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Evaluation of improved earthen canal, pre-cast canal and buried pipe irrigation systems based on water losses

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ABSTRACT

A research work was conducted on water distribution systems in three different STW irrigation schemes at Nalchity Upazila in Jhalakati district, Bangladesh. Water distribution systems were improved earthen canal, pre-cast canal and buried pipe irrigation system. The main objectives of the study were to determine water loss and compare among improved earthen canal, pre-cast canal and buried pipe irrigation systems for water distribution to the field based on water losses towards providing useful information for the improvement of command area for surface irrigation. The capacity of selected three STWs was 14 litre/sec. The command area of shallow tubewell under improved earthen canal, pre-cast canal and buried pipe system were found 3.22 ha, 4.6 ha and 6.13 ha respectively. It was observed from the investigation that the average water loss through improved earthen canal, pre-cast canal and buried pipe systems were 4.85 1/s/100 m, 3.23 1/s/100 m and 0.35 1/s/100 m respectively. The minimum water loss was observed from the buried pipe and then from pre-cast canal. The buried pipe distribution system was superior to others for command area development and reducing water losses. Thus, water losses from shallow tube well can be decreased by providing pre-cast canal substantially to be buried pipe distribution system.

Introduction

Bangladesh is predominantly agricultural country with a total area of 14.39 million hectares of which 9.57 million hectares (66 percent) are under cultivation. Irrigation facilities in the country started to develop during the late 60's and about 12 percent (1.16 million ha) of the total cultivable land was brought under irrigation during 1978 to meet full or partial demand (Bhuiyan, 1976). Obviously, various types of studies are carried out for addressing the issues and problems associated with both the operation and management of irrigation systems. Amongst these, Improvement of performance of water distribution system is the prominent one.

Proper water distribution system and its efficient management play very important role in the command area development of any irrigation project. In Bangladesh, use of earthen open channel for water distribution is common in the minor irrigation sector. These earthen open channel distribution systems generally have very low conveyance and distribution efficiencies, resulting in less irrigated area (Sattar *et al*. 1988; Sanjit and Tareq, 1996; Hasan *et al*. 1992) and high maintenance cost. It is fact that, traditional earthen channel distribution systems confront some physical obstructions and canals suffer from high seepage, leakage and evaporation losses. One of the major weakness of the minor irrigation sector is the huge amount of losses of irrigation water that occur to lack of knowledge of management as well as, to some extent, due to negligence of farmer.

Water loss in the irrigation channel network is presumable responsible for such low coverage. This loss in the field ranged from 15 to 20 percent of the total water supply (Dutta, 1982). Michael (1978) in a consultancy report mentioned that the farmers in Bangladesh mainly used earthen canals for conveying water to irrigate their fields because of low initial cost, and considerable conveyance losses occurred mainly due to leakage. Recent literatures reveal that, this loss may be as high as 50-60 %, although it varies with soil type and channel conditions. Channel water loss adds to the pumping cost in minor irrigation systems, and thus reduces the command area, as well as overall efficiency of irrigation.

Field open channels in surface water distribution systems in Bangladesh generally originate from a DTW or a STW, or even from a major canal outlet, run in a random manner with a little consideration of topographical features of the areas (BARI 1988). Seepage and evaporation losses are high in such systems. Besides these, Michael (1987) reported that about 2 to 4 percent of the cultivable land area is taken up by open channels in these systems. Plausible economic solutions of some of these problems, in the areas with plain topography and having heavy to medium textured soils, include construction of improved (compact) earth channel with necessary water control structures and strengthen operation and maintenance to improve performance of the system. Water loss depends upon season, water table, soil land topography, channel geometry and other flow characteristics. Amongst the water losses, water lost through the irrigation channel network is quite significant (Miah, 1984).

