REPORT NO. R-32

An Evaluation of Outlet Calibration Methods

A contribution to the study on

Collective Action for Water Management below the Outlet, Hakra 6-R Distributary

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Arjen During

1 Introduction

This paper reports on the efforts undertaken to calibrate the six IIMI sample watercourses on 6-R Distributary of Hakra Branch Canal. These watercourses are studied under the research study as proposed by Cris de Klein in 1996: Collective Action for Water Management. This research falls within IIMI's Dutch-funded project: "Managing Irrigation for Environmentally Sustainable Agriculture in Pakistan".

One purpose of this report is to document a process of learning that might be of benefit to others that want to perform similar exercises in Pakistan. Especially, the selection of a discharge formula to be used for AOSM-structures has been preceded by much discussion. By reporting on these discussions and the outcomes thereof, the time and effort of researchers can be saved in future endeavours.

The second purpose is to present the outcomes of the daily staff gauge readings for the six sample outlets. These outcomes will be further used in the study on Collective Action for Water Management Below the Outlet, as the actual daily discharges are expected to be one of the important physical factors that explain water management activities at the watercourse level.

This report gives an overview of the choice of a discharge formula for the Adjustable Orifice Semi-module (AOSM) structures[1], the methods used during calibration, and the problems encountered and the solutions applied in the calibration efforts, as well as the calculations of daily discharges using the calibrated formulae. Lastly, some conclusions are drawn from the daily discharges as measured, and they are compared with the design discharges. Design and actual allowances for the six watercourses are presented and the water availability is related to the cropping patterns.

2 Choice of a Formula for Calibration of AOSM Outlets

2.1 Introduction

In the following sections, two different formula that are both used to calculate discharges through an AOSM outlet are compared. One is the formula used by the Irrigation Department for the design of the structures. The other is a formula that has been derived from the submerged flow formula for an orifice and was used in the Training Course on Field Calibration of Irrigation Outlets that was organized by IIMI in 1995 (see IIMI, 1996).

2.2 Design formula AOSM/APM

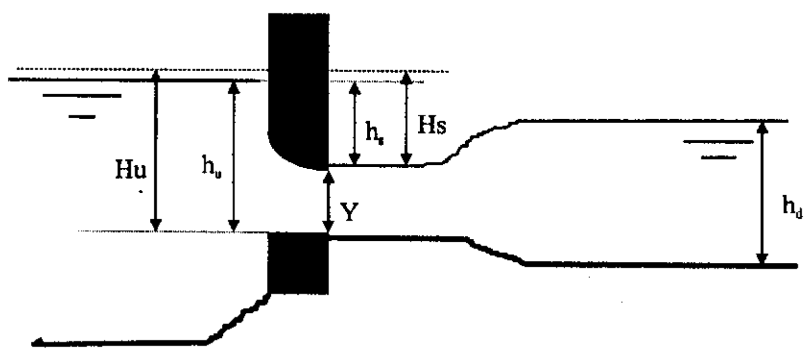
The formula as used by the Irrigation Department to design the dimensions and crest elevation of AOSM structures is given below. In the following discussion, it will be referred to as the "design" formula.

[1] The AOSM is a later version of Crump's Adjustable Proportional Module (APM). The names are frequently interchanged. An explanation of the difference can be found in Mahbub and Gulhati, 1951; p.80.

$$Q = 7.3 * B * Y\sqrt{h_s}$$

Where: Q = discharge
B = width of the opening
Y = height of the opening
h_s = height between upstream water level and suffit of the roof block

See Figure 1 for a cross profile through an AOSM structure. In the formula as used by the Irrigation Department, 7.3 is the empirically derived constant for this particular structure, which is claimed to be a constant (Visser, 1996).



Hu = the energy head over the crest of the AOSM
h_u = the water depth above the crest
Hs = the energy head above the suffit of the roof block
h_s = the water depth over the suffit of the roof block
h_d = downstream water depth
Y = height of the opening of the orifice (crest to suffit of the roof block)

Figure 1. Cross profile of an AOSM outlet structure.

Theoretically, the discharge formula for a sliding gate (from which the formula for the AOSM is derived) is:

$$Q = \sqrt{2g*}B\alpha W\sqrt{Hu - \alpha W}$$

$$[L^3.T^{-1}] = [L^{1/2}.T^{-1}]*[L]*[-]*[L]*[L^{1/2}]$$

In this formula, g is the gravity, H is the energy head over the crest of the structure, W is the height of the opening and α is the contraction coefficient, which is generally on the order of 0.61. The formula for a sliding gate is derived from the formula for an orifice, where the issuing jet is supported. This implies that the velocity in the jet is assumed to be the same for all practical purposes (see paragraph 2.5 on page 37 in Mahbub and Gulhati, 1951 for a more detailed explanation). Therefore, in case the jet is supported, the discharge varies with the head to the top of the orifice, instead of to the center of the opening as is the case for a jet leaping into free air.

When the AOSM is considered, the shape of the roof block is more or less similar to the contraction line when a rectangular sharp gate is considered. Therefore, the assumption can be made that the water as flowing from the downstream opening of the AOSM is fully contracted and Y = αW. If the velocity component of H is considered to be negligible, Hu = h_u, so that:

$$Hu - \alpha W = h_u - Y = h_s.$$

Also, 2g = 64.4 (in the imperial system). Therefore, theoretically, the discharge formula for the AOSM is:

$$Q = 8.02 * BY * \sqrt{h_s}$$

The value of 7.3 as used in the empirical formula is smaller because the friction and velocity losses are included in this factor.

However, the constant in this formula is not really a constant and changes with different values for Y/h_s. Mahbub and Gulhati explain that for large orifices (or low water levels, that is) the actual discharges will start to differ considerably from the discharges calculated with a normal orifice formula. Up to where the working head (h_s) equals the height of the opening of the orifice, the discharges can be calculated with the orifice formula, while at lower heads they suggest using the following formula for a rectangular orifice (see p. 34 in Mahbub and Gulhati):

$$Q = \frac{2}{3}\sqrt{2g} * c * B\left[(h_s + W)^{\frac{2}{3}} - h_s^{\frac{2}{3}}\right]$$

This shows that the constant c used in this formula is not a real constant, but can be regarded as one for values of h_s greater than 2Y.

2.3 The Cd-formula

Another much used formula to calculate discharges through an AOSM-outlet is derived from the "submerged flow formula", which is referred to here as the c_d- formula.

$$Q = c_d\sqrt{2g} * BY\sqrt{h_u}$$

Where:
- Q = discharge
- c_d = discharge coefficient
- h_u = height from crest to upstream water surface
- g = gravity acceleration

In this formula, c_d is not a constant, its value changes with changing values for h_u and Y. In the literature (Ankum, 1991), the formula for c_d is given as:

$$c_d = \frac{\alpha}{\sqrt{1 + \alpha W / h_u}}$$

In case of an AOSM (where the assumption is made that αW=Y and α has been included in Y), this can be written as:

$$c_d = \frac{1}{\sqrt{1 + Y / h_u}}$$

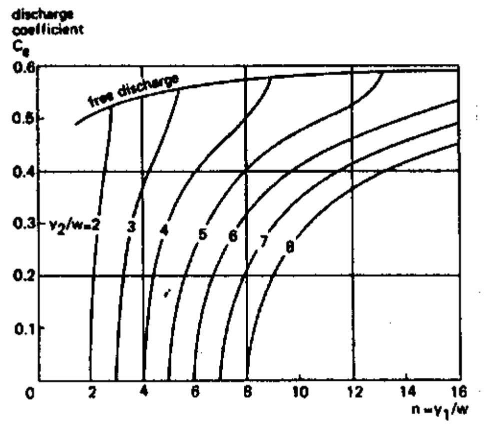
2.4 Submurged flow formula

When submerged flow is considered, the situation becomes even worse, as than the constant is dependent on both upstream and downstream water depths and the variation in possible values for c_d becomes enormous (0 to appr. 0.6). See Figure 2 for an impression of the possible changes of c_d with different upstream and downstream water levels. Here these are expressed by the ratios of the up- or downstream water level over the gate opening (fixed in the case of a single AOSM). This implies that for a good calibration of an AOSM under (partially) submerged conditions, the curve should be divided into different ranges for which different values of c_d are valid. The data to calibrate the five sample outlets with an AOSM structure under submerged flow conditions were not available.

There is a need to note that the formula used for submurged flow is the same always. The submerged flow formulla for an AOSM is:

$$Q = c_d \sqrt{2g} * BY\sqrt{h_u - h_d}$$

In this formula, h_d is the downstream water depth over the crest.



Source: Bos, 1989; p.275

Figure 2: Discharge coefficient for free and submerged flow for the c_d-formula

2.5 Comparison of the two formula for modular flow

For a comparison of the two formulae that have been given above for describing modular flow through an AOSM structure, see Figure 3 below. Here, the curve as described by the two different formulae is graphically represented for a sample outlet on watercourse (W/C) 61-L. For the calculation of the c and c_d values, the discharge measurements taken for this outlet were used. Notice that the curve has a distinctly different form. Over the range of h_u that is to be used for calculating the daily discharges using the AOSM formula, h_u= 1.5 ft. (to be explained later) to the maximum measured h_u of 4 ft., the difference in Q calculated with the two formulae is maximally 46% of the discharge calculated using the design formula (See Table 1 below).

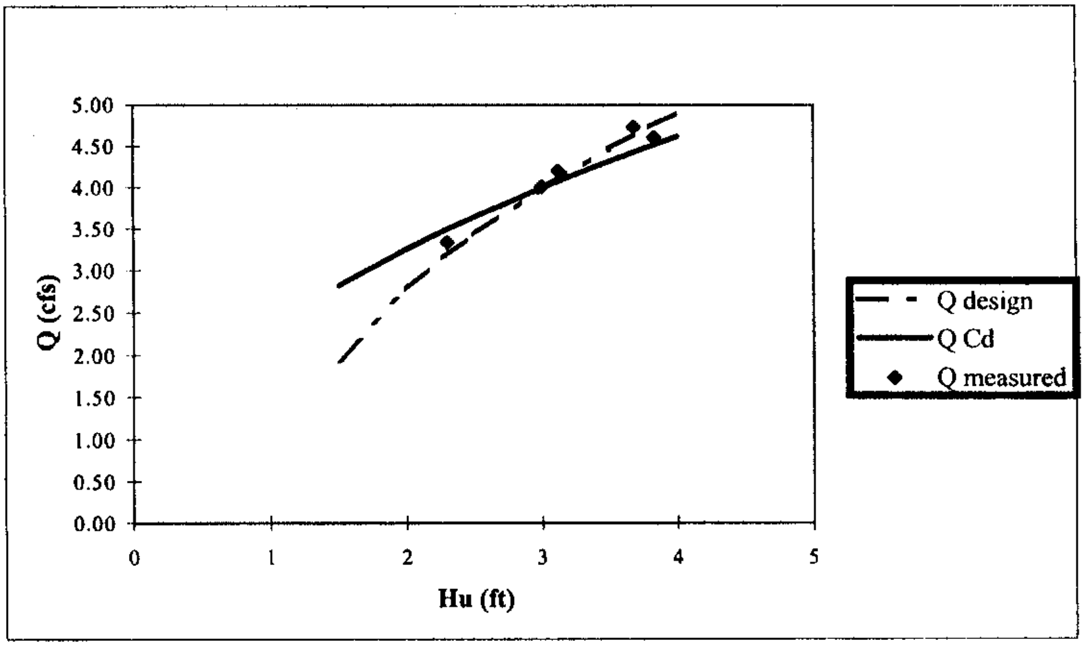


Figure 3. Comparison of Two Discharge Formulae for Watercourse 61-L, Hakra 6-R Distributary.

