# IMPACT ASSESSMENT OF IMPROVED DISTRIBUTION SYSTEM OF SELECTED SHALLOW TUBEWELL IRRIGATION SCHEMES

**MD. ENAMUL HAQUEE**

**DEPARTMENT OF WATER RESOURCES ENGINEERING**

**BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY (BUET)**
**DHAKA-1000, BANGLADESH**

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# IMPACT ASSESSMENT OF IMPROVED DISTRIBUTION SYSTEM OF SELECTED SHALLOW TUBEWELL IRRIGATION SCHEMES.

**A Project Submitted**

**By**

**MD. ENAMUL HAQUEE**

**(Roll No. 100616014F)**

**In partial fulfillment of the requirements for the degree of**
**Master of Engineering in Water Resources**

**DEPARTMENT OF WATER RESOURCES ENGINEERING**

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**Bangladesh University of Engineering & Technology (BUET)**

**Department of Water Resources Engineering**

## CERTIFICATION OF PROJECT

The project work entitled "Impact Assessment of Improved Distribution System of Selected Shallow Tubewell Irrigation Schemes" submitted by Md. Enamul Haquee, Roll No.: 100616014F, Sesson: October, 2006 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Engineering in Water Resources on December 19, 2010.

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|---|---|
| Dr. M. Mirjahan<br>Professor<br>BUET, Dhaka. | Chairman |

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|---|---|
| Dr. Md. Sabbir Mostafa Khan<br>Professor<br>BUET, Dhaka. | Member |

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| | |
|---|---|
| Dr. Md. Ataur Rahman<br>Associate Professor<br>BUET, Dhaka. | Member |

# DECLARATION

It is hereby declared that this project work or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Signature of the candidate | Countersigned

Md. Enamul Haquee

Prof. Dr. M. Mirjahan

(Supervisor)

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# ABSTRACT

A study was conducted to assess the impact of improved distribution systems of six selected shallow tubewell (STW) irrigation schemes in Paikgacha upazila of Khulna district. Three of the shallow tubewell irrigation schemes has compacted earthen canal and the rest has lined canal. The impact of improved distribution system was assessed by comparing the performance of the schemes under pre and post - improvement situations. The indicators used for performance comparison are- duty of water, water use efficiency, overall irrigation efficiency and cost effectiveness of the improvement works.

The pre improvement (2006 - 07) problems of the selected schemes were: more loss of irrigation water, fuel and oil cost or electric bill was high, production cost was more due to higher irrigation cost and more land required to make traditional earthen canal. The distribution system was improved during the month of December, 2007.

For improvement of the system, the bottom of the earthen canal was compacted properly with 8 - 12 cm of earth filling (clay soil) by two steps. A sand layer of 2.5 cm was placed on the canal bottom. Then pre-cast slab was installed in the canal maintaining proper alignment and slope. For compacted earthen canal, a layer of clay with cowdung was put on the bottom and sides of the canal after complete compaction.

The comparative assessment revealed that the duty of water increased by 10% for lined canal distribution system and 7% for compacted earthen canal distribution system with respect to traditional earthen canal distribution system. Water use efficiency increased by 14% for lined canal distribution system and 10% for compacted earthen canal distribution system compare to traditional earthen canal distribution system.

The average overall irrigation efficiency under pre and post improvement situations for the selected lined canal distribution system were 29% and 33%, respectively. It was increased by 4% with respect to traditional earthen canal distribution system. The

average overall irrigation efficiency under pre and post improvement situations for the selected compacted earthen canal distribution system were 29% and 32%, respectively and it was increased by 3% compare to traditional earthen canal distribution system.

The benefit - cost ratio of the pump owners increased by 6% for lined canal distribution system and 10% for compacted earthen canal distribution system with respect to traditional earthen canal distribution system. The average value of benefit - cost ratio for lined canal under post improvement situation 1.28 was found to be less than the value for compacted earthen canal 1.40. This is due to higher initial cost of the lined canal system compare to compacted earthen canal system. The improvement of the system does not have any impact on the profitability of the farmers. This is because the farmers pay the same rate of irrigation charge both before and after the improvement of the systems.