Kraatz (1971) reported that seepage rates from channel built in sandy soil are often very high and can be fairly low if the conveyed water carries a heavy sediment load which deposits and build up a fairly impermeable layer on the bank bed of the channel. If improvement is made up in the channel network e.g. canal alignment, canal dimension, removing grass and compaction of channel, using lining material or polythene sheet, a considerable amount of pumped water can be saved. A properly designed water distribution system will make irrigation easy and efficient. Several types of structures are used to convey, divert and control irrigation water on the farm. Good irrigation structures are essential part of an irrigation layout. Earthen channel can be built stable side slopes with banks strong enough to carry the required flow of water safely. They should have ample capacity to carry the design discharge at no-erosive velocities. Side slops should be flat enough so that the banks will neither cave in nor slide when they saturated with water. However, the buried pipe distribution system (BPDS) may be the best solution to these problems (Bentum and Smout, 1993), especially for uneven topography and light textured soils (Jenkins, D. 1983).

Various studies have been carried out for addressing the issues and problems associated with both the operation and management of those irrigation scheme, Among those issues loses of irrigation water is frequently and prominently talked about. Hence the main objective of this work was to determine and compare the loss of water in improved earthen canal, pre-cast canal and buried pipe irrigation systems towards providing useful information for the improvement of command area for surface irrigation.

Materials and Methods

Location of the study area

The study site is located at Nalchity Upazila under Jhalakati district which is about 20 km away from district headquarters. The study was conducted on demonstration of irrigation canals. The land distribution of the area is mostly as follows:

High land	19%
Medium high land	30%
Medium low land	16%
Low land	20%
Homestead and water bodies	15%

More or less all the areas are dominated by sandy loam soil. The topography of the land is relatively medium and flat. There are shallow tubewells and deep tubewells in these areas with a fairly good water distribution system.

The climate of the study area is tropical. The average annual rainfall in this area as recorded at the nearest meteorological station, Barisal was 170 cm. The highest mean monthly temperature was 37^0C in May and the lowest was15^0C in February. The percentage of relative humidity ranged between 46% and 84%. The mean monthly evaporation rate varied from 58 mm to 131 mm over the year. From the relationship between the rainfall and the evaporation, it was found that the period from November to April was moisture deficit period. The dry season is very important for the farmers to determine irrigation water application.

Improved earthen canal

The normal discharge capacity of a STW in Bangladesh is 14 L/s. The canals are to be designed so that it can carry this discharge 20-25% free board is generally considered canal, in this study the canal was designed for a capacity amounting16L/s. The demonstrated improved earthen canal and Pre-cast rectangular canal represent in Figure 1**.**

Figure 1: Improved earthen canal (left) and Pre-cast rectangular canal (right)

Buried pipe irrigation systems

As underground pipeline water distribution system consists of buried pipes and some allied structures for the efficient functioning of the system. The use of this system is usually limited to areas irrigated by wells using pumps. With pumps, the necessary pressure head to operate the underground distribution system can be obtained with very little extra power. Some important components of a typical buried pipe system are pump stand, conveying pipe line, riser pipe, delivery valve, outlet platform, air vent, end plug..

Methods of measuring canal water loss

Seepage and percolation losses are the main concern of water loss in irrigation canal. The most common methods that are used for the measurement of loss in the irrigation canals are: a) Ponding method and b) Inflow-outflow method.

Inflow-outflow method

In this experiment, inflow-outflow method was used. Because; ponding method is used to measure seepage and percolation loss in a short selection of small irrigation canals. Water leakage, spillage and piping may be controlled easily. Consequently, inflow-outflow method was employed for this study. The following materials were required for measuring water loss by inflow- out flow method: flume-1, flume-2, meter sale, ruler, spade, paper, pencil etc.

Canal water loss measurement by inflow-outflow method

Canal water loss in between two sections of the canal is the difference between the discharges measured at the head section and the tail section. This method determines the losses under operational condition and estimates reliable figures if the discharge measurements are accurate. Sufficient cares were taken to avoid any side flow (both in and out) between the sections through rat holes, cracks, etc. The conveyance loss was estimated using the following equation:

$$S1 = \frac{(Q1-Q2)}{L}\, x\, 100 \quad (1)$$

S1 = Loss in the canal, l/s/ 100 m
Q1 = Flow rate at section 1, l/s
Q2 = Flow rate at section 2, l/s
L = Distance between section 1 & 2, m