Table 1: Comparison of two AOSM discharge formulae for 61-L, Hakra 6-R

Hu	Hs	Q1	Q2	Q1-Q2	% of Q1	% of Q2
1.5	0.45	1.94	2.83	-0.89	-46	-31
2	0.95	2.78	3.26	-0.48	-17	-15
2.27	1.22	3.15	3.48	-0.33	-10	-9
2.5	1.45	3.43	3.65	-0.21	-6	-6
3	1.95	3.98	4.00	-0.01	0	0
3.5	2.45	4.46	4.32	0.15	3	3
3.8	2.75	4.73	4.50	0.23	5	5
4	2.95	4.90	4.61	0.28	6	6

Design formula: **Q1 = c*b*y*sqrt(Hs)**
Cd formula: **Q2 = c_d*b*y*sqrt(2g*Hu)**
y = 1.05 c = 7.3
b = 0.37 c_d = 0.75

This large difference in the low values can be understood from the fact that the discharge measurements used for calibrating the two formulae were largely taken in the upper range of water levels. This explains why in this range the curves are closer together. This also indicates that as long as the calibrated outlet mostly functions within this upper range of water levels, not too much difference in outcomes has to be expected. The accuracy of the callibration and the daily staff guage readings can be expected to be on the order of 10% or less. As can be seen in Table 1, the difference in calculated values become 10% at an h_u of 2.27 ft. This implies that only for the lowest

30% of the measured range is the difference in calculated values exceeding the expected (wished for) accuracy.

Outlets that have been calibrated with one formula can easily be converted into the the other formula, because all of the values that are needed to do so are available (Y, B, Q, and h_u).

2.6 Concluding remarks

As explained above, both formulae that are regularly given for the modular flow through an AOSM give different values for the discharge at one and the same h_u. The formula that is closest to the theory underlying these kind of structures is the formula in which the suffit of the roof block is used as a reference level. Also, for this formula the discharge coefficient seems to be less dependent on the upstream water depth than in the case where the crest level is used as a reference level (c_d-formula). However, this study of the difference in dependence of the constants on the upstream water level was not conclusive. Still, from a review of the theory and literature dealing with these formulae, the author has got the impression that with the "design" formula more accurate discharges will be calculated. Therefore, the design formula has been chosen to calibrate the five AOSM sample outlets on Hakra 6-R Distributary.

As long as the measurements are mostly situated in the upper range of water levels, the difference in accuracy obtained with one formula in comparison with the other will be negligible.

3 Methods Used

3.1 Discharge measurements for calibration

The sample outlets on Hakra 6-R Distributary had to be calibrated in order to make it possible to calculate the daily discharges by measuring water depths only. To do so, white marks were placed upstream of the structure and downstream, making it possible to measure the water level up- and downstream of the structure using a staff gauge with reference to a fixed benchmark level. The white marks were related to the crest level of the outlet using a leveling instrument.

To be able to accurately calibrate the outlets, it was thought useful to take several discharge measurements. Most of these measurements were taken using current meters. Two types of current meters were used during the research period -- a direct velocity current meter and a Pigmy 005 -- for which revolutions were counted and a calibration table was used to calculate the velocity from the number of revolutions counted.

First, the width of the watercourse (w/c) was measured with the help of the staff gauge. Then the width was devided into several sections (the number depending on the width of the w/c). The depth of the water was measured for each section. Measurements were taken in the middle of each section, at 0.6 of the depth below the water surface. Three measurements per section were used to come to an average velocity per section. The derived velocity was multiplied by the area of the section to calculate the discharge in the section. The total discharge in the watercourse was calculated as the sum of the discharges in the individual sections.

The upstream and downstream white mark readings were taken before and after the measurements. If there was no considerable fluctuation in water levels (less than 0.02 ft) before and after the discharge measurement, the measurement would be accepted; otherwise, the discharge would be measured again.

3.2 Measurement and calculation of daily discharges

To be able to calculate daily discharges, the water levels in the distributary (upstream white mark) and in the watercourse (downstream white mark) were measured every working day for most of the period from 3 July 1996 to 15 April 1997. The levels were measured from the underside of the whitemark to the water surface. Later, these measurements were used to calculate the working head over the crest of the structure, which was used to calculate the daily discharges.

For the calculation of the daily discharges in the five IIMI sample watercourses on Hakra 6-R Distributary where an AOSM is installed as an outlet structure, the "design" formula has been used for the upper range of h_u.: $Q = c * B * Y\sqrt{h_s}$

In this formula, the c value was calibrated using the discharge measurements. The formula was only calibrated for modular flow conditions. Most outlets always flow modular and for those that are sometimes submerged, not enough measurements under non-modular circumstances were available to calibrate the submerged flow formula.

Because of the form of the roof block, the AOSM functions as a free flowing flume (FF) for a considerable range where the water is still touching the roof block (pers. com. Marcel Kuper). For every outlet this range differs. The different ranges have not been measured in the field and only a few of the daily discharge measurements fall in this range. Therefore, it has been decided to estimate this range by looking at the way the curves for orifice flow and flume flow fit together. This was done graphically in the computer software Excel, where it is easy to compare different curves and decide which one fits best. In this way, the ranges for which each of these formulae would be used were decided.

The formula used for the free flowing flume (FF) is: $Q = 2.95*b*(h_u)^{1.5}$
The discharge coefficient was suggested by Marcel Kuper, and finds its origin in literature about these kinds of structures.

The outlet for Watercourse 10-R has a pipe outlet. Here, the discharge formula for a pipe outlet was used. The flow through this outlet was always submerged, so the formula has been calibrated for submerged circumstances only. The formula used is: $Q = c_p * A * \sqrt{2g(h_u - h_d)}$

4 Calibration of the Six Sample Outlets on Hakra 6-R Distributary

4.1 Introduction

In the following sections, an explanation is provided on how the calibration calculations for the six IIMI sample watercourses on Hakra 6-R Distributary were performed. The problems faced along with the assumptions and estimations made to overcome these problems is also discussed. In some instances, discharge measurements have been discarded. Where so, the measurements and calculations have been thoroughly checked before deciding to discard the measured value in question.

4.2 Watercourse 7-L

The outlet of Watercourse (W/C) 7-L is an Open Crump AOSM (OCAOSM) (see Figure 4). The OCAOSM consists of an AOSM orifice, that is connected to the distributary by a pipe. The pipe ends in a stilling well, in which the AOSM is constructed. The discharge for an OCAOSM can be calculated similarly to the discharge of an AOSM, with the upstream water level being taken in the stilling well, instead of in the distributary.

To calibrate the OCAOSM at W/C 7-L, seven discharge measurements have been used (6 current meter measurements and 1 flume measurement). For each measured value of Q and h_u, the constant c was calculated. For W/C 7-L, all of the resulting c-values have been used to calculate the average c-value, which happened to be exactly equal to the design value of 7.3. Thus, the derived discharge formula has been used to calculate the daily discharges for the period 4 July 1996 to the canal closure in January 1997. The range for using the OM (orifice modular) formula was $h_u > 0.6$ ft. For $h_u < 0.6$ ft., the formula for a free flowing flume (FF). The rating curve and the measured discharges are graphically presented in Figure 4.

Table 2. Calibration of Watercourse 7-L Outlet.

Ha	Hb	Hu	Hd	Q	C	Qc	Q-Qc	% of Q
0.58	1.34	4.50	1.14	1.64	7.16	1.67	-0.03	-1.94
0.74	1.46	4.34	1.02	1.35	6.01	1.64	-0.29	-21.39
1.44	1.03	3.64	1.45	1.48	7.27	1.49	-0.01	-0.36
1.97	1.57	3.11	0.91	1.31	7.04	1.36	-0.05	-3.63
2.19	1.4	2.89	1.08	1.53	8.58	1.30	0.23	14.98
2.23	1.44	2.85	1.04	1.36	7.69	1.29	0.07	5.13
3.46	1.58	1.62	0.90	0.91	7.33	0.91	0.00	0.36
				Avg. c=	**7.30**			

b= 0.27 WMup= 5.08 All Q's are in [cfs]
y= 0.42 WMdown= 2.48 All heights and width are in [ft]

- y= the height of the opening of the AOSM
- b= the width of the opening of the AOSM
- WMup= the level of the upstream white mark related to the crest of the outlet
- WMdown= the level of the downstream white mark related to the crest of the outlet
- Ha= the measurement from the upstream white mark (WMup) to the upstream water level
- Hb= the measurement from the downstream white mark (WMdown) to the downstream water level
- Hu= the height of the upstream water level above the crest of the outlet
- Hd= the height of the downstream water level above the crest of the outlet
- Q= the measured discharge
- c= the constant for the discharge formula calculated from Q
- Qc= the discharge as calculated using the average c-value
- % of Q= the percentage deviation of the calculated value, Qc, from the measured Q
- Qtheory= the discharge calculated using the design value of 7.3 for c (not calculated in this case as average c = 7.3).

Table 2 shows that some of the measurements deviate considerably from the discharge calculated with the calibrated discharge formula (using 7.30 as the c-value in this case). However, by discarding these points, one arrives at exactly the same c-value. Therefore, all points have been considered.

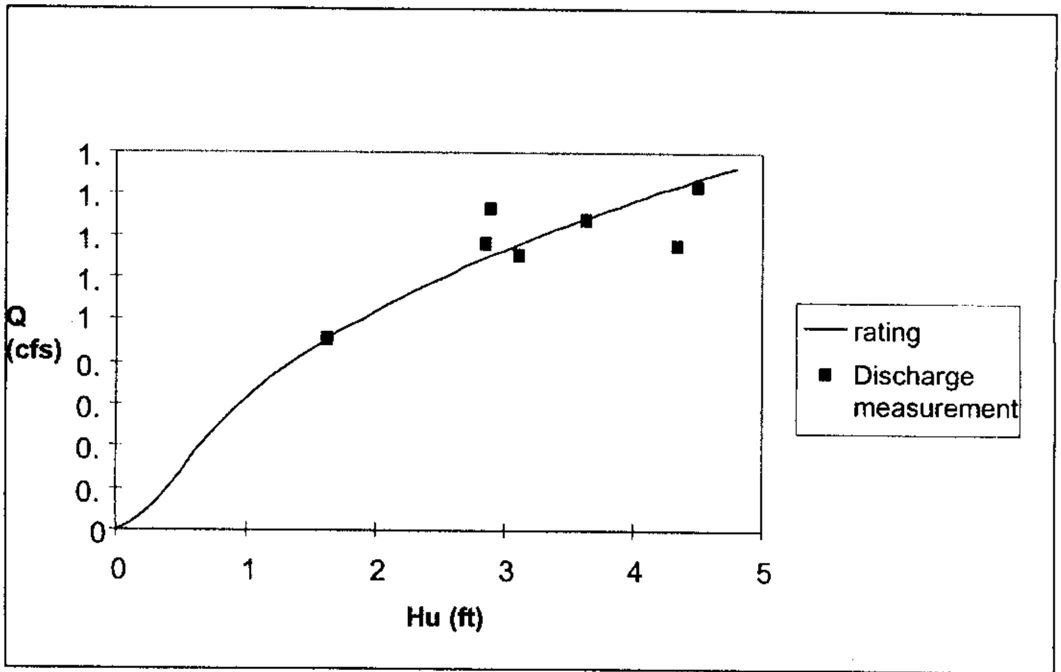


Figure 4.Discharge calibration of outlet for Watercourse 7-L, Hakra 6-R Distributary: discharges and rating curve before canal closure (15 January 1997).

During canal closure in January 1997, the "machine" of W/C 7-L was taken out of the outlet structure by the Irrigation Department to be readjusted to the design dimensions. The sub-engineer for this part of Hakra 6-R related that NESPAK (a Pakistani consultancy firm) had checked the dimensions of all the outlets and compared them with the design dimensions. The outlets that deviated from the design dimensions were to be readjusted during the closure period. As a consequence of this, the discharge formula for the AOSM at head of W/C 7-L changed.

After the closure, the changed b and y were measured and the outlet (crest and white marks) were leveled anew. For the constant, the design value of 7.3 has been used. Earlier research in the Chishtian Sub-division suggests that the discharge through AOSM structures can be calculated with a higher than 90% accuracy by using the design discharge coefficient of 7.3 (Visser, 1996). Also, the earlier calibrations of the AOSM sample outlets showed that the calibrated discharge formulae were all within 10% of the outcomes of the design formula, which strengthens the outcomes of this earlier research.