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**ABBREVIATIONS**

| | |
|---|---|
| AETEP | Agricultural Engineering Technologies Project |
| ASIRP | Agricultural Services Innovation and Reform Project |
| BARC | Bangladesh Agricultural Research Council |
| BARI | Bangladesh Agricultural Research Institute |
| BAU | Bangladesh Agricultural University |
| BCR | Benefit Cost Ratio |
| BRRI | Bangladesh Rice Research Institute |
| BUET | Bangladesh University of Engineering and technology |
| DAE | Department of Agricultural Extension |
| DFID | Department for International Development |
| DTW | Deep Tubewell |

| | |
|---|---|
| Ei | Overall Irrigation Efficiency |
| ET | Evapotranspiration |
| $ET_0$ | Reference Evapotranspiration |
| FAO | Food and Agricultural Organization |
| GOB | Government of Banagladesh |
| IDA | International Donor Agency |
| Irr. | Irrigation |
| Kc | Crop coefficient |
| MOA | Ministry of Agriculture |
| MPO | Master Plan Organization |
| R & M | Repair and Maintenance |
| STW | Shallow Tubewell |
| UNDP | United Nations Development Programme |
| WUE | Water Use Efficiency |

Chapter 1

# INTRODUCTION

## 1.1 Background

Irrigation plays a vital role for food security in Bangladesh. Total land area in Bangladesh is about 14.6 Mha. At present, the net cultivated area is about 8.1 Mha and about 1% of agricultural land is going out of production every year due to other uses including infrastructure development. With the available water of the country, about 76% of the cultivable area can be irrigated of which about 63% are presently under irrigation. Due to fluctuation in availability and lack of control over surface water about 79% of the irrigated area use groundwater (Ghani, 2010). By 2009, Bangladesh has created facilities for 5.13 Mha of irrigated area. Total number of shallow tubewells used for irrigation during 2008-09 is about 13,74548 which cover 3.25 Mha. In 2009, shallow tubewells were operated at about 43% of their rated capacity and irrigated about 2.36 ha per unit against potential of 5 to 6 ha (MOA, 2009).

Increased crop production and sustainable agricultural development depend on the efficient utilization of irrigation water. Due to very limited availability of rain water during dry season (November - April) the Boro rice is fully dependent on irrigation. Therefore, the expanding demand for food grains in the country will most likely be met from expansion of irrigated area with the available water resources.

In Bangladesh, rice is the largest irrigation user with over 82% of the total irrigated area. All modern variety (MV) Boro is irrigated, whereas only a small proportion of the Aus and other crops (7% and 5%, respectively) receive either full or supplemental irrigation. MV Boro cropping has been the driving force behind minor irrigation expansion (BADC, 2005). The irrigated single-crop Boro could reach about 4 Mha (WARPO, 2000).

Proper water distribution system and its efficient management play a very important role in the command area development of any irrigation project. In Bangladesh, earthen canal water distribution is commonly used especially in minor irrigation sectors. These existing earthen canal water distributions suffer from a number of problems such as low conveyance efficiency, less area covered and high maintenance cost. About 2 to 4 percent of the cultivable land is taken up by the open channel distribution system (Michael, 1987).

Recently, much concern has been expressed about improving the performance of existing irrigation system, as many have lower efficiencies and crop yields from their potential. Planners, administrators and donor agencies seem to be shifting attention from building new irrigation systems to improving the performance of the existing systems. To realize this goal, there is a need to develop and implement practical methodologies to upgrade the performance of the system and enable farmers to achieve higher benefits from the use of irrigation water. Therefore, attempt should be made to utilize this costly resource with minimum waste.