Discharge measurement by using a cut-throat flume

The cut-throat flume is an attempt to improve on the parshall flume, mainly by simplifying the construction details. The flume has a flat bottom, vertical walls and a zero-length throat section. Since it has not throat section (Zero throat length) it was given the name cut-throat by the developers (Skogerboe et al., 1973). Under free flow conditions, critical depth occurs in the vicinity of minimum width (w), which is called the flume throat or the flume neck (Figure 2).When the flow conditions are such that the downstream flow depth, is raised to the extent that the flow depths at every point through the structure become greater than critical depth, resulting in a change in the upstream depth, the flume is operating under submerged flow conditions and requires that two flow depths be measured, one upstream (h_a) and the other downstream (h_b) from the flume neck. The submergence (S), is defined as the ratio of the downstream depth to the upstream depths, often expressed as percentage.

$$S = h_b/h_a \quad (2)$$

The attainment of critical depth it possible to determine the flow rate knowing only an upstream depth (e.g., ha). This is possible because whenever critical depth occurs in thee flume the upstream depth, ha is not affected by changes in the downstream depth, lib. For free flow, the ratio of inlet flow depth h_a to flume length should preferable be less than 0.4. The relationship between flow rate Q and upstream depth of flow h_a in a cutthroat flume under free flow conditions can be written as:

$Q=C_1 h_a^{n_1}$............................... (3)
Where,
Q = flow rate, cusec
C_l = Free flow coefficient

The value of ni was found to be dependent only upon the flow depth, L. Therefore, the value of n_l is constant for all cut-throat flumes of the same length, regardless of the throat width, w. Furthermore, the values of n_1 from the flumes tested plotted as a smooth curve as shown in Fig. 4.

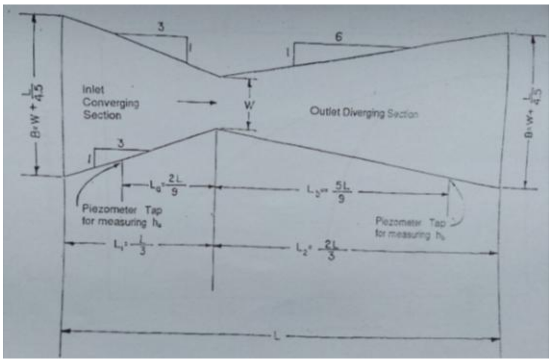

Figure 2: Cutthroat flume

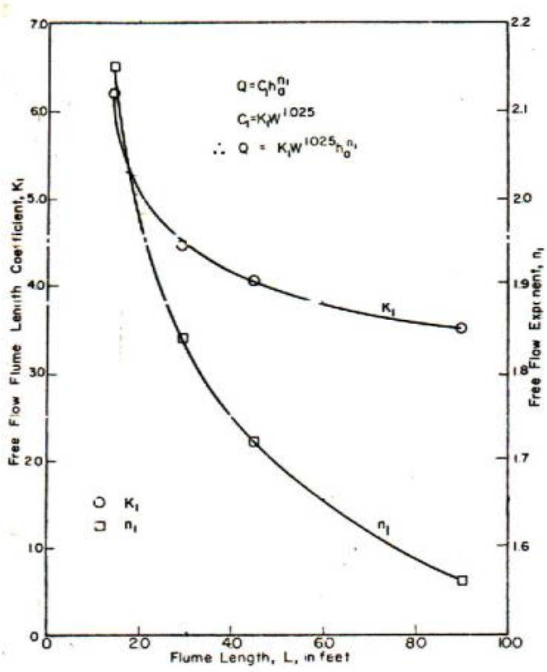

Figure 4: Generalized free flow ratings for cutthroat flumes

The value of the free flow coefficient is a function of the flume length and throat width, W. This relationship is:

$C_1 = K_1 W^{1.025}$.. (4)
Where
C_1= the free flow coefficient
K_1 = the flume length coefficient (Fig.4)
W = the throat width in feet

Pre-cast canal

Seepage and percolation loss of water through pre-cast canal were measured same as earthen canal. The seepage and percolation loss of water through the bottom and sides of the pre-cast section were measured by inflow-outflow method for design canal section.