The desired accuracy for the daily discharges was not more than 90%, and the re-calibration of the outlet would have taken a substantial amount of time from the field staff, which was not available. So, from the opening of the canals in February 1997 onwards, the design constant (7.3) has been used to calculate the daily discharges for the W/C 7-L sample outlet. The new dimensions of the outlet have been measured: y = 0.36, b = 0.26. Also, the crest and the upstream white mark have been re-measured. It turned out that the machine has been replaced at a level 0.62 ft. higher than before the closure. This, in combination with the reduction in size of the opening, results in a considerable reduction of the discharge passing through the *mogha* (see Table 3). The range for which the FF values will be used for the daily discharge after the canal closure has graphically been assessed to be: $h_u < 0.5$ ft. See Figure 5 for a representation of the rating curve used to calculate the daily discharges after the canal closure.

The chosen solution seems to have a high probability of falling within the desired accuracy. Further research into the relation between actual c-values and the design c-value would be recommendable, because if the design value can be used with more than 90% accuracy for non-tampered outlets, this would save enormous amounts of time now spent on the calibration of these outlets.

Table 3. Changes in discharge over the normal operating range of Watercourse 7-L before and After canal closure.

	y (ft)	b (ft)	c	WMup elevation
W/C 7-L before closure	0.42	0.27	7.3	5.08
W/C 7-L after closure	0.36	0.26	7.3	4.46

Hs,before	Hs,after	Qbefore	Qafter	% reduction
1	0.38	0.83	0.42	49.1
1.5	0.88	1.01	0.64	36.8
2	1.38	1.17	0.80	31.4
2.5	1.88	1.31	0.94	28.4
3	2.38	1.43	1.05	26.5
3.5	2.88	1.55	1.16	25.1
4	3.38	1.66	1.26	24.1

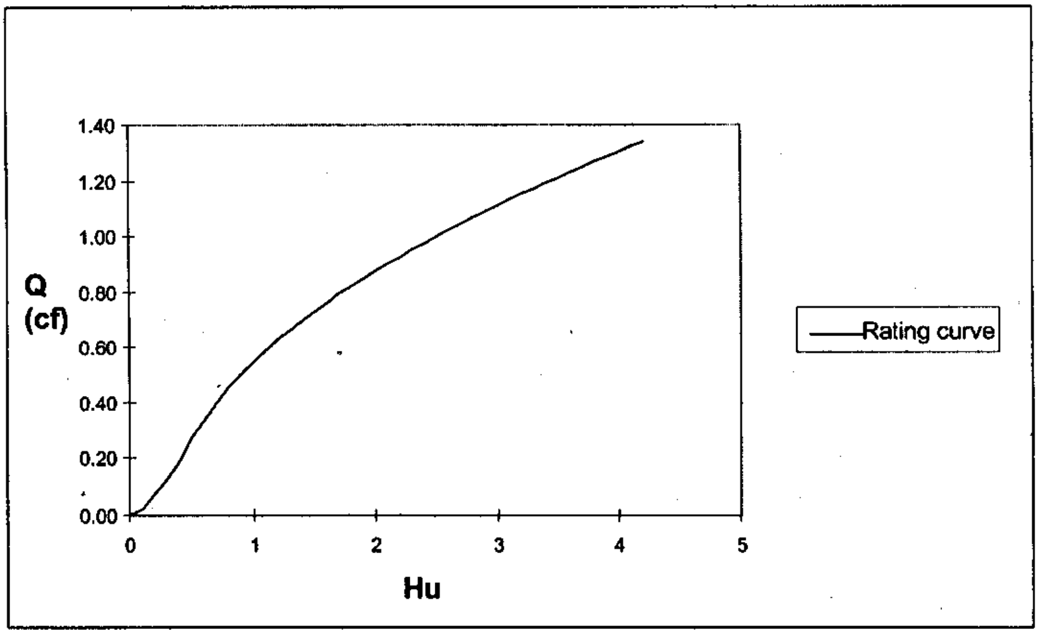


Figure 5. Discharge calibration of Watercourse 7-L, Hakra 6-R Distributary: rating curve after canal closure (04 February 1997).

4.3 Watercourse 10-R

The outlet in the sample Watercourse 10-R is a pipe outlet. In the opening of the pipe, a metal throat was fixed with a diameter of 12-inches. This throat was regulating the discharge coming through the pipe. During the closure period in January 1997, the outlet was changed from a 12-inch pipe outlet to a 6-inch outlet. However, this change was very temporary, as shortly after the reopening of the canals, the installed 6-inch diameter, 6-feet long metal pipe was removed and the old gap was restored as an outlet; only, this time without the metal throat, which had been removed when the new outlet was installed. The new opening is not as regularly shaped as the old one, but still has more or less the same size (12-inch diameter). Therefore, it was decided to continue using the discharge formula as was used before the closure period.

The calibration of a pipe outlet in itself is not an easy job. In this case, some circumstances even aggravated the situation, making this calibration and the resulting daily discharges less accurate than those of the AOSM's in the other sample watercourses. At first, the outlet was judged to be a severely tampered Scratchly type outlet and the discharge formula for this kind of outlet had been used for this structure. Also, the calibration was based on only one current meter measurement, and the leveling equipment that was used to relate the white marks to the "crest level" later proved to be severely deregulated. The upstream white mark had been placed in the stilling well on the downstream side of the pipe.

During a field visit in November 1996, it was found that the water level in the stilling well and downstream of the stilling well had the same level. It was concluded that the stilling well was so severely tampered that, in fact, the pipe from the distributary to the stilling well functioned as the outlet structure. It was, therefore, decided that the upstream white mark had to be moved to the distributary side of the pipe. In a later field visit, when the distributary was on third preference, the metal ring of 12 inches constructed on the upstream side of the pipe was discovered and it became apparent that this outlet was meant to be a pipe outlet.

Since that time, five current meter measurements have been conducted in order to calibrate this outlet (see Table 4). The discharge formula for a pipe outlet is:

$$Q = c_p * A * \sqrt{2g(h_u - h_d)}$$

Table 4. Discharge calibration of the pipe outlet for Watercourse 10-R.

Date	Ha	Hb	Q	Hu[2]	Hd	Hu-Hd	Cp
10/16/96	3.77	1.18	2.69	1.37	1.21	0.16	1.07
10/16/96	3.84	1.20	2.43	1.33	1.19	0.14	1.03
10/19/96	4.08	1.35	2.83	1.20	1.04	0.16	1.13
10/27/96	1.27	0.27	5.09	2.76	2.12	0.64	1.01
11/04/96	1.44	0.21	4.86	2.66	2.18	0.48	1.11
						avg. Cp	**1.07**

D = 12 inch = 1 ft WMup (crest = 0.0) = 3.46

A = 0.785 ft^2 WMdown = 2.39

[2] Ha was measured along the side of the disty, i.e. under a slope of 1:1.5. Therefore, Hu was calculated here as Hu = 3.46 - 0.5547*Ha.

With this value for c_p (1.07), the daily discharges for W/C10-R have been calculated. For the period from 4 July 1996 up to 14-10-1996, no upstream water level measurements were available as they had been taken in the stilling well and were thus useless. The water level in the distributary was estimated using the daily measurements in the stilling well of W/C 7-L outlet. For the range in which data were available for both W/C 10-R and W/C 7-L (from 15-10-1996 to 31-12-1996), the differences in relative, daily water levels for the two outlets were calculated (34 measurements were available in this period). On average, this deviation was 0.08 ft. with a standard deviation of 0.11 ft. The maximum deviation was 0.39 ft. These differences are surprisingly high, seeing that the two outlets are situated very close together and there is no other outlet taking off between the two. In general, the time span between the two readings was not very large (between 10 and 20 minutes), which makes it unlikely that these large fluctuations would occur. However, there was no better alternative to arrive at a reasonable estimation of the daily discharges for this outlet.

Due to this method, many daily discharges in the first period of measurements have not been calculated for W/C 10-R. In the data series for W/C 7-L during this period, many days the outlet was closed due to rain and no measurements were taken, making estimation of the water level at W/C 10-R impossible. An attempt was made to derive these water levels from the measurements taken at W/C 45-L., but the differences in water levels between the measurements in W/C 10-R and W/C 45-L, were so large that this estimation would not have made sense. Also, some of the estimated values for h_u in W/C 10-R were discarded as the value for h_d was larger than the estimated h_u value, which would have resulted in a negative discharge.

4.4 Watercourse 45-L

The outlet in W/C 45-L is an AOSM. Some important assumptions were made when calibrating W/C 45-L. Firstly, the outlet is part of the time flowing modular and other times non-modular. As the influence of these different flow conditions on the discharge constant cannot be found in the c-values calculated from the current meter measurements, it is assumed that the influence of the flow condition is negligible compared to the inaccuracy in the current meter measurements. Also, when observing the flow in the outlet under different flow conditions it became apparent that the outlet is always working in a range close to modular flow, it is never really severely submerged. This strengthens the idea that the differences in discharge due to non-modularity of the flow are negligible compared to other inaccuracies and are therefore ignored. So, for the range where the AOSM discharge formula is used to calculate the daily discharges, the flow condition is ignored, and modular flow is assumed.

Secondly, for the calculation of the discharge constant, two measurements have been discarded, as they were way out of range compared with the other measurements taken in the same range. (see Table 5 and Figure 6). The reasons for these measurements to be so different are not known. Potential causes can be that the outlet was partly blocked, that a measuring error was made in assessing the cross profile of the measured section, or that the current meter was temporarily deregulated (lack of oil on the propeller?). Anyway, the discarded measurements are so far off from the expected accuracy (>90%) for these kind of current meter measurements, that they cannot be considered for calibrating the discharge formula.

Table 5. Discharge calibration of outlet for Watercourse 45-L.

Date	Flow cond	Ha	Hb	Hu	Hd	Q	c	Qc	Q-Qc	% of Q	Qtheory	% of Qc
10/15/96	ON	0.34	0.47	3.78	1.19	2.37	7.48	2.26	0.11	4.46	2.31	2.2
11/4/96	?	0.58	0.48	3.54	1.18	2.10	6.88	2.18	-0.08	-3.80	2.23	2.2
10/16/96	ON	0.99	0.42	3.13	1.24	1.98	6.98	2.03	-0.05	-2.40	2.07	2.2
10/19/96	OM	1.18	0.42	2.94	1.24	1.93	7.06	1.95	-0.02	-1.19	2.00	2.2
8/7/96	OM	1.36	0.92	2.76	0.74	1.88	7.15	1.88	0.00	0.03	1.92	2.2
10/21/96	ON	1.88	0.52	2.24	1.14	1.69	7.32	1.65	0.04	2.42	1.69	2.2
						avg. c	**7.14**					
Discarded												
10/11/96	ON	0.32	0.33	3.80	1.33	1.86	5.85	2.27	-0.41	-22.10	2.32	2.2
10/27/96	?	0.58	0.37	3.54	1.29	1.92	6.29	2.18	-0.26	-13.53	2.23	2.2

y = 0.50 WMup = 4.12

b = 0.35 WMdown = 1.66

For calculating the daily discharges, the FF-formula with c=2.95 was used for values of h_u smaller than 0.6 ft. For water levels more than 0.6 ft. above the crest, the OM formula was used with the calibrated value of 7.14 for c.

