Haryana, India. Agric. Water Manage, 97: 1443–1451.

Soupir, M. L., S. Mostaghimi and Jr. C. E. Mitchem. 2009. A comparative study of stream-gaging techniques for low-flow measurements in two Virginia tributaries. J.A.W.R.A. 45: 110–122. doi: 10.1111/j.1752-1688.2008.00264.x

Tariq, J. A. 2010. Improving operational performance and management of canal irrigation system using hydraulic modeling. Ph D. Thesis, CEWRE, University of Engineering and Technology, Lahore, Pakistan, pp. 1-191

Westphal, J. A., D. B. Thompson, G. T. Stevens and C. N. Strauser. 1999. Stage–discharge relations on the middle Mississippi river. J. Water Resour. Plan. Manag. ASCE, 125 (1): 48–53.

Zardari, N. and I. Cordery. 2009. Water productivity in a rigid irrigation delivery system. Water Resources Management, 23: 1025-1040.

(Received 15 June, 2012; Revised 04-12-2012)