Buried pipe system

Water losses in the buried pipes as well as the earthen canal originated from the outlets of the selected systems were measured during the Rabi season. Water losses in the buried pipes were determined by both inflow-outflow and ponding methods.

Ponding method

The ponding test was used to measure water loss in buried pipe distribution system.A flap valve was fitted on the discharge pipe. All outlet valves on the pipelinesunder test were closed completely to stop leakages. The header tank and the pipelines were filled with pumped water until overflow occurred through the air-vents(s), when the pump was stopped and the flap valve was closed automatically be back water pressure. After sometimes, when the water level in pump stand stabilized, the drop of water level in the tank with time was recorded. Then the cumulative volume loss was calculated using the following equation:

$V_c = 1000 L \pi (D^2 + nd^2)/4$ .... (5)
Where
V_c = Cumulative volume loss in the pump stand and the air vents, litres
n = No. of air vent on the line under test
D = Internal diameter of pump stand, m
d = Internal diameter of a an air vent, m
L = Cumulative drop of water level in the pump stand, m

In flow-outflow method

Two standard cutthroat flumes of size 91.44 cm x 20.33 cm were set in a Channel (flume l) near the outlet of buried pipe and (flume 2) a distance apart. The flume readings were taken simultaneously when steady flow occurred in the channel. The distance between the two flumes was measured. Then from the known flume discharges and the distance between the losses of water per 100m was calculated using the following relationship.

$CL = \frac{(Q1-Q2)}{L}\ x\ 100$…………………… (6)

Where
CL = Water loss in the channel, l/s/100
Q1 = Discharge in flume l, l/s
Q2 = Discharge in flume 2, l/s
L = Distance between two flumes, m

Methods of measuring command area for shallow tube well

Gross command area was determined by walking through the whole scheme as well as by marking area on the site map which was irrigated and also could be irrigated from the tube well. Utilization of land under the gross command area were also demarcate on the site map. Knowing the plot area with the help of manager and the respective landowner, the gross command area was calculated. The actual command area was obtained in consolation with pump operator, Scheme manager and prominent villagers. This was checked 'by filed visits on the basis of *Mouja* map and block registers, plots under each outlet and crops grown in each plot.

The intended command areas of each STW were taken from the respective managers who collected the same from the DAE, Nalchity, Jhalakati. The intended area was based on 14 1/s pump discharge. The same was also calculated based on actual available discharge. Total irrigated area covered by a pump is called command area of that pump. Command area was calculated by following equation.

Estimated command area (m^2),
CA= $\frac{Total\ discharge\ irrigation\ pump\ per\ day\ (m^3)}{\text{Net irrigation requirement (m)}}$……… (9)

Data collection for seepage and percolation measurement

To calculate the water using the equation (6) discharge Q_1 and discharge Q_2 were measured at a distance L. The upstream flow depth, h_a and down stream flow depth h_b were also measured. The flow depths of water of the canal were recorded by means of a graduated scale. There are some losses of water as evaporation from the surface of the canal. But in the field condition, evaporation is generally neglected in most of the cases. So, in this study, evaporation losses were avoided i.e., these was considered as seepage loss.

Data collection for command area

All meteorological data (evapotranspiration, running time of irrigation pump, crop co-efficient) were collected from Department of Agriculture Extension, Nalchity, Jhalakati.

Determination of water losses of different types of canals

The Conveyance loss of water through improved earthen canal, pre-cast rectangular canal and buried pipe system were measured in Shankorpasha, and Bhairabpasha area near about Nalchity Upazila under Jhalakati District. The conveyance loss of water through improved earthen canal was determined by inflow-outflow method is presented in Table 1.The conveyance loss of water through pre-cast canal was determined by both ponding method and inflow-outflow methods are presented in Table 2.The water loss through buried pipe system was determined by both ponding method and inflow-outflow methods are presented in Table 3.