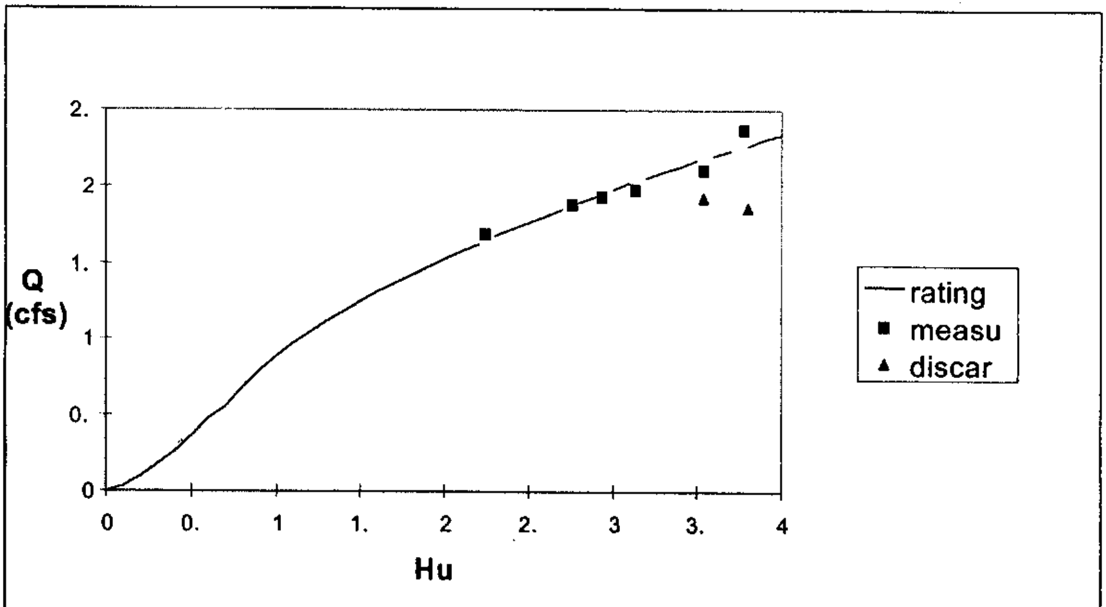


Figure 6. Discharge measurements and rating curve of outlet for Watercourse 45-L, Hakra 6-R Distributary.

4.5 Watercourse 61-L

The outlet for W/C 61-L is also an AOSM. The dimensions of this outlet have, so far, been changed twice during the research period. On August 10, 1996, the outlet was enlarged by the Irrigation Department. During the canal closure, the outlet size was reduced again and the discharge at full flow was reduced to almost exactly the discharge the outlet used to draw before enlargement (see Table 7 for details). For the first period (3 July to 10 August 1996), no calibration measurements are available. Here, the design constant of 7.3 was assumed. In this period, not a single measurement in the free flow (FF) range was taken, so no effort was done to find the range over which the outlet used to work as a free flowing flume. As for the other outlets, the discharge measurements, on which the calibration from 10 August 1996 until the canal closure (15-01-1997) was based, were conducted with a propeller current meter. Details are given in Table 6.

For similar reasons as described for W/C 45-L, two points have been discarded (see Table 6 and Figure 7). The resulting c-value is the average of the remaining values. The flow condition was always modular (FF).

Table 6. Discharge measurements for outlet of Watercourse 61-L.

Ha	Hb	Hu	Hd	Q	c	Qc	Q-Qc	% of Q	Qtheory	% of Qc
0.29	0.09	3.83	1.25	4.60	7.10	4.82	-0.22	-4.78	4.73	1.9
0.44	0.08	3.68	1.26	4.73	7.51	4.69	0.04	0.89	4.60	1.9
1.00	0.11	3.12	1.23	4.20	7.51	4.16	0.04	0.97	4.08	1.9
1.12	0.38	3.00	0.96	4.01	7.39	4.04	-0.03	-0.67	3.96	1.9
1.82	0.57	2.30	0.77	3.34	7.69	3.23	0.11	3.23	3.17	1.9
				avg. c	**7.44**					
Discarded										
0.28	0.38	3.84	0.96	3.53	5.44	4.83	-1.30	-36.78	4.74	1.9
0.36		3.76	1.34	4.2	6.57	4.76	-0.56	-13.30	4.67	1.9

y = 1.05 WMup = 4.12
b = 0.37 WMdown = 1.34

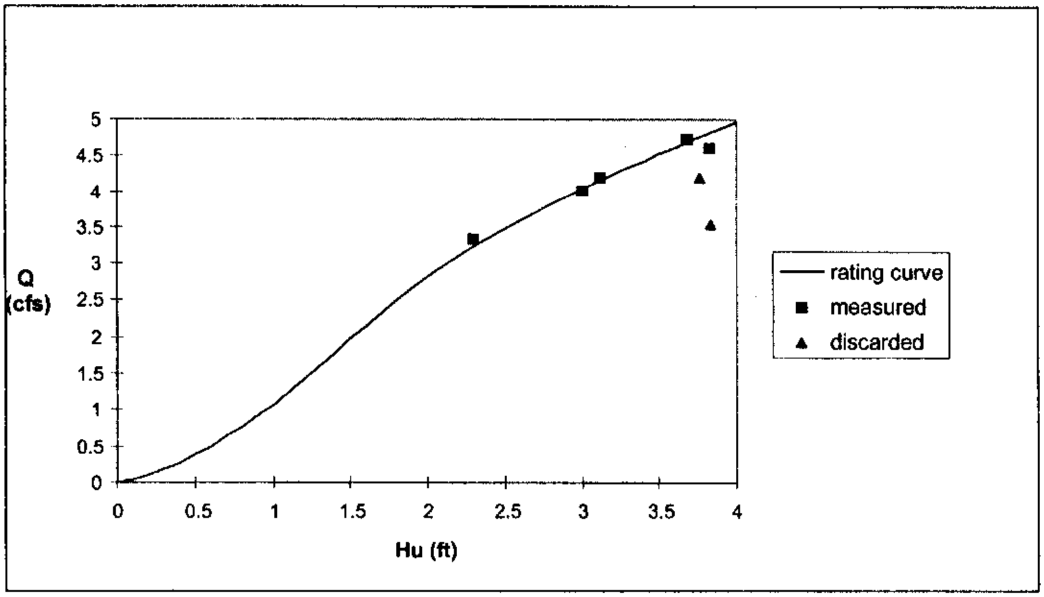


Figure 7. Discharge measurements and rating curve for outlet of Watercourse 61-L, Hakra 6-R Distributary.

Looking at the differences between the theoretical value for c and the calculated value in Table 6 shows that here too, as for the other AOSMs, the values calculated using the design formula are very close to the values calculated using the calibrated c-value. The difference is 1.9%. Until canal closure, the FF formula was used to calculate the daily discharge data for values of h_u smaller than 1.5 ft.

During canal closure, this outlet, too, was changed by the Irrigation Department. In the case of W/C 61-L, they have raised the level of the crest with concrete, without changing the width of the outlet. The crest level has been raised by 0.36 ft., resulting in a new WMup elevation of 3.76. The newly measured y is 0.67. For similar reasons as explained for W/C 7-L, the outlet has not been recalibrated. Instead, the design c-value (7.3) has been used to calculate the daily discharges from the closure period onwards. The change in discharge due to the change in crest elevation and y is given in Table 7. Figure 8 gives the rating curve as used after the annual closure period.

Table 7: Changes in discharge over the normal operating range of 61-L before 10/08/96, until canal closure, and after canal closure.

	y	b	c	WMup elevation
61-L before 10/08/96	0.64	0.37	7.3	4.09
61-L before closure	1.05	0.37	7.54	4.12
61-L after closure	0.67	0.37	7.3	3.76

Hs before 10/08	Hs before closure	Hs after closure	Q before 10/08	% of Q before closure	Q before closure	Q after closure	% of Q before closure
0.97	1	0.62	1.70	58.1	2.93	1.42	48.6
1.47	1.5	1.12	2.10	58.4	3.59	1.92	53.4
1.97	2	1.62	2.43	58.6	4.14	2.30	55.6
2.47	2.5	2.12	2.72	58.7	4.63	2.63	56.9
2.97	3	2.62	2.98	58.7	5.07	2.93	57.7
3.47	3.5	3.12	3.22	58.8	5.48	3.20	58.3
3.97	4	3.62	3.44	58.8	5.86	3.44	58.8

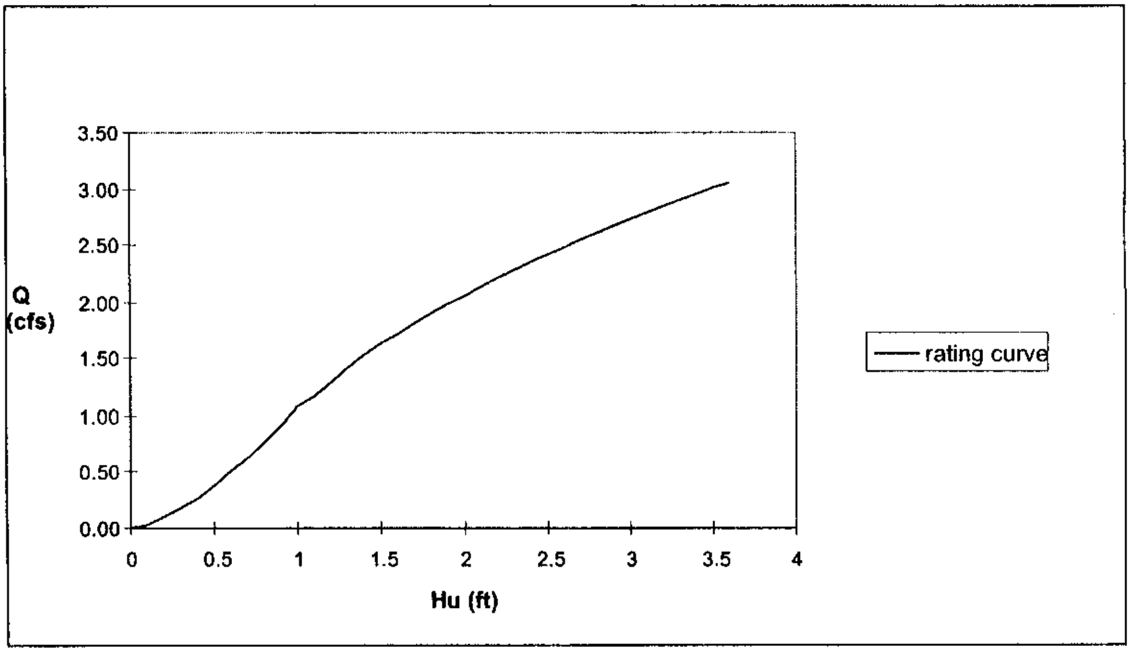


Figure 8. Rating curve for outlet of Watercourse 61-L, Hakra 6-R Distributary after canal closure.

4.6 Watercourse 101-R

Once again this outlet is an AOSM, but this is a special case as the outlet has been tampered. Underneath the "machine", a hole has been created that considerably increases the discharge of this outlet. The exact dimensions of the hole are not known, as it does not have a regular size and shape. The outlet has been calibrated using the AOSM formulae, and assuming that the hole underneath the outlet has to be added to y and has the same width. This implies that the reference level for the calculation of h_u is not the crest, but the bottom of the hole, 0.45 ft. lower This resulted in y=1.13. These assumptions yielded acceptable results, seeing that the calibrated c-value is 7.67, and that the curve runs nicely between the measured points. The curve resulting from a logarithmic regression on the measured points has a largely similar form as the calibrated curve, which reinforces the idea that this curve can be used. Also, the curves for the orifice and for the flume range nicely fit together. See Figure 9 for a comparison of the calibrated curve, the logarithmic curve, and the measured points for this tampered outlet. Note that R-squared for this curve is 0.87. Figure 10 gives an overview of the calibration curve. For the calibration of W/C 101-R, all of the current meter measurements have been used. They are listed in Table 8.

For the calculation of the daily discharges before the closure period, the FF formula has been used for values of h_u smaller than 1.45 ft.

Table 8. Discharge measurements for outlet of Watercourse 101 R.