Irrigation water is a scarce and costly resource among all agricultural inputs. The cost of irrigation water is increasing day by day with the increase demand of irrigation water. Irrigation water is also a critical factor to make crop production a success in Bangladesh. As a result, one drop of water is being considered as a valuable national resource. When it is limited, every drop of water should be utilized properly for optimum and economic yield. Irrigation as an input is also important because the productivity of other inputs such as seed and fertilizer depends on the availability of water supply to the crop fields. Therefore, it is essential that the production of rice can be increased substantially by using irrigation with proper distribution system to meet the requirements of the growing population.

Due to increasing costs of constructing new irrigation systems, developing countries like Bangladesh should direct her attention to the possibilities of improving the performances of existing irrigation system through modern technology and management. Therefore, performance improvement of existing irrigation systems can be one of the ways of making the systems cost effective.

The Department of Agricultural Extension (DAE) undertook a pilot project entitled "Agricultural Services Innovation and Reform Project (ASIRP)" and it was started in 1999 and ended in 2004. The main objective of the project was to reduce the loss of irrigation water at the field level through improved distribution system and for this some field demonstration (compacted earthen canal) was implemented. A GOB/IDA/DFID/FAO review mission carried out an implementation review of the project (ASIRP) and recommended that with the adoption of on - farm water management technologies, irrigation coverage could be increased by 29% and cost of irrigation could be reduced by 25% and for this reason a country wide programme is necessary. The Department of Agricultural Extension (DAE) undertook again a pilot project entitled "Enhancement of Agricultural Production and Rural Employment through Extension of Agricultural Engineering Technologies Project (AETEP)" in 2005. This project aims to implement improved water distribution systems for 2240 shallow tubewell schemes under112 upazilas. The present study has been undertaken to assess the impact of improved distribution system like lined canal and compacted earthen canal on the performance of six such selected shallow tubewell irrigation schemes in Paikgacha upazila under Khulna district.

## 1.2 Objectives

The objectives of the present study are:

- To assess the impact of improved distribution system on the performance of the selected shallow tubewell irrigation schemes.
- To determine the cost effectiveness of the improvement works.

Chapter 2

# IMPROVED DISTRIBUTION SYSTEMS FOR MINOR IRRIGATION

Mahmud and kabir (2006) conducted a study on performance of shallow tubewell (STW) irrigation units in Fulpur Upazila of Mymensingh District and found that water use efficiency (WUE) of 3 STW units varied from 0.471 to 0.612 (kg/$m^3$). They also found that the values of duty varied from 0.239 to 0.314 (ha/lps) with an average value of 0.279 (ha/lps).

Sarker (2002) carried out a field study during 1999 - 2000 irrigation season on on-farm water management for increasing water use efficiency of Boro rice for STWs and found that the average conveyance losses were found to be 5.67 lps, 3.80 lps and 0.28 lps per 100m for existing earthen channel, improved earthen channel and hose pipe irrigation systems, respectively. The average water saved in comparison to existing earthen channel was 32% for improved earthen channel and 95% for hose pipe. Average time saved in comparison to existing earthen channel was 27% for improved earthen canal and 48% for hose pipe. The average cost of construction per 100m for existing earthen canal, improved earthen canal and hose pipe were found to be Tk. 1150.00, Tk. 5000.00 and Tk. 4200.00, respectively.

Mondal (2000) conducted the performance evaluation of 10 STWs of Rajbari district using some selected standard indicators such as hydraulic, agricultural and socio-economic indicators. The results of the analysis showed that delivery performance ratio of STW are 1.21. No relation was found between pump discharge and command area. But a good correlation was found to exist between pump discharge and command area. The average discharge of STW is 17 l/sec which was greater than the respective national average discharge of 12 l/sec. In the unlined portion of the STW canal, the average conveyance loss was 4.1 mm/day. Agricultural performances, evaluated in terms of irrigated area performance (0.76), yield performance (1.16) and production performance (0.87) were greater than the national averages.

