CORRECTION OF TIME-ALLOCATION IN A ROTATIONAL WATER DISTRIBUTION SYSTEM, BASED ON FLOW CHARACTERISTICS IN OPEN CHANNELS

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ABSTRACT

A field study to determine water discharge distribution with respect to time and location as a result of rotational irrigation system has been conducted in the Maneugteung Irrigation Scheme (MIS), Cirebon, West Jawa.

Data of flow characteristics in term of flow velocity and discharges under existing canal condition and system management were collected during dry season, during which a rotational water distribution system was applied in the scheme. The flow velocity and discharge of each canal section were measured by current meter. Results of the measurement then were used to develop relationships between canal length and cumulative time required to travel and to attain normal flow depth of each canal section.

Result of the study reveals there was a significant time lag between the time of release and time of arrival at a particular site in the assigned open channel. This means that irrigation water availability along the canal varies depend on water discharge, flow depth and physical condition of the canal. Attempting to obtain equity in water distribution among water users, it is suggested that the travel time and time to attain normal flow depth have to be added to the allocated time for distributing water for each irrigation block.

INTRODUCTION

Most irrigation systems in Java were designed as supplemental irrigation for serving rice based cropping. Therefore, the irrigation water is delivered by continuous flow method. However, during dry seasons, when water is shortage, rotational water distribution system may be applied in some irrigation schemes.

Basically, a rotational water distribution system provides water for one or some tertiary blocks an exclusive use of the water for a specific period of time. The water is delivered to the assigned tertiary block(s) according to the allocated time-share, and then it moves to other blocks until the whole command area is irrigated, and the circle is repeated. The method is believed could improve equity among the water user during the water is limited, and has been successfully used for small irrigation schemes. For large schemes, the method may require some modification and improvement (Bishop, 1983).

In time sharing, the allocated time distribution for each block is usually proportional to its area without considering its distance from the source when water has to travel along the canals system before reaching the fields. By this method, the equity as the main objective of the rotational water distribution method, very often can not be achieved and "head-tail" problem is arising. Such problem still prevail in some irrigation schemes in Indonesia especially during the irrigation water is scarce (Oad, R and G. Levine, 1985).

The paper intends to analyze the influence of location and time factors on availability of irrigation water in main canal system. The analysis is based on the results of field observation in the MIS. During the dry seasons, the available water in the scheme is very limited, while the demand is increasing sharply, so the equity in water distribution is becomes the most important issue in the area.

THEORETICAL CONSIDERATION

The distribution of available water along canals of an irrigation system resembles both management capability of the irrigation officials or operators, and the functional performance of the irrigation structures. This reveals that performance of an irrigation system at any particular location from main intake down to tertiary offtakes is the end result of an interaction between technical and managerial performance.

The discharge of irrigation water (Q) along a main canal, varies according to location or canal length (x) and time (t), or it can be expressed as $Q(x,t)$. It means that $Q(x,t)$ represents the influence of hydraulics and management factors. With respect to hydraulics of an open channel conveyance system, the discharge of irrigation water (Q) can be expressed as a function of flow depth (h),

$$Q(x, t) = f\ h(x, t) \quad \text{.......... (1)}$$

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The equation implies that flow depth along an irrigation canal varies with respect to time (t) and location (x). If hydraulic and volumetric losses occur during the water is traveling along the canal system, the theoretical discharge distribution *Q (t)* along the canals can be figured as shown in Fig. 1.

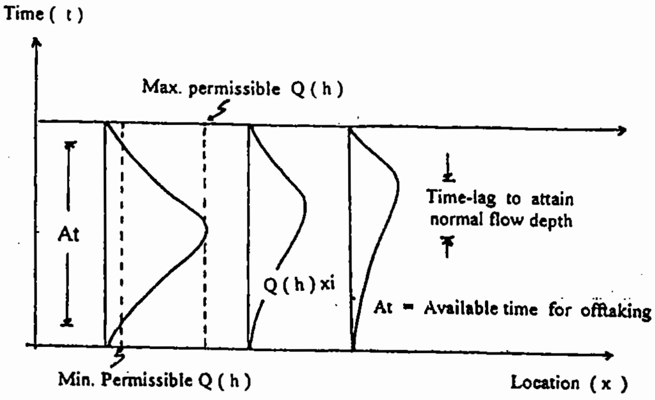

Figure 1. Theoretical distribution of Q(x) in an open channel

Based on the design criteria, the maximum conveyance capacity of an open channel is the maximum discharge corresponds to maximum permissible depth and velocity. For unlined open channel of medium soil texture, the maximum permissible velocity, which can be used, is between 0.5 and 0.8 m/sec (Anonymous, 1986). The minimum permissible velocity is set in accordance with sediment type and its concentration of the irrigation water, so that sedimentation along the canal may not occur.