Ha	Hb	Hu	Q	c	Qc	Q-Qc	% of Q	Qtheory	% of Qc
0.59	0.56	2.81	2.69	7.35	2.81	-0.12	-4.37	2.67	-4.8
0.61	0.37	2.79	2.96	8.13	2.79	0.17	5.72	2.66	-4.8
0.66	0.42	2.74	2.83	7.90	2.75	0.08	2.88	2.62	-4.8
0.73	0.36	2.67	2.68	7.64	2.69	-0.01	-0.30	2.56	-4.8
1.11	0.56	2.29	2.54	8.35	2.33	0.21	8.15	2.22	-4.8
1.3	0.44	2.1	2.05	7.37	2.13	-0.08	-4.06	2.03	-4.8
1.33	0.21	2.07	1.86	6.79	2.10	-0.24	-12.91	2.00	-4.8
1.33	0.42	2.07	2.14	7.81	2.10	0.04	1.87	2.00	-4.8
			avg. c=	**7.67**					

b = 0.25
y (including hole) = 1.13

WMup = 2.946
WMdown = 0.932

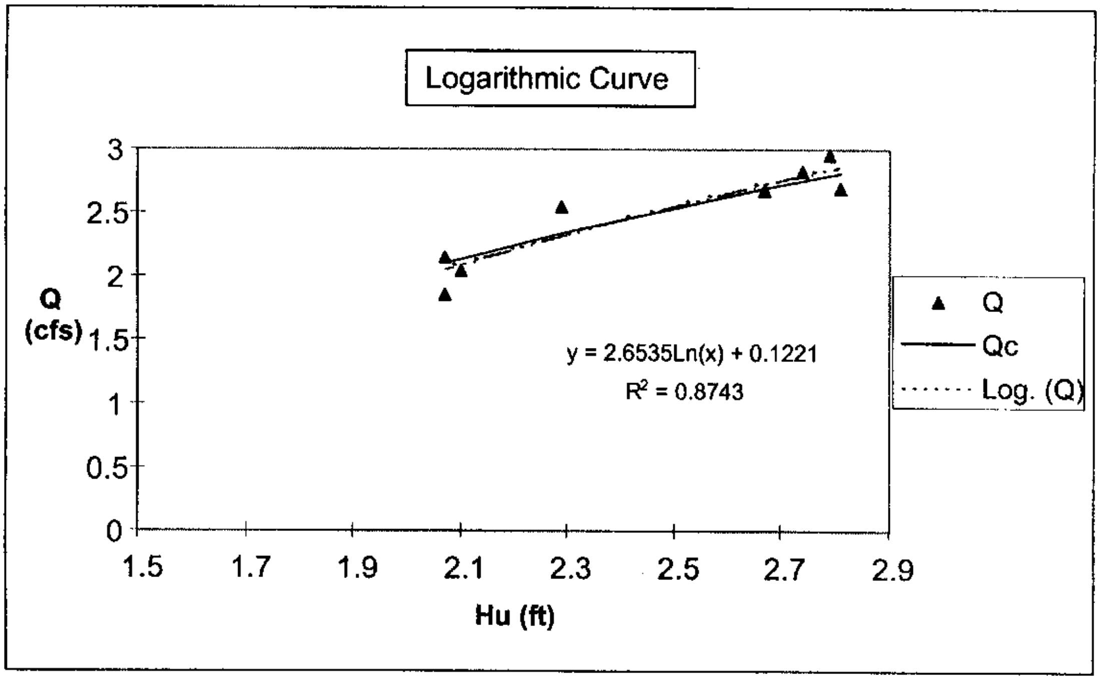


Figure 9. Discharge measurements and calibration for outlet of Watercourse 101-R, Hakra 6-R Distributary.

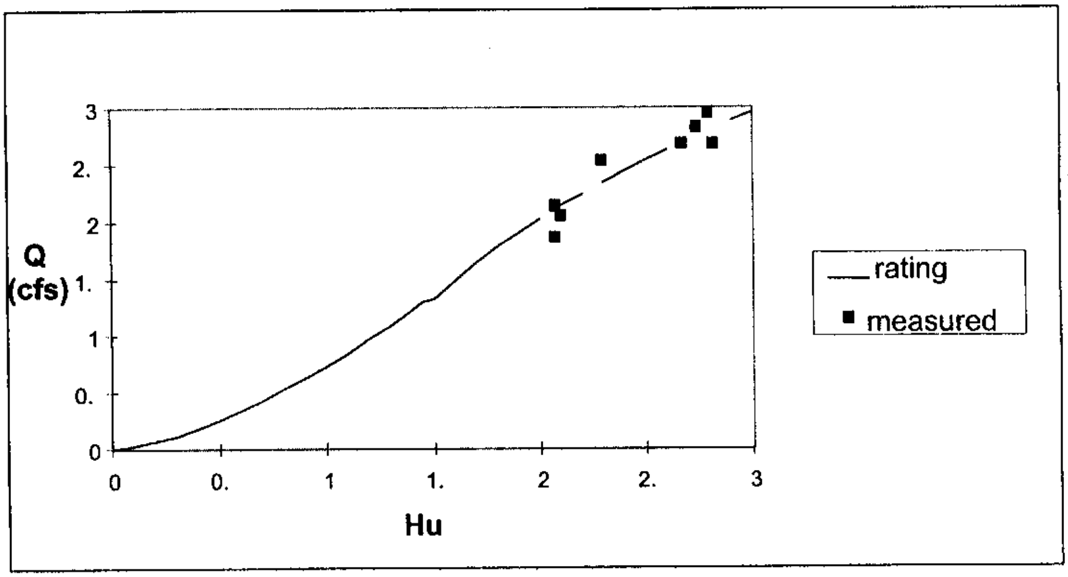


Figure 10. Discharge measurements and rating curve for outlet of Watercours 101-R Distributary

During the closure period, the farmers closed the hole underneath the outlet with a brick and some concrete. In this way, they managed to avoid having their outlet repaired during the closure period. Directly after the closure, the hole was reopened. The same discharge coefficient will be used for the data obtained after the canal closure.

4.7 Watercourse 117-R

This outlet, too, is an AOSM. The calibration did not cause any major problems. During the canal closure, this outlet was short-listed to be changed, but the farmers succeeded in keeping the Irrigation Department from doing anything. The dimensions of the "machine" and the crest level have been checked after the closure and were still exactly the same.

The calibration of the outlet was slightly problematic, as the upstream white mark had to be changed or replaced five times. At first, it was situated at the side of the upstream wall of the outlet, and frequently drowned. Therefore, it was replaced to the top of the wall, where it still drowned occasionally. This white mark (no.2) was removed by the farmers and a new one (no.3) was placed, again at the top of the structure. Then, the farmers raised the wall of the outlet to keep the water from flowing over the structure at high water levels in the distributary. The white mark was again replaced, now to the higher part of the wall where it would not drown any more (no.4). After this, the white mark was removed by the farmers twice and had to be replaced and leveled anew (no.5 and 6). No.5 white mark was removed before it had been leveled and the daily discharges for these 14 days are an estimation.

At present, the "white mark" that is used, no.6, is actually not a white mark, but just a line scratched into the concrete on the outlet wall. It is hoped that in this way it will not be removed again. All of the changes in white marks, except for no.5, have been taken into account when calculating the daily discharges.

For the calibration of the outlet, six current meter measurements have been used, two have been discarded (see Table 9). To calculate the daily discharges, the average c-value has been used.

The formula for FF has been used for values of h_u smaller than 1.1 ft. The rating curve is given in Figure 11.

Table 9. Discharge measurements for outlet of Watercourse 117-R.

Ha	Hb	Hu	Hd	Hs	Q	C	Qc	Q-Qc	% of Q	Qtheory	% of Qc
0.31	1.69	2.47	-0.25	1.63	3.45	7.66	3.46	-0.01	-0.16	3.29	-4.8
0.70	1.62	2.73	-0.18	1.89	3.68	7.59	3.72	-0.04	-1.11	3.54	-4.8
0.82	1.82	2.61	-0.38	1.77	3.55	7.56	3.60	-0.05	-1.43	3.43	-4.8
1.13	1.71	2.30	-0.27	1.46	3.30	7.74	3.27	0.03	0.90	3.11	-4.8
1.35	1.80	2.08	-0.36	1.24	3.10	7.89	3.01	0.09	2.78	2.87	-4.8
1.40	1.86	2.03	-0.42	1.19	2.92	7.59	2.95	-0.03	-1.11	2.81	-4.8
					avg. C=	7.67					
Discarded											
0.82	1.71	2.61	-0.27	1.77	4.04	8.61	3.60	0.44	10.87	3.43	-4.8
0.82	1.52	2.61	-0.08	1.77	3.94	8.39	3.60	0.34	8.61	3.43	-4.8

b = 0.42 WMu (no4) = 3.43
y = 0.84 WMd = 1.44

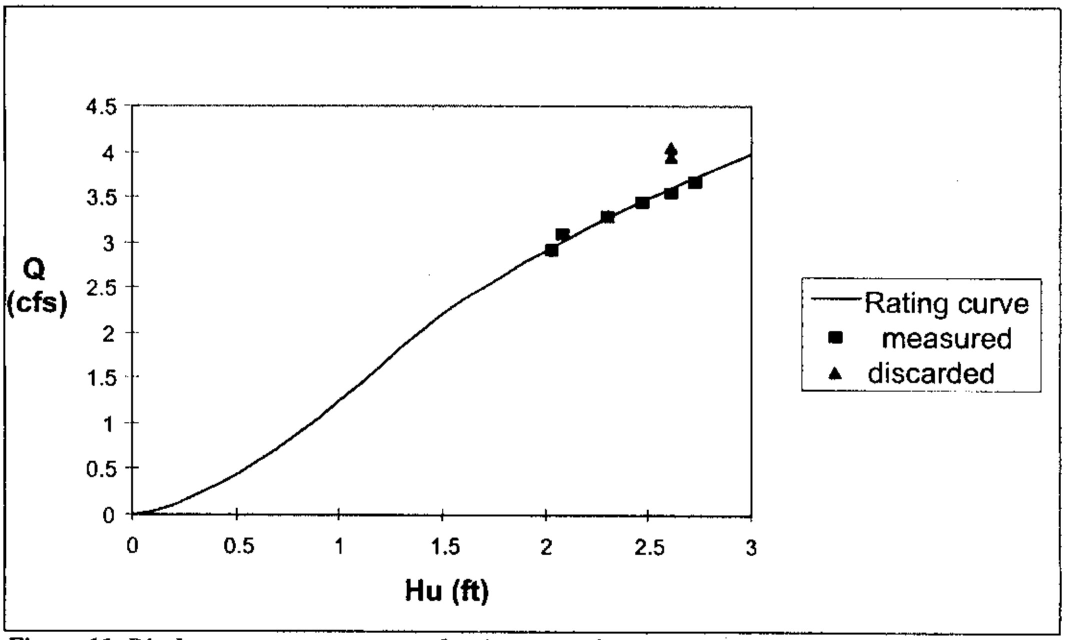


Figure 11. Discharge measurements and rating curve for outlet of Watercourse 117-R,Hakra 6-R Distributary

4.8 Concluding remarks

In studying the data obtained with different current meter measurements for the five AOSM outlets (between 6 and 8 values per outlet), it became apparent that the c-values arrived at were rather close to the value originally used in the design formula, 7.3. The differences in discharges calculated with the original design formula and the calculated c-values do not exceed 5% for any of the outlets studied. On the basis of this information, the finding of Visser (1996) that for a non-tampered AOSM the design c-value of 7.3 can be used with an inaccuracy of less than 10%, can be reconfirmed. Much time of the field staff can be saved by assuming this value for AOSMs and APMs instead of performing discharge measurements.

Submerged flow conditions have been ignored, as they did not occur in most of the outlets, and where they occurred, they did not seem to be of such magnitude, that within the obtained accuracy for the calibration it would make a difference. Also, not enough measurements under submerged conditions were conducted to get an accurate impression of the values for c_d that should be used in the submerged flow formula. Again, the c_d factor is not a constant and thus should be known for the different ranges of submergence.

5 Daily Discharges

The daily discharges that have been calculated for the period from 3 July to 31 December 1996 for the six sample watercourses are graphically presented in Figure 12. The daily discharges for the period from 3 July 1996 to half April 1997 are given in Annex 1 for the watercourses separately. In all of these figures, the grid lines coincide with the days on which the distributary changes from one rotation to the next. The first preference in the figure is second preference, which is followed by third, and then first, and so on. The distributaries on Hakra Branch Canal are rotated every 8 days, with Hakra 6-R Distributary receiving water according to first, second or third preference for 8 days in turn. During first preference, the distributary is maintained at full supply level, during second preference a distributary is given as much as is possible seeing the water availability in Hakra Branch, and on third preference a disributary gets whatever is left, but might as well be dry.