BRRI (1999) reported that irrigation coverage increased about 42 percent after introducing the PVC and plastic pipe distribution system in a Deep Tubewell (DTW) scheme. BRRI (1998) reported that about 95% conveyance loss could be reduced by using PVC and flexible plastic pipe. It also reported that irrigation timing was reduced by about 50% in comparison with earthen channel irrigation systems at Rajshahi and Chuadanga.

Rahman and Desai (1997) carried out a study on on-farm water management in summer rice. Application of 5 cm of irrigation water to rice field one day after standing water disappeared was compared with farmers' water management practices. In the experimental treatment averaged over 3 years, 29 percent of the irrigation water could be saved with about 55 percent higher yield per unit of water applied.

Rashid and Mridha (1997) conducted a study to assess the impact of improved systems and practices at farmers' level in terms of irrigated area (duty), conveyance losses, water use efficiency and operating cost in 1989-90 and 1990-91 irrigation seasons. Due to improvment of the schemes, the area irrigated with per unit of pump discharge increased by 53-88% in 1989-90 and 21-23% in 1990-91 irrigation seasons over bench mark study in 1988-89 irrigation season. Water use efficiency increased by 7-19% in 1989-90 and 5-9% in 1990-91 irrigation seasons. The operating cost reduced by 9-21% in 1989-90 and 4-18% in 1990-91 irrigation seasons.

Rashid *et al.* (1996) conducted another study on different schemes in Rangpur, Jessore and Manikgonj area to determine the water use efficiency at farm level. Three deep tubewells (DTWs), three shallow tubewells (STWs) and three low lift pumps (LLPs) were selected for the study in each of 3 selected districts. The water use efficiency for rice was 88, 88 and 87 percent under STW, DTW and LLP, respectively. The average irrigation coverages were 20.9 ha, 4.2 ha and 11.9 ha, under STW, DTW and LLP respectively.

Biswas and Mondal (1993) observed in a study that the average duty of STW schemes in four areas in Bangladesh was 0.372 ha/lps. They also concluded that the overall conveyance efficiency of STW projects was less than 70 percent and the efficiency of STWs was greater than that of DTWs.

Hassan *et al*. (1992) conducted a study on two selected tubewells of North Bangladesh Tubewell Project. It was found that water losses in the main lined canals were 91 and 52 lit/hr/$m^2$ before repairing of the canals while the corresponding figures were 43 and 7 lit/hr/$m^2$ after repairing of the canals. Similarly, water losses in the earthen canals were 105 and 208 lit/hr/$m^2$ which were 8% and 9% of the outlet discharges.

Dutta and Mondal (1989) evaluated the performance of two STW schemes in Manikgonj district managed by Proshika Landless Group based on data of 1985 irrigation season. The investigation traced out three ways of capacity under utilization of Landless Group controlled irrigation equipment: the actual pump discharge was well below the rated discharge, the command area with respect to existing pump discharge was trailing behind the potential value and the average operating hour per day.

Sattar *et al*. (1988) indicated that average duty of water was 0.21 ha per liter per second in the North Bangladesh tubewell project. He also showed that the mean water losses in the lined main canal and in earthen field canal were 91 lit/ha/$m^2$ and 138 lit/ha/$m^2$, respectively. The total distribution loss (both lined and earthen canal) through the conveyance system was about 40% of the tubewell discharge.

Haque *et al*. (1987) conducted an evaluation of the impact of the improvement of canals and cultural practices in the areas under 3 DTW schemes. Channels were improved through compaction. This improvement was performed in a limited channel section at one scheme only. It was found that the conveyance losses were reduced by 3 to 6 percent. The command area of the scheme increased in the first year but decreased in the following year mainly due to irregularities of power supply.

Hossain *et al.* (1987) conducted an impact evaluation of improved canal systems, use of rotational water distribution and improved cultural practices in the areas of four deep tubewells. In each of the schemes only 100m of the canal was improved by compaction. As a result conveyance losses were reduced by 2 to 15%.