In the case of runoff on the river irrigation system, a remarkable flow fluctuation may occur. Accordingly, there is a period of time at which the canal is run under minimum or maximum flow depth. To some extents, operating the irrigation structures can control the depth fluctuations in the irrigation canals. To achieve a normal flow depth, the assigned canal requires a certain additional time (Δ t), from the time when the irrigation water arrives. So the discharge becomes

$$Q(x, t) = Q[x, (t + \Delta t)] \qquad \text{.............} (2)$$

From point of view of water distribution, this additional time should be included as the allocated time distribution. Beside this additional time, the water needs a certain time to travel from the main intake to the reached location at the canal. Theoretically, this travel time is determined by water discharge, geometric shape of the canal, flow depth, type of canal material, tributaries and canal obstructions (Mawardi, 1991). All of these factors change according to time and location. For a good canal condition, where flow velocity is constant, the travel time is a linear function of its canal distance. In order to achieve better equity among water users, all of the above variables should be take into account.

Referring to travel time *tv*, and the time to attain normal flow depth Δ t , the corrected allocated time distribution becomes :

$$td = ta + tv + \Delta t \qquad \text{.........................} (3)$$

where *ta* is the allocated time distribution at particular location in the current water distribution practice. Considering the practice of rotational water distribution, the allocated time distribution therefore, should be improved. The time correction could practically be predicted by developing a regression line between *tv* and the distance from the main intake to particular site, and observing the Δt along the assigned canal.

METHODOLOGY

The study was conducted in the MIS, Cirebon, West Java, during the dry season of 1997. The system was designed originally to serve rice and sugarcane crops. The water is delivered in continuos flow basis, but during the dry season when water in the source was scarce, a rotational water distribution was applied.

Flow characteristics in the main canal in term of flow velocity and water discharge along the canal *Q(x,t)*, were measured by current meter and installing water level recorder at certain location along the canal. Study location and field measurements as shown in Figure 2. By this measurement, water distribution in term of time and location along the canal could be described , and relationships between canal length and cummulative time required to travel and to attain normal flow depth could be developed. The relationships are used to determine additional time for time allocation of rotational water distribution.

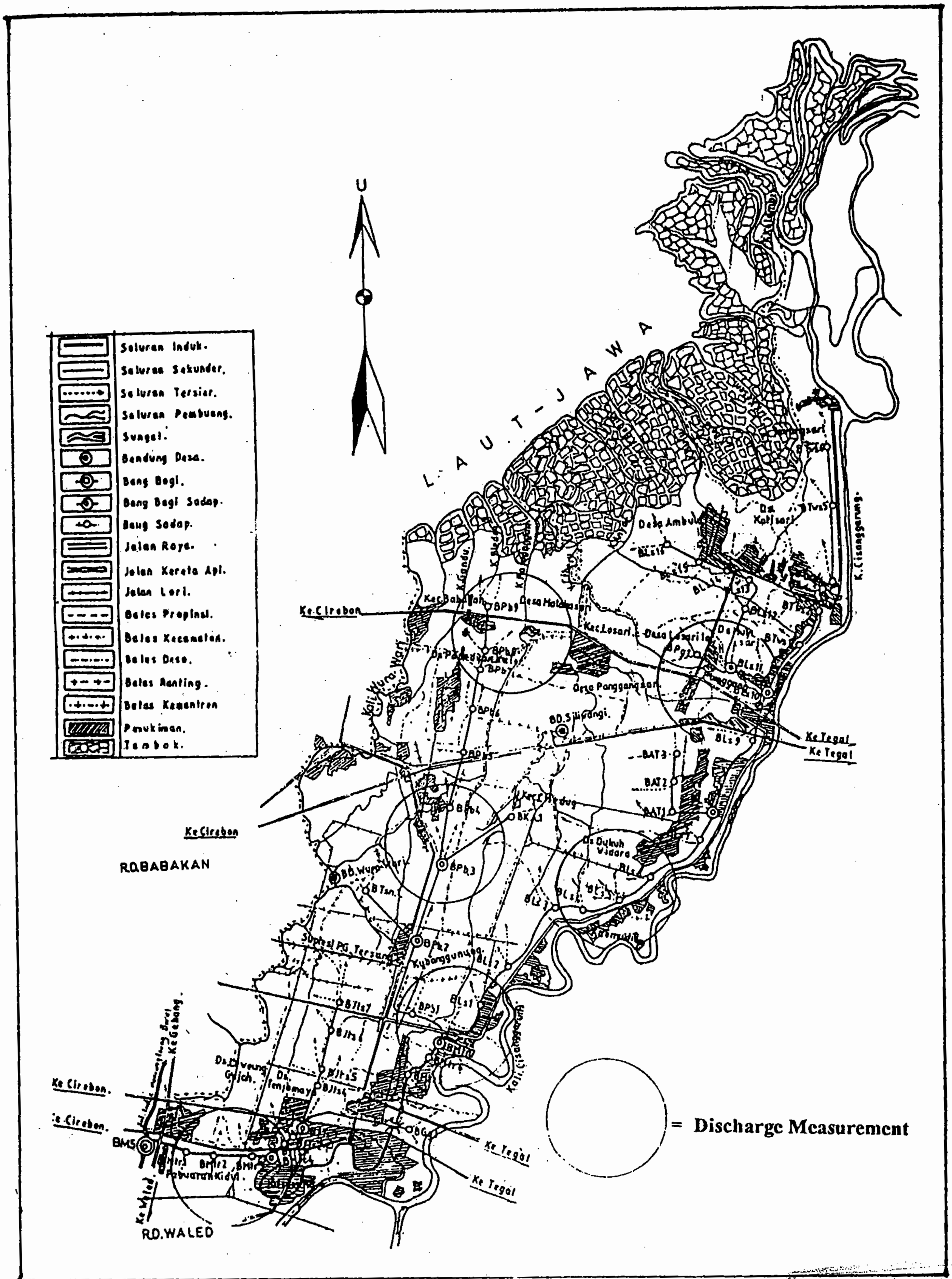

Figure 2. Study location and field measurements

RESULTS AND DISCUSSION

Travel time and time to attain normal flow depth

Relationships between canal length and cumulative time to travel and time to attain normal flow depth of both primary and secondary canals for different water discharges are shown in Tables 1 and 2. By using these data, a linear relationship between canal length and cumulative time then can be derived as shown in Figures 3 and 4. A note should be made here that the term of normal flow depth which is used in this study means the flow depth in the assigned canal does not change with time ($dy/dt = 0$), where y is the flow depth, and without considering changes in flow velocity.

Table 1. Travel time and time to attain normal flow depth at Primary canal of the MIS

Canal length, m	Cumulative time to arrive for Q1 (minute)	Cumulative time to arrive for Q2 (minute)	Cum. time to be normal for Q1 (minute)	Cum. time to be normal for Q2 (minute)
0	0	0	0	0
200	5	4	21	12
400	7	10	40	35
600	11	13	52	47
1000	21	28	109	80
2000	45	50	125	114
3000	72	90	148	143
4000	95	115	158	157
5000	123	145	200	182
6000	152	178	220	195
7000	170	210	235	225

Note : Q1 = 2.698 m^3/sec ; Q2= 1.403 m^3/sec

Table 2. Travel time and time to attain normal flow depth at secondary canal of the MIS

Canal length, m	Cumulative time to arrive for Q1, (minute)	Cumulative time to arrive for Q2, (minute)	Cum. time to be normal for Q1, (minute)	Cum. time to be normal for Q2 (minute)
0	0	0	0	0
100	2	3	11	20
200	6	7	22	31
300	10	10	35	36
500	13	15	47	54
1100	28	40	66	80
2100	64	68	133	100
4100	150	165	209	179
5100	164	191	231	237
6100	186	238	270	272
6600	205	261	286	311

Note : Q1= 0.518 m^3 /sec ; Q2= 0.752 m^3 /sec

The Fig. 3 and 4 show that both primary and secondary canals still have a good performance with respect to flow velocity. This performance is shown by the linear relationships between canal length and cumulative time. Although the measured flow velocity in the main canal varies between 0.23 to 0.5 cubic mater per second , for earth canal and 0.5 to 1.0 cubic meter per second for lined canal, this velocity range is still below the maximum permissible velocity. However, at some locations, the velocity is under the minimum permissible velocity for main canal system. This low velocity presumably influences the sedimentation rate along the canal. This is indicated by the changes of the canal cross section (canal width and flow depth). High sedimentation occurs mainly along the curving canal sections and sections which are close to upper stream of diversion and offtake structures.

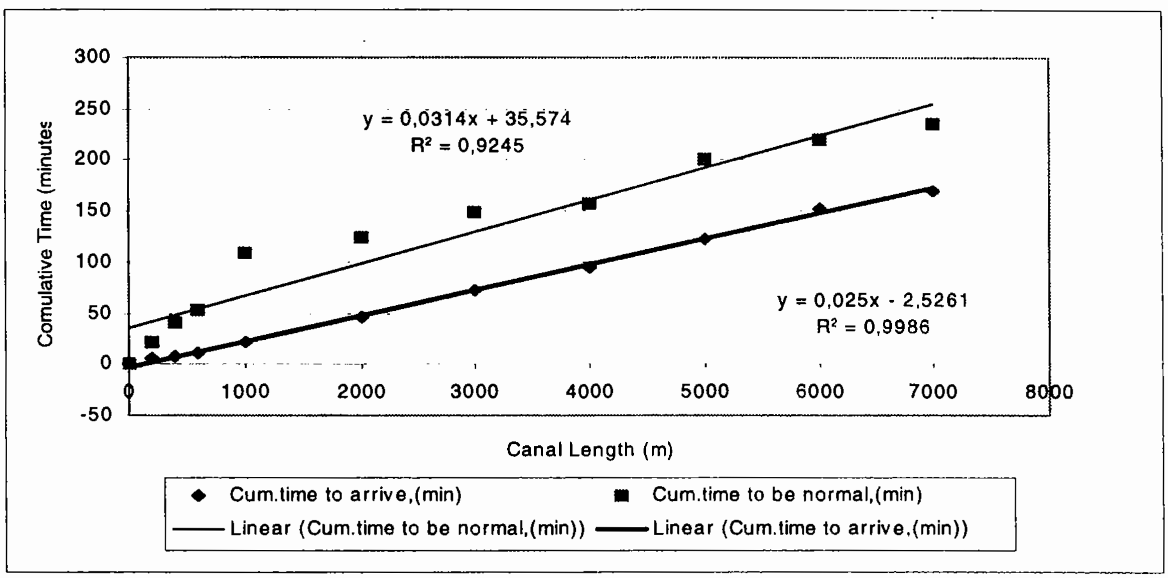

Figure 3. Travel time and time to attain normal flow depth at primary canal

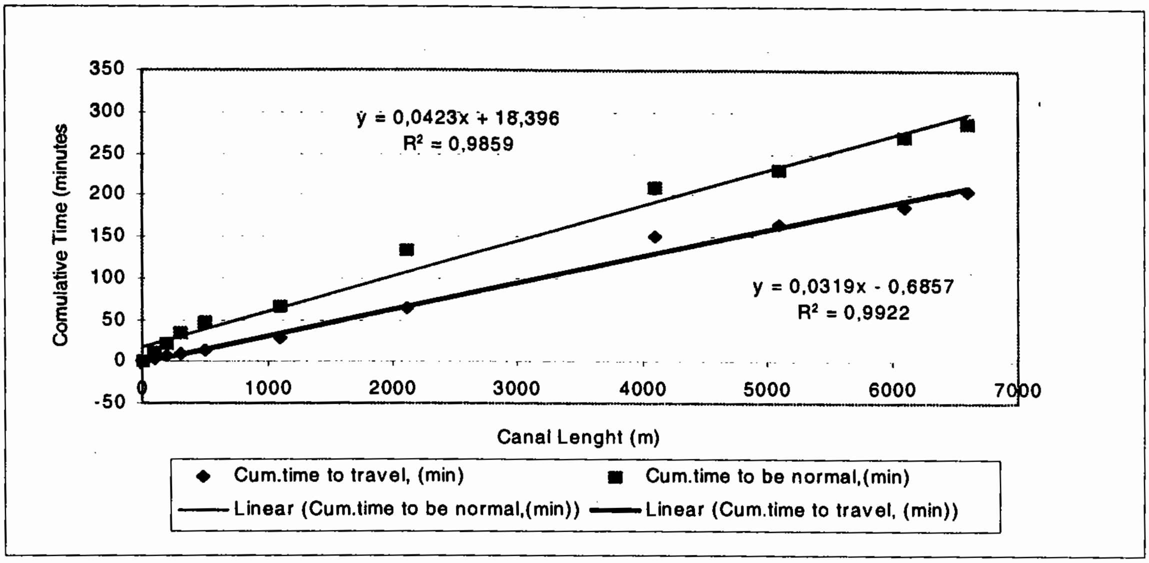

Figure 4. Travel time and time to attain normal flow depth at secondary canal

The Fig.3 and 4 also show that besides the physical condition of the canal, the water discharge has also significant influence on the travel time. This situation is consistent with the basic theory of flow in an open channel as has been discussed earlier. The slope of the regression lines can notice the different of travel time due to the different of water discharge. Linear relationship also showed between canal length and cumulative time to attain normal flow depth.

An important thing in an open channel conveyance system is that the water requires a certain time to attain a steady normal flow depth from its minimum depth. This additional time (Δ t) tends to be different for different water discharge, canal condition and location. From management point of view, this additional time should be added to the allocated time in the time distribution of rotational water distribution. The value of travel time and additional time at each canal location can directly be determined by developing relationship between canal length and cumulative travel time as shown in the Fig. 3 and Fig.4.

Discharge and offtake time distribution.

The time required to attain normal flow depth is different for different canal location as has been discussed earlier. It means that the allocated time of rotational water distribution system should not only proportional with the irrigated area, but also to its distance of each rotational block to the main offtake. Considering that the travel time is shorter for higher water discharge in the canal, therefore, the allocated time should also accounted the actual available discharge of each canal section.

The opportunity offtake time for each tertiary block along the main canal mainly depends on the hydraulic head of the water in the assigned canal. Since the hydraulic head is determined by the flow depth (y), therefore, the opportunity offtake time of each tertiary block also depends on the flow depth. As the flow depth varies with time and location, so there is a certain distribution pattern of opportunity offtake time prevails along the canal during the canal operation. When the accumulated time required to travel and to attain normal flow depth in the certain canal is plotted against the canal length, this relationship can be used to determine the total required time $(tv + \Delta t)$ of each canal section .

Every tertiary offtake and measuring device structures requires a certain water elevation in order to be operated properly. If the normal water flow in each canal section is set up as the required water elevation, a distribution of opportunity offtake time along the canal could be determined directly using the Figs. 2 and. 3. The opportunity of each tertiary offtake starts, when the normal flow depth has attained at the assigned location. When the discharge decreases as a result of gate closing or illegal offtaking in the canal, the opportunity offtake time is decreasing accordingly until the water is totally stop. By the way , the opportunity offtake time at certain canal location also varies with time .

As has been mentioned before, the objective of water distribution is mainly to distribute the available water to each tertiary unit in an irrigation schemes in a proportional amount of water (volume) to fulfill their irrigation requirement. When equality is set as the basic principle one, the possible time duration of getting water should be take into account rather than the only the discharge . The far of a tertiary offtake from the main offtake , the longer the allocated time has to be. An improper water distribution in an irrigation scheme, not only because of to improper management decision, but also to the functional performance of the irrigation system. Result of the field observation concerning with the physical condition of the canal system in the MIS show that the elevation of the base of some tertiary offtakes were higher than the average water elevation in the main canal. It means that some of the tertiary offtakes can only be operated properly when the flow depth is at maximum level, or the users have to install such wooden balk at downstream of the offtakes in order to increase the water elevation. This treatment is directly disturbing the distribution of water in the canal .

CONCLUSIONS

Based on the above discussion it could be concluded that the time availability for offtaking water for each tertiary block along the main canal system varies with time and location, and influenced by the water discharge released from the main intake. The distribution water availability is mainly influenced by the significant time lag between time of release and time of arrival at particular site along the canal. Beside that, the required time by each canal system to attain its normal flow depth has also significant influence to the distribution of offtake time. The significance is showed by the coefficient correlation of larger than 0.9 for both primary and secondary canals. In order to improve equity of water distribution in rotational irrigation system, the allocated time-sharing should be corrected by take into account the travel time and time to attain normal flow depth.

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