From Figure 12, it can be seen that, in general, the rotation between the different distributaries on Hakra Branch Canal is followed. During first and second preference, the outlets, in general, receive maximum discharge. During third preference, the distributary can be expected to be dry, unless there is enough water in Hakra Branch, then water will be let into Hakra 6-R Distributary as well. Figure 12 shows that in some cases there is quite a considerable amount of water coming in at third preference. Other times, the distributary is completely dry. So, the farmers cannot count on any water to come to them during third preference. During first and second preference, however, they can be quite sure to receive full flow during their turns.

A remarkable thing about the rotation in the distributary is that it is an eight-day rotation, whereas the *warabandi* schedule is only seven days. The extra eighth day is for filling of the canal when a preference is changed. This means that every third preference the farmers having their turn on the first day of this preference have considerable chance to also miss their turn on the last day of third preference and, thus, miss two consecutive irrigation turns. However, by using this system, it is assured that it are not always the same farmers that are affected by irregularities in canal flow due to a change in preferences.

Annex 1 shows that, in the last weeks of December and the first two weeks of January, the water supply was rather haphazard. The reason for this is not exactly known. However, during this period, the water demand was not really high, which is also evident from the fact that the farmers closed their outlets in a number of cases. Although there was some water needed to give the last pre-irrigation gifts to be able to perform land preparations for wheat, and farmers wanted to give a last gift of water to the freshly sown wheat crop before the annual canal closure (from 15 January to 4 February).

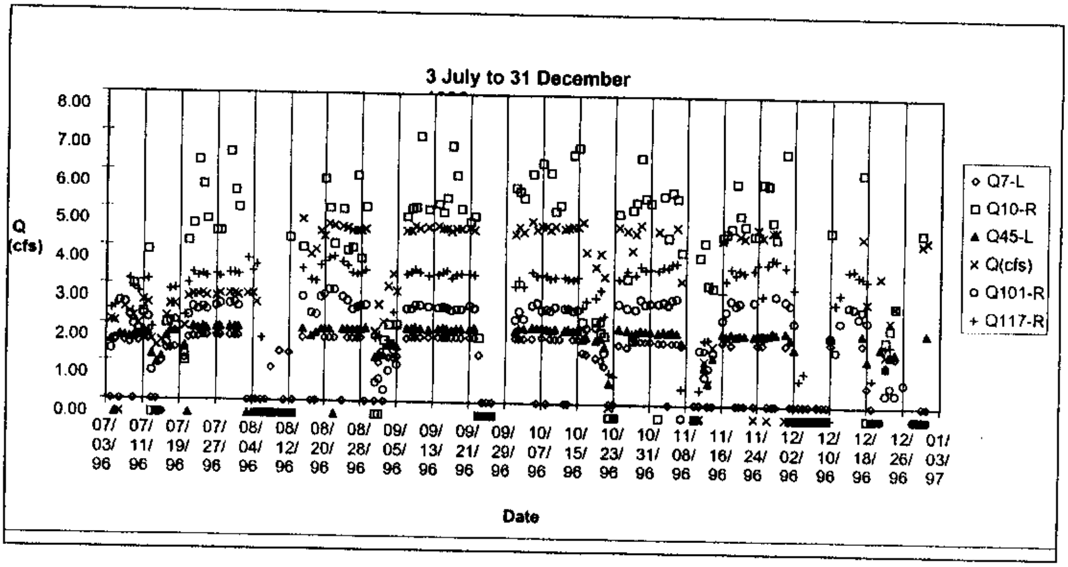


Figure 12. Measured Daily Discharge for the 6 IIMI Sample Watercourses at Hakra 6-R Distributary.

In Table, 10 an overview is given of the number of days on which discharge measurements were conducted in the period from 3 July 1996 to mid-April 1997 and how many days the outlet was found to be partly or completely blocked at the time of observation. Due to the fact that only one measurement/observation is conducted each day, this gives only an impression of the actual discharges and the amount of time the outlet is blocked by the farmers. In reality, the outlet can be opened and closed many times during a day. The stability of the discharges measured on first and second preference (see Figure 12) suggests that, for these preferences, one discharge measurement per day was enough to obtain a good impression of the amount of water entering the watercourse command area that day. During third preference, the discharge is much more variable and here considerable errors will be made by treating the daily measured value as the discharge for the entire 24 hours in a day.

Table 10. Overview of number of days staff gauge observations were performed and outlet closure.

Water-course	Total no. days	Not meas-ured	Annual canal closure	Days no water at 3rd preference	Days no water at 2nd preference	Days no water at 1st preference	Days outlet closed	Days outlet partly blocked	Total days daily discharge calculated
7-L	286	59	20	24	3	-	49	1	130
10-R	286(18)	58	20	27	7	4	6	-	146
45-L	286	58	20	26	2	2	9	5	164
61-L	286	58	20	29	2	-	16	9	152
101-R	286	56	20	36	6	5	7	7	149
117-R	286	62	20	29	5	5	6	13	146

Differences in the days that there was no water in the distributary at third preference between the first three outlets and the two tail ones are not due to a head-tail difference, as might be expected, but to the fact that in the two tail watercourses local people have been assigned to take the gauge readings. These persons have taken many readings during the month of December, when, for several reasons, the amount of readings taken in the other four watercourses was rather low.

From Figure 12, the graphs presenting the daily discharges for the separate sample watercourses in Annex 1, along with Table 10, the following can be observed:

- Changes in the full supply level for the watercourses in which the outlet has been changed during the research period have been indicated graphically in the graphs in Annex 1;
- Discharges actually obtained at full supply level are higher than sanctioned (design) discharges for all of the watercourses;
- Outlet closure by the farmers is most frequent in W/C 7-L and then in W/C 61-L;
- Reliability of water supply at first and second preference is quite good and does not differ much between head and tail watercourses, although the variation in supply at full supply level is higher in the tail reach of the distributary;
- Tail watercourses often get relatively more water than the head, especially at lower discharge in the distributary and after rains, when many outlets upstream have been closed by the farmers of those watercourses; and
- Watercourse 10-R has very high fluctuations in the discharge as a result of high differences in degree of submergence when the water turn is in the head reach compared to when the water turn is in the tail reach of the watercourse; in the tail reach, the land has a high elevation causing a reduced flow velocity and a backwater effect that reaches all the way upstream to the (always submerged) pipe outlet.

6 Daily Discharges in Relation to Other Physical Factors

By using the information obtained by the daily discharges measurements, the actual full supply level discharge (Qact FSL) for each of the sample watercourses can be estimated. When these Qact. FSL are related to the actually cultivated command areas (CCA cultivated)[3], then, an impression is obtained of the actual allowances for the sample watercourses. These can be than compared with the design allowances as given by the Irrigation Department for the same watercourses. To arrive at the "real" allowance, there is a need to multiply the calculated allowances by two-thirds, because for one-third of the time (i.e. at third preference) the farmers cannot be sure of receiving any water. (See Annex 2 for an overview of the physical characteristics of the sample watercourses and the cropping patterns for Kharif 1996.)

The actual allowances calculated in this way can be compared with the cropping patterns to see if higher water requirements coincide with higher water allowances. Table 11 shows that for the six sample watercourses during Kharif 96 the results are not as expected. The allowances are highest in the three right side watercourses. In contrast, the larger areas planted with water demanding crops (i.e. sugarcane, rice, fodder, jantar) are found in the left side watercourses. So, contrary to expectations, the higher allowances are found in watercourses with lower crop water requirements. This indicates that another factor is needed to explain this seeming paradox.

This explanation can be found by taking the watertable depths for the sample watercourses into consideration. In the left side watercourses the watertable is very close to the field level and much waterlogging occurs. This can be observed from the percentage of the watercourses command area that is permanently waterlogged. On the right side, the water table is in general situated much deeper and no permanent waterlogging occurs. The proximity of the water table to the field level explains the choice for waterlogging resistant crops, rather than water demanding crops. The higher water

[3] The CCAact is calculated on the basis of patwari data about the cropping patterns. It is the area actually cultivated and thus receiving irrigation water. The waterlogged, un-cultiviable and fallow areas have been excluded.

requirements of these crops are fulfilled from the groundwater, explaining why the water allowances are relatively low. This also explains the higher incidence of outlet closure along the left side watercourses and especially watercourse 7-L.

Table 11. Physical characteristics of the sample watercourses on Hakra 6-R Distributary during Kharif 1996: design and actual.

Watercourse	7-L	10-R	45-L	61-L (before O/L change)	61-L (after O/L change)	101-R	117-R
design CCA (in acres)1)	331	618	467	556	556	275	451
2/3 of design allowance	2.4	2.4	2.4	2.6	2.6	3.2	3.3
CCA cultivated, *patwari* data	222.2	540.9	299.1	372.9	372.9	244.9	332.1
2/3 Qact (cfs)/1000 acres of CCAcult.	5.0	6.8	4.9	5.4	8.8	7.6	7.4
waterlogged area as % of CCAgross	**12.8**	0	**18.4**	**15.5**	**15.5**	0	0
fallow as % of CCAgross	20.1	10.2	14.8	13.4	13.4	8.1	7.4
Low CWR and/or W/L sensitive crops	33.8	**79.4**	57.0	42.3	42.3	**83.5**	**87.5**
High CWR and W/L resistant crops	**65.7**	19.4	**42.9**	**57.5**	**57.5**	14.4	10.9

1) As given by the Irrigation Department

The change in size of the outlet for Watercourse 61-L during the season can be explained from information obtained from interviews with shareholders of this watercourse. After the heavy rains in July, much of the planted cotton crop had been destroyed. Also, the water table gas risen and made it impossible to plant cotton again in part of the watercourse command area. One of the larger shareholders planted his fields with rice to circumvent this problem. However, by doing so, he increased his water demands during the remainder of the season. On his own, he decided to go to the Irrigation Department and arrange for the outlet to be enlarged; in this way, satisfying his increased crop water requirements. It is so far unknown what has been the effect of this individuals action on other shareholders and on the waterlogging situation in the watercourse command area.