Dutta (1985) carried out a study on on-farm water management of 100 minor irrigation projects in Ghatail-Kalihati and Gazipur-Pubali areas. He reported that water losses in the shallow tubewell, deep tubewell and low lift pump irrigation projects were as high as 21, 17 and 21 percent of the pumped discharge per 100m length of the canal.

Mia (1979) conducted a study on 19 deep tubewells to quantify the water loss in distribution system and to assess the share of water loss and other engineering factors to the poor acreage. It was found that the losses in the main distribution canal ranged from about 30 to 87% with an average value of about 58%. The causes of such a huge amount of water loss were high seepage rate, inefficient canal section, poor level of maintenance of distribution canals, absence of control structures and lack of proper irrigation schedule.

Chapter 3

# DESCRIPTION OF THE STUDY SCHEMES

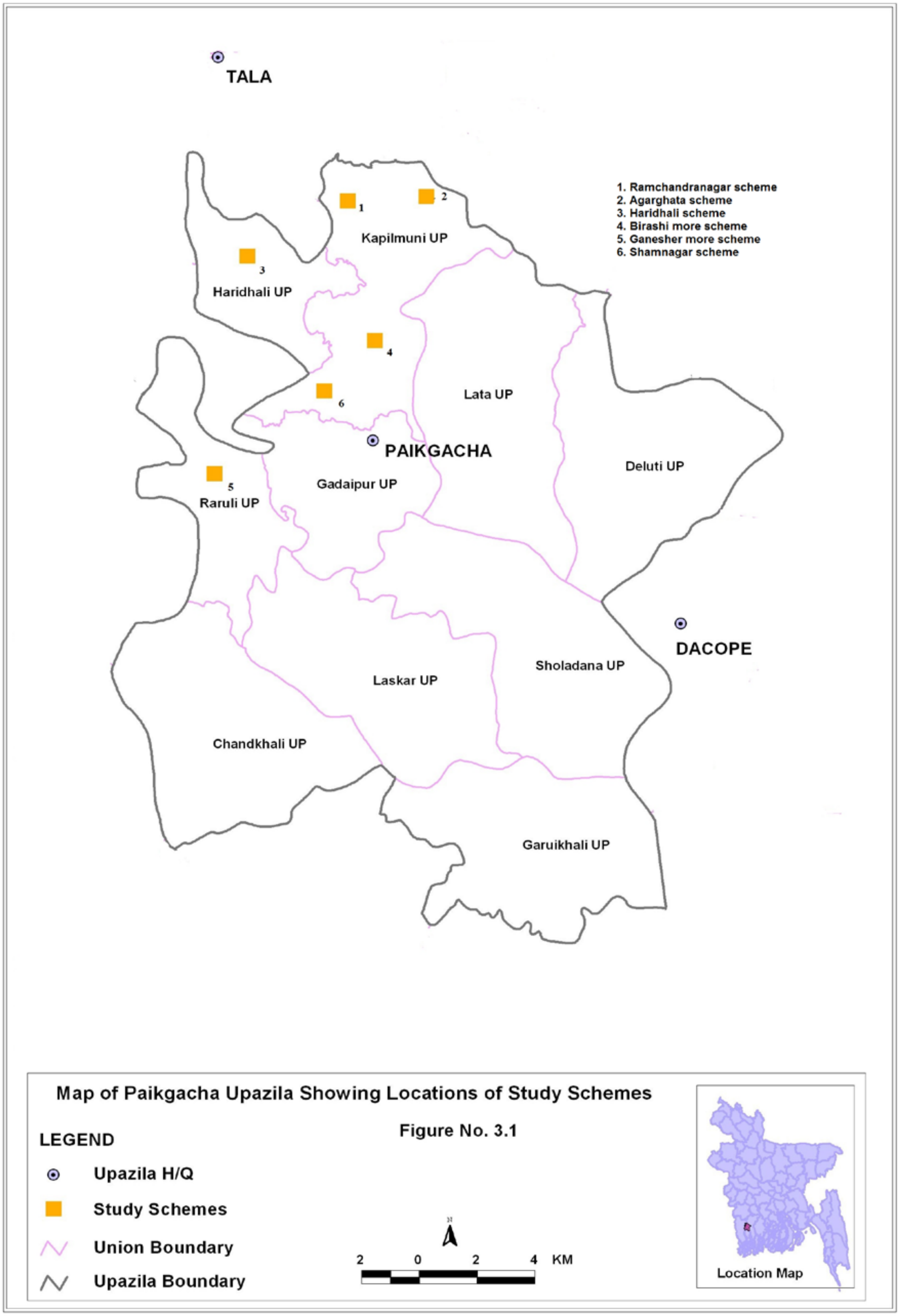
## 3.1 Location of the study area

The study was conducted during the growing season of Boro rice in Paikgacha upazila under Khulna distict. The study area having an area of 82 $km^2$ which includes three unions namely Haridhali, Kapilmuni and Raruli. There are about 2950 shallow tubewells in the upazila of which 12 shallow tubewells has lined canal and 30 shallow tubewells has compacted earthen canal. Six irrigation schemes - three with lined canal and three with compacted earthen canal were selected for the study. The name of the study schemes are- Ramchandranagar, Agarghata, Haridhali, Birashi More, Ganesher More and Shamnagar. The locations of the study schemes are shown in fig. 3.1. The criteria for selection of study schemes were- i) availability of data for the pre and post improvement situation ii) accessibility and iii) farmers co-operation.

## 3.2 Climate

The study area experiences a tropical monsoon climate with three distinct seasons i.e., summer (March to May), Monsoon (June to October) and winter (November to February). In summer, the mean maximum temperature is above $35^0$C whereas in winter the mean minimum temperature is below $12^0$C. The mean annual rainfall is about 1600 mm and about 80% of the rainfall occurs during the monsoon season. The relative humidity varies from 70 % to 85 %.