Table 1: Water loss from pre-cast canal

Obs. No.	Flume No.	h_a (in.)	h_b (in.)	h_a/h_b	Flow cond^n	K_1	n_1	C_1	Q (cusec)	Distance between two sections(m)	Conve-yance loss(l/s/100m)
1	1	6.66	3.60	0.54	Free flow	5.2	1.98	3.431	1.06	40	**5.66**
	2	6.40	3.55	0.55		5.2	1.98	3.431	0.98		
2	1	6.55	3.50	0.53		5.2	1.98	3.431	1.03	35	**4.85**
	2	6.38	3.50	0.54		5.2	1.98	3.431	0.97		
3	1	6.00	3.40	0.56		5.2	1.98	3.431	0.86	35	**4.04**
	2	5.80	3.40	0.58		5.2	1.98	3.431	0.81		

Table 2: Water loss from pre-cast canal

Obs. No.	Flume No.	h_a (in.)	h_b (in.)	h_a/h_b	Flow cond^n	K_1	n_1	C_1	Q (cusec)	Distance between two sections(m)	Conve-yance loss(l/s/100m)
1	1	5.6	3.2	0.57	Free flow	5.2	1.98	3.431	0.70	40	**4.2**
	2	5.4	3.2	0.59		5.2	1.98	3.431	0.64		
2	1	4.9	2.6	0.53		5.2	1.98	3.431	0.58	35	**3.23**
	2	4.8	2.6	0.54		5.2	1.98	3.431	0.54		
3	1	4.7	2.5	0.51		5.2	1.98	3.431	0.53	25	**2.26**
	2	4.6	2.5	0.53		5.2	1.98	3.431	0.51		

Table 3: Water loss from buried

Obs. No.	Length of pipe (m)	Water Level in the pump Stand (m)		Total Volume lost (litre)	Time, t(min.)	Water loss(l/s/100m)
		At the beginning	At the end			
1	200	1.74	0.04	630.55	15	**0.35**
2	200	1.89	0.05	682.48	18	**0.31**
3	200	1.97	0.08	708.44	15	**0.39**

Table 4: Water loss in different canals

Item	Water loss (1/s/100 m)
Improved earthen canal	4.85
Pre-cast canal	3.23
Buried pipe	0.35

Results and Discussion

Irrigation water supplies to the field without losses or even negligible losses at lower initial costs are always preferable from the view point of economic consideration. Proper utilization of canal for the whole year without damage is also an important factor to the farmers of developing countries. Hence, to minimize water losses and to have efficient water distribution system at farm level, the feasibility and suitability of earthen canal, pre-cast canal and buried pipe system were experimented.

Water loss through seepage, percolation and evaporation is a dynamic property of a soil, which depends on soil texture and structure, location of field, weather and climatic condition of the field, depth of plough pan, bulk density, porosity and organic matter content of the soil, depth of water table, topography and vegetative matter on the soil, types of canals, structure of canal and irrigation distribution system. The canal water loss varied at different locations under different conditions. Usually, the water loss was high under earthen canal, moderate in precast canal and low in buried pipe system.

Comparison of water loss in different canals

The canal water loss through the improved earthen canal was found in the range of 4.04 1/s/100 m to 5.66 1/s/100 m (Table l). The average canal water loss through improved earthen canal was found to be 4.85 1/s/100 m (Table 4). This is an agreement with Rashid et al. (1990) who found to be 7 1/s/100 m in the improved (compacted) earth canal in the Manikganj district, Bangladesh. Biswas *et al*. (1984) reported that about 50% of pumped water may be lost using earthen canal system. The canal water loss through the pre-cast canal was found in the range of 2.26 l/s/100 m to 4.2 l/s/100m (Table 2). The average canal water loss through the pre-cast canal was 3.23 1/s/100 m (Table 4) i.e. about 28% of pumped water lost when pre-cast used. The canal water loss though the buried pipe distribution system was found to range in between 0.31 1/s100 m to 0.39 1/s/100 m (Table 3). The average canal water loss through buried pipe distribution system was 0.35 l/s/ 100 m (Table 4) i.e., about 5% of pumped water lost in BPDS. Water from different canal includes seepage, leakage, percolation and evaporation. Sometimes flow over the canal banks (spillage) occurs and was included in the water loss.