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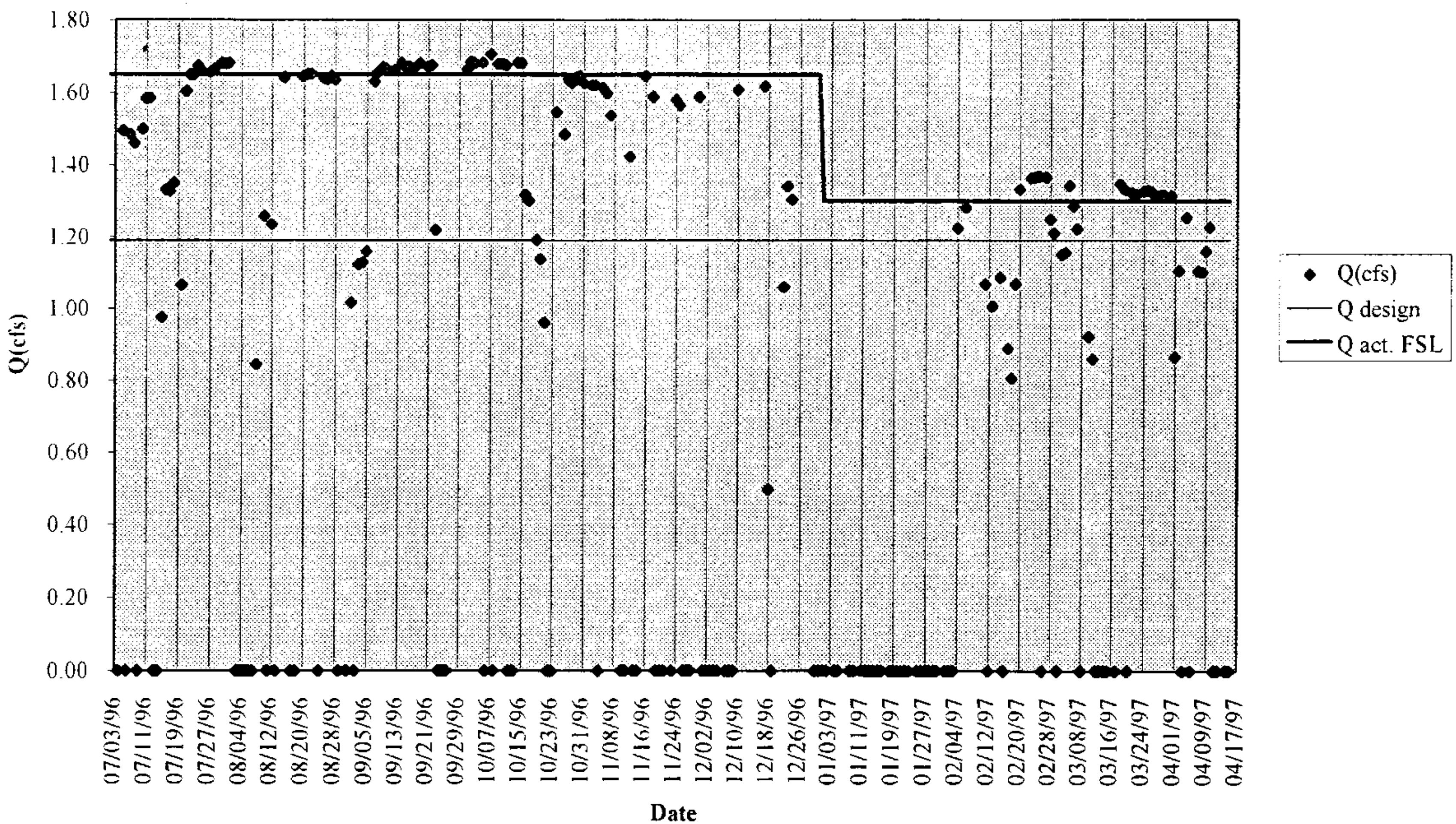
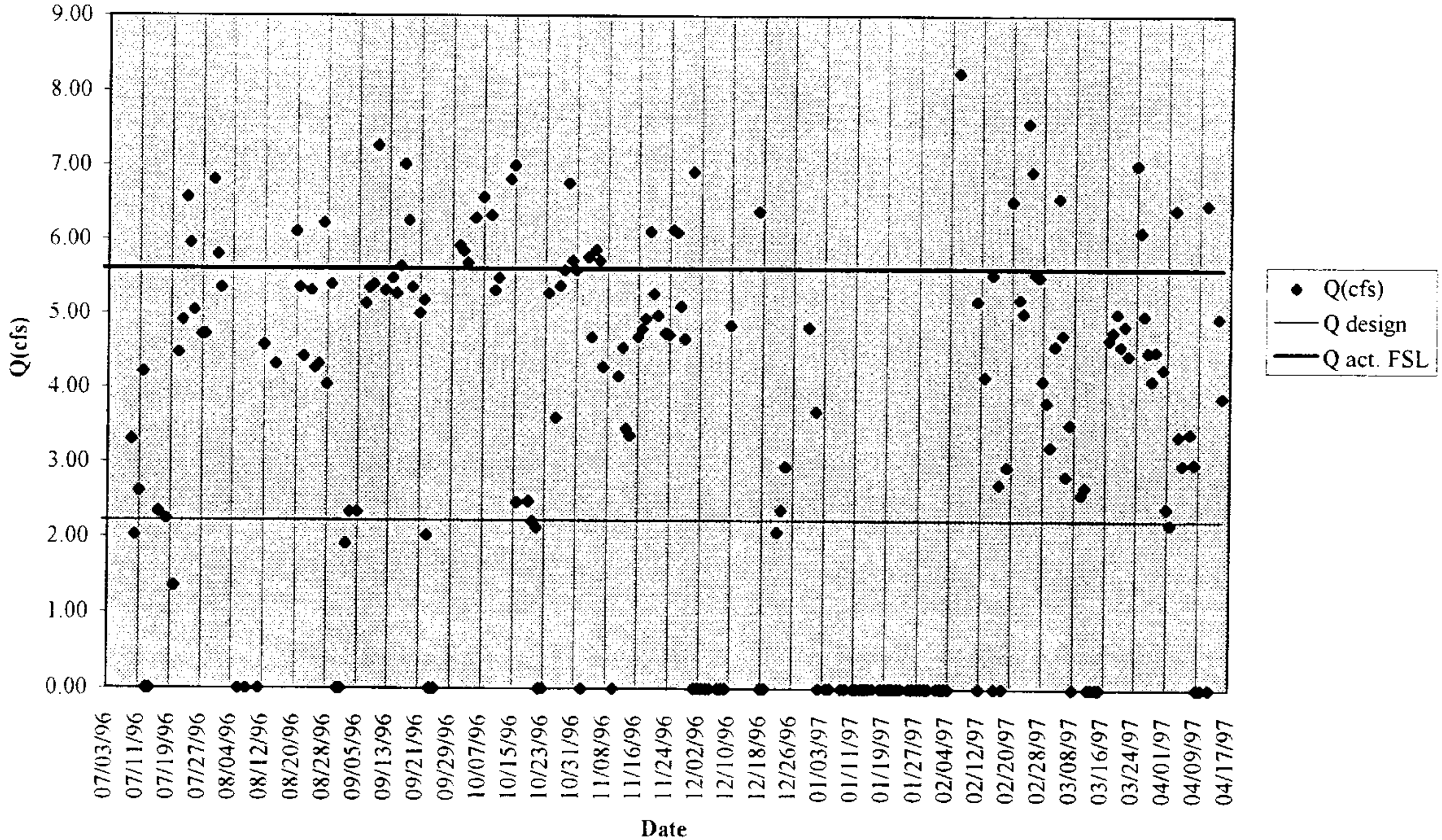
Annex 1: Graphical Representation of the Daily Discharges for the Six Sample Watercourses on Hakra 6-R, Distributary, Hakra Branch Canal.

Measured Daily Discharges for W/C 7-L, Hakra 6-R Distributary.



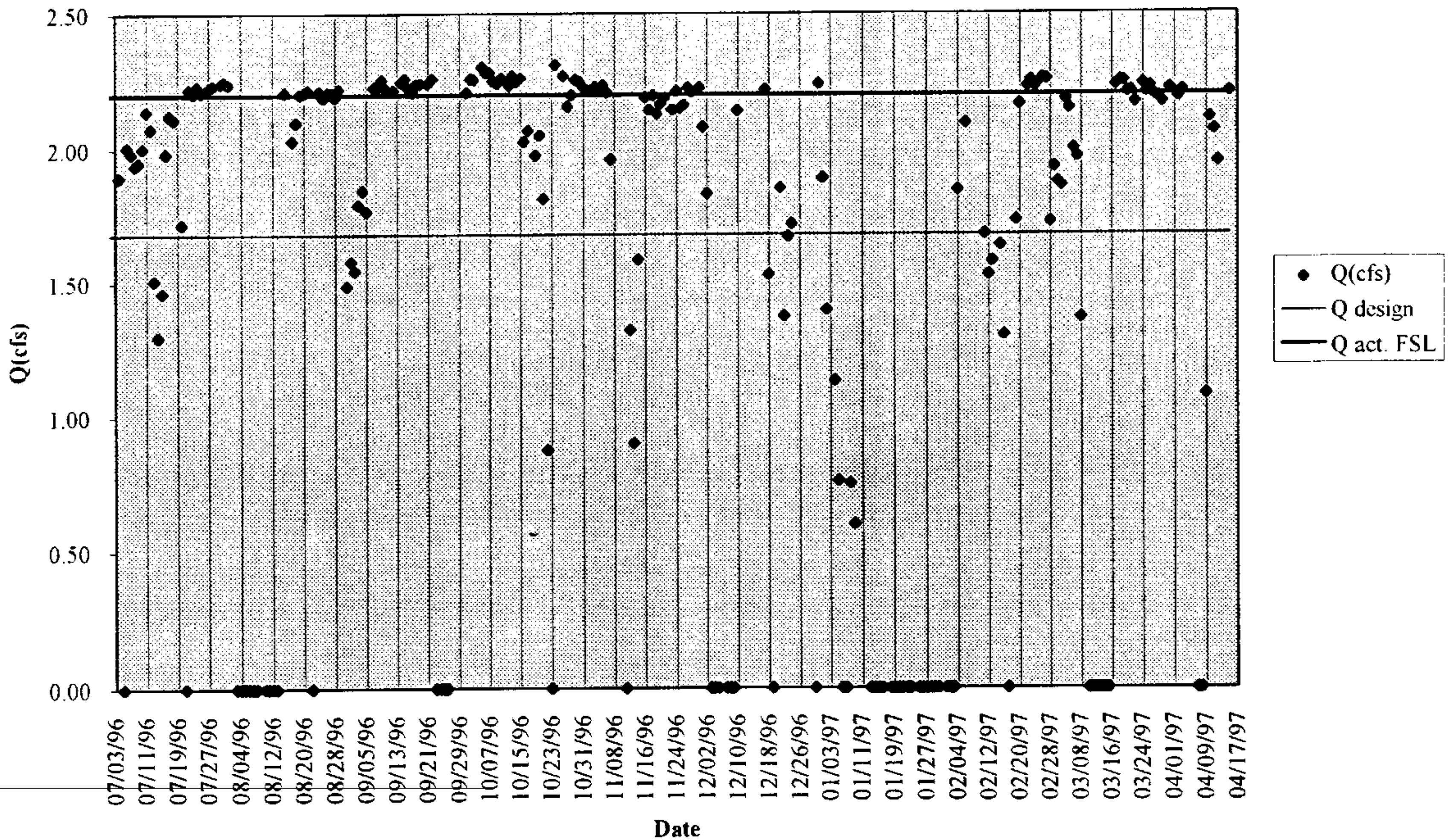
ANNEX 1

Measured Daily Discharges for W/C 10-R, Hakra 6-R Distributary.



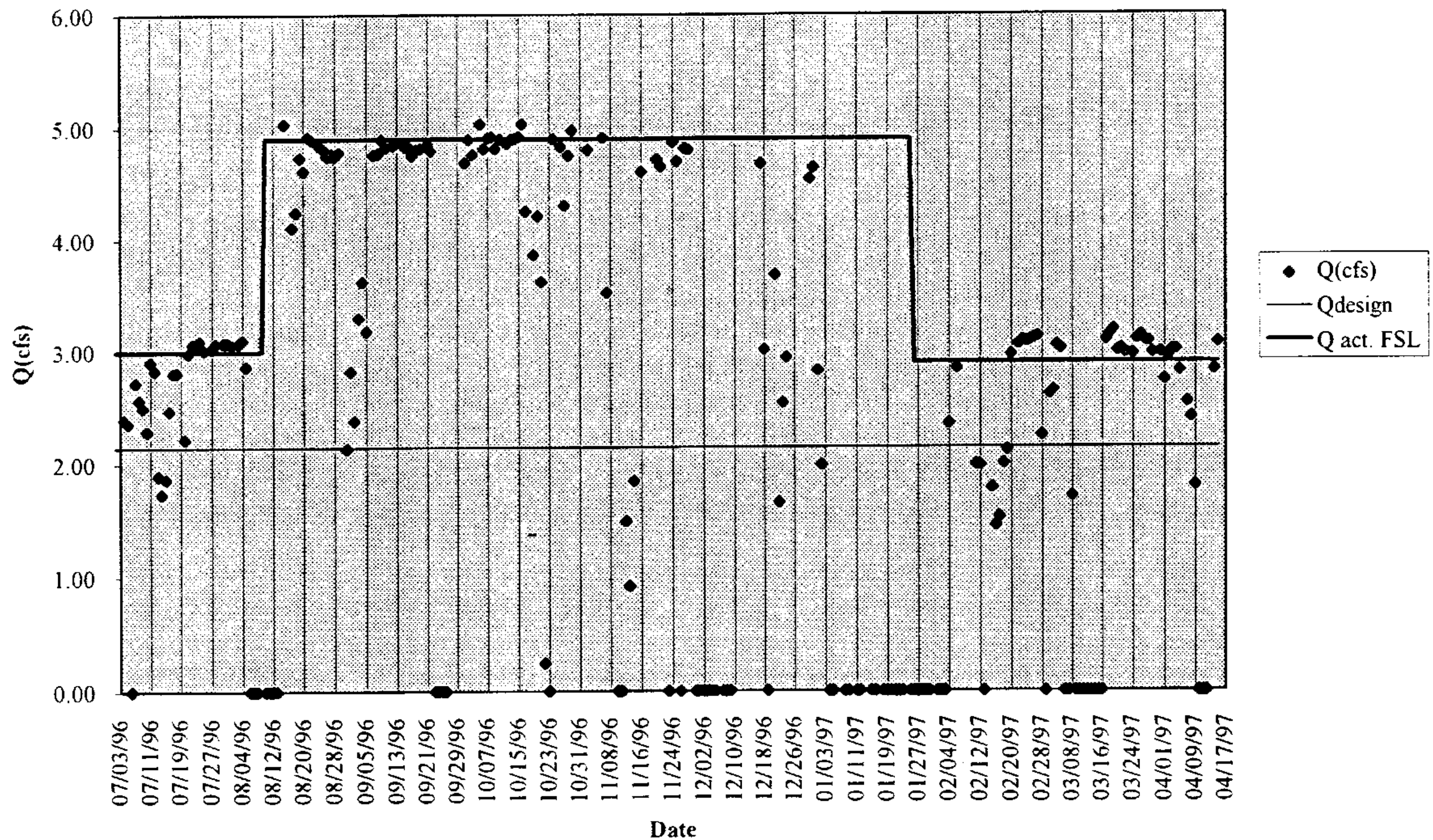
ANNEX 1

Measured Daily Discharges for W/C 45-L, Hakra 6-R Distributary.