The soil of the study area is predominantly clay to clay loam and land is medium high. Various cropping systems are adopted by the local farmers. The main cropping pattern is Aman, Boro and Aus. Cropping intensity of the Paikgacha upazila is 189%.


TALA
1. Ramchandranagar scheme
2. Agarghata scheme
3. Haridhali scheme
4. Birashi more scheme
5. Ganesher more scheme
6. Shamnagar scheme
Kapilmuni UP
Haridhali UP
Lata UP
PAIKGACHA
Deluti UP
Gadaipur UP
Raruli UP
DACOPE
Sholadana UP
Laskar UP
Chandkhali UP
Garuikhali UP
Map of Paikgacha Upazila Showing Locations of Study Schemes
Figure No. 3.1
LEGEND
Upazila H/Q
Study Schemes
Union Boundary
Upazila Boundary
2 0 2 4 KM
Location Map

### 3.3 Descriptions of the selected schemes

#### 1) Ramchandranagar Scheme

The Ramchandranagar Scheme is located in Kapilmuni union of Paikgacha upazila. The design command area is 5.05 ha. Land is medium high and soil is clay. The scheme is managed by the pump owner. The basic information on the shallow tubewell is given in table 3.1.

Table 3.1: Basic information related to STW units

| Name of the schemes | Tube well dia (inch) | Tube well depth, ft. | Screen length, ft. | Design dis. (l/sec) |
|---|---|---|---|---|
| Ramchandranagar Scheme | 4.00 | 185 | 60 | 28.00 |
| Agarghata Scheme | 3.00 | 165 | 40 | 28.00 |
| Haridhali Scheme | 3.00 | 160 | 40 | 28.00 |
| Birashi More Scheme | 3.00 | 160 | 40 | 28.00 |
| Ganesher More Scheme | 3.00 | 160 | 40 | 28.00 |
| Shamnagar Scheme | 3.00 | 165 | 40 | 28.00 |

After harvesting, the pump owner collected the irrigation charge as one-fourth of the total crop. Year of installation of shallow tubewell was 1984 and since then traditional earthen canal distribution system was used upto 2006 - 07 irrigation season. The pump is run by diesel engine. In 2007 - 08 irrigation season, distribution system of the scheme was improved.

For improvement of the system, bottom of the earthen canal was compacted properly with 8 – 12 cm of earth filling (clay soil) by two steps. Then a sand layer of 2.5 cm was given on the canal bottom. Before setting the slab in the canal, alignment as well as slope was maintained properly. Bottom of the canal was higher than the side land. The size of the pre-cast side slab was 60cm × 18cm × 4 cm whereas for bottom slab the size was 60cm × 28cm × 5cm. Standard type cement, medium size sand and 0.25 inch size khoa were used for making pre-cast slab. The ratio used for making cement concrete was 1:2:4. The slab was kept two weeks for curing. The cement mortar of ratio 1: 4 (cement: sand) was used for joining the slabs. The canal was rectangular in shape. The length of the canal improved was 200m of the total canal length 350m. So the distribution system improved was 57% of the total irrigation canal. There are 12 outlets and 5 checks in the canal which are made of CC block and wood. A typical cross section of a rectangular lined canal is shown in fig. 3.2. A photograph of lined canal in Ramchandranagar scheme is shown in fig. 3.3.

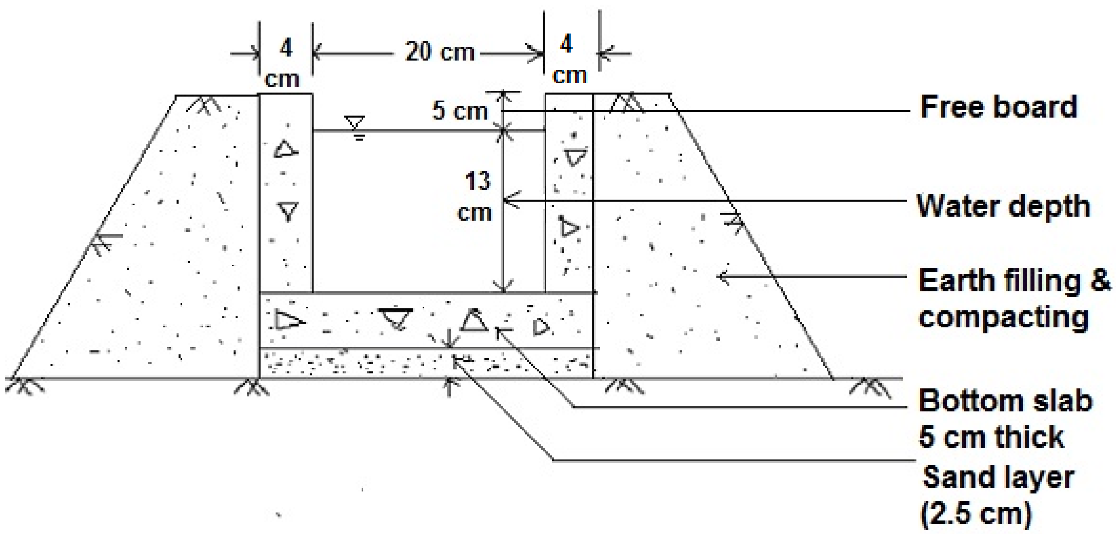



Fig 3.2: Typical cross section of a rectangular lined canal

Fig. 3.3: Lined Canal in Ramchandranagar Scheme

**2) Agarghata Scheme**

The Agarghata Scheme is situated in Kapilmuni union of Paikgacha upazila. The design command area is 4.10 ha. Land is medium high and soil is clay loam. The scheme is managed by the pump owner. The basic information on the shallow tubewell is given in table 3.1. After harvesting, the pump owner collected the irrigation charge as one-fourth of the total crop. Year