Command area under improved earthen canal

Assumed, (Michael, A.M. 1987)

Highest evapotranspiration during Boro season = 4.5 mm/day, Crop coefficient = 1.25, Discharge of pump= 141/s, Running time of irrigation pump = 18hr/day, Field efficiency = 40%, Conveyance efficiency = 50%

$\text{Net irrigation requirement} = \frac{(45 \, x \, 1.25)}{(0.50 \, x \, 0.40)}$ = 28.12 mm = 0.0281 m

$\text{Total discharge of irrigation pump per day} = \frac{14 \, x \, 60 \, x \, 18}{1000}$ = 907.2 m

$\text{Estimated command ara, CA} = \frac{907.2}{0.0281}$ = 32284.6 m^2 = 3.22 hec

Command area under pre-cast canal

Assumed, (Michael, A.M. 1987)
Highest evapotranspiration during Boro season = 4.5 mm/day, Crop coefficient = 1.25, Discharge of pump= 141/s, Running time of irrigation pump = 18hr/day, Field efficiency = 40%, Conveyance efficiency = 72%

$\text{Net irrigation requirement} = \frac{(45 \, x \, 1.25)}{(0.72 \, x \, 0.40)}$ = 19.53 mm = 0.0195 m

$\text{Total discharge of irrigation pump per day} = \frac{14 \, x \, 60 \, x \, 18}{1000}$ = 907.2 m

$\text{Estimated command ara, CA} = \frac{907.2}{0.0195}$ = 46523.07 m^2 = 4.6 hec

Command area under pre-cast canal

Assumed, (Michael, A.M. 1987)
Highest evapotranspiration during Boro season = 4.5 mm/day, Crop coefficient = 1.25, Discharge of pump= 141/s, Running time of irrigation pump = 18hr/day, Field efficiency 40%, Conveyance efficiency = 95%

$\text{Net irrigation requirement} = \frac{(45 \, x \, 1.25)}{(0.95 \, x \, 0.40)}$ = 14.80 mm = 0.0148 m

$\text{Total discharge of irrigation pump per day} = \frac{14 \, x \, 60 \, x \, 18}{1000}$ = 907.2 m

$\text{Estimated command ara, CA} = \frac{907.2}{0.0148}$ = 64340.4 m^2 = 6.13hec

Comparison of command area development in different canals

The cultivable command area of shallow tube well under improved earthen canal, pre-cast canal and buried pip distribution systems were 3.22 hec, 4.6 hec and 6.13hec respectively. It was observed that command area may be increased by saving canal water without any extra costs.

The command area development by pre-cast canal over the improved earthen canal was 43% and buried pipe distribution systems was 187% respectively. The total area covered by canals increased after pre-cast canal and buried pipe distribution system. Irrigation of this extra land reduces the production cost. Information on command area development by different canal is shown in Table 5.

Table 5: Information on command area development by different canals

Item	command area (hec)	Developing command area over improved earthen canal (%)
Improved earthen canal	3.22	
Pre-cast canal	4.60	43%
Buried pipe	6.13	187%

The water loss through the improved earthen canal was average 4.85 1/s/100m whereas through pre-cast canal was found to be average 3.23 Vs/ 100 m which is 23.57% less of that improved earthen canal. Similarly water loss through the buried pipe system found to be average 0.35 l/s/100 m. Buried pipe distribution system can be preferred over open canal where poorly cohesive soils would result in high seepage losses or for variation in ground level irrigable land cannot be reached by an open canal when water is valuable in terms of crops and limitation of water resource.

Conclusion

The water loss in improved earthen canal, pre-cast canal and buried pipe distribution systems were found to be 4.85 l/s/100 m, 3.23 l/s/100 m and 0.35 l/s/100 m respectively. The command area of a shallow tube-well under improved earthen canal, pre-cast canal and buried pipe distribution system were found to be 3.22 ha, 4.6 ha and 6.13 ha respectively.
In this study, the percentage of increased land for pre-cast canal and buried pipe system were 43% and 187% respectively. Thus, command area can be increased by providing pre-cast canal and buried pipe distribution system. However, considering water loss and area coverage buried pipe system should be given emphasis to use for irrigation.

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