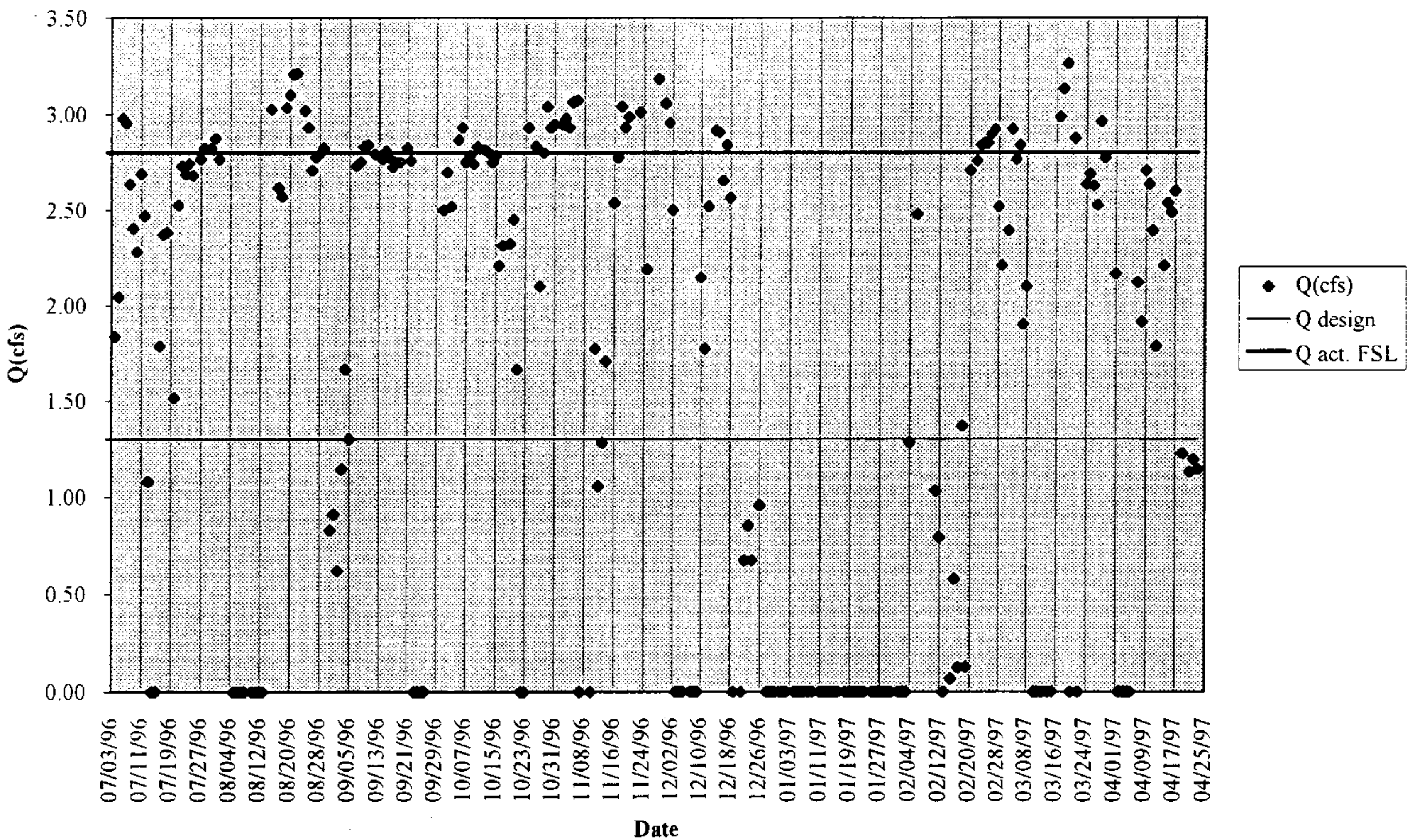
ANNEX 1

Measured Daily Discharges for W/C 61-L, Hakra 6-R Distributary.



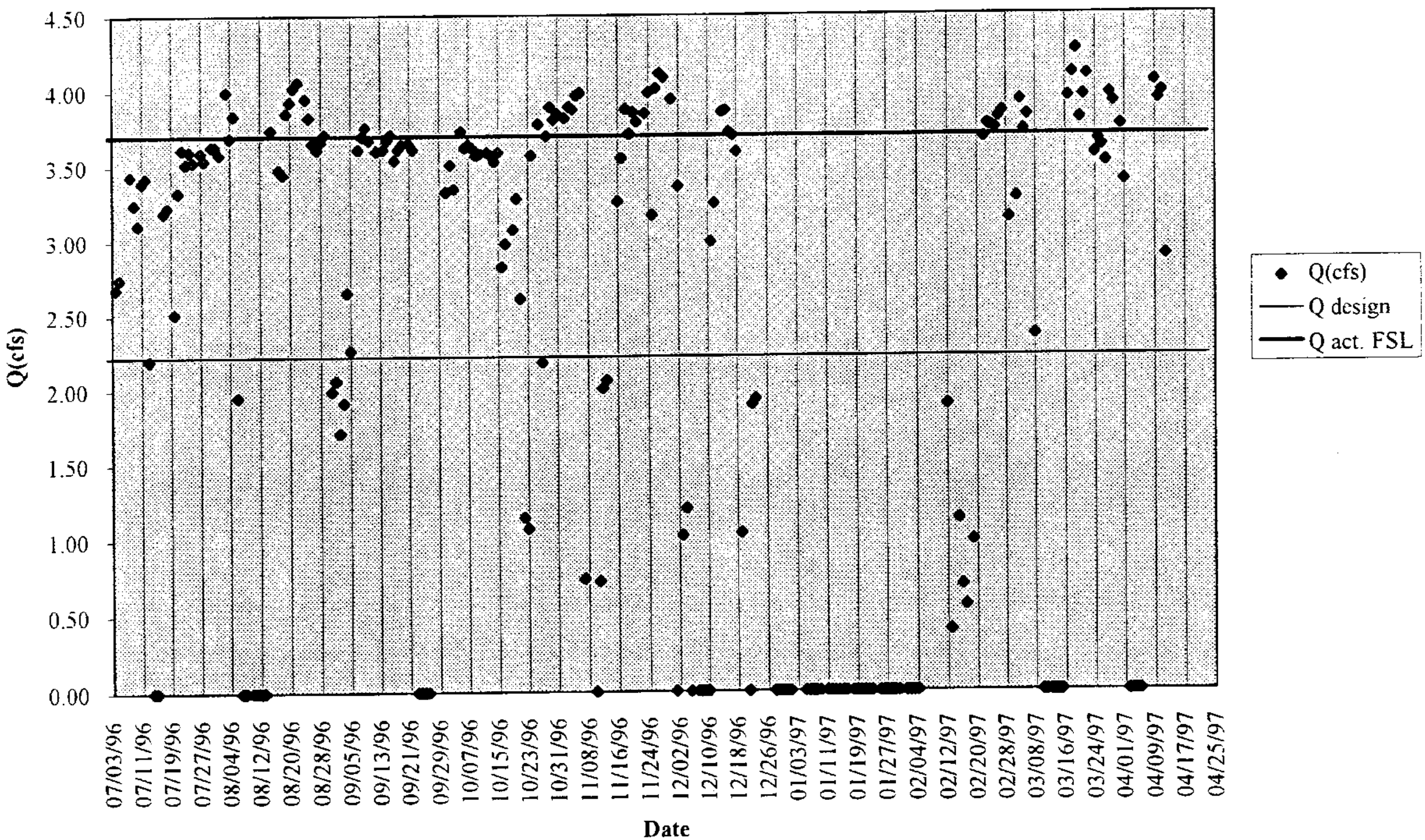
ANNEX 1

Measured Daily Discharges for W/C 101-R, Hakra 6-R Distributary.



ANNEX 1

Measured Daily Discharges for W/C 117-R, Hakra 6-R Distributary.



Annex 2: Physical characteristics of the sample watercourses on Hakra 6-R Distributary for Kharif 1996: design and actual.

		7-L	10-R	45-L	61-L (before O/L change)	61-L (after O/L change)	101-R	117-R
Outlet No.1)		5	6	25/31	33	33	55 C	61 A
Rd/side1)		7590/L	10500/R	45198/ L	61030/L	61030/L	100714/R	117695/ L
design GCA (in acres)1)		655	988	483	556	556	275	480
design CCA (in acres)1)		331	618	467	556	556	275	451
design discharge (Q) in cusecs1)		1.19	2.22	1.68	2.14	2.14	1.3	2.22
design CCA/Q (in # of acres per 1 cusec)		278	278	278	260	260	212	203
design allowance (cusecs per 1000 acres)		3.6	3.6	3.6	3.8	3.8	4.7	4.9
2/3 of design allowance		**2.4**	**2.4**	**2.4**	**2.6**	**2.6**	**3.2**	**3.3**
GCAgross, *patwari* data		331.2	602.3	447.8	524.2	524.2	266.5	358.5
CCA cultivated, *patwari* data		222.2	540.9	299.1	372.9	372.9	244.9	332.1
% of CCAgross		67%	90%	67%	71%	71%	92%	93%
Q actual FSL		1.65	4.2-7.0 avg.: 5.6	2.2	3.0	4.9	2.8	3.7
2/3 Q actual FSL		1.1	3.7	1.5	2.0	3.3	1.9	2.5
2/3 Qact (cfs)/1000 acres of CCAgross		3.3	6.1	3.3	3.8	6.2	7.0	6.9
2/3 Qact (cfs)/1000 acres of CCAcult.		**5.0**	**6.8**	**4.9**	**5.4**	**8.8**	**7.6**	**7.4**
Waterlogged area as % of CCAgross		**12.8**	0	**18.4**	**15.5**	**15.5**	0	0
Fallow as % of CCAgross		20.1	10.2	14.8	13.4	13.4	8.1	7.4
MAIN CROPS	Cotton	33.8	71.9	55.2	42.0	42.0	76.2	71.4
% OF CCAcult	Oilseed	0	5.7	1.7	0.3	0.3	1.0	0.5
	orchard (+ crop)	0	1.8	0.1	0	0	6.3	15.7
Low CWR and/or W/L sensitive crops		33.8	**79.4**	57.0	42.3	42.3	**83.5**	**87.5**
	Fodder	28.3	16.0	29.9	19.6	19.6	12.1	9.5
	Sugarcane	24.4	2.9	5.9	14.0	14.0	1.9	1.4
	Rice	11.6	0.5	0.5	20.7	20.7	0	0
	Jantar	1.4	0	6.6	3.2	3.2	0.4	0
High CWR and W/L resistant crops		**65.7**	19.4	**42.9**	**57.5**	**57.5**	14.4	10.9

1) As given by the Irrigation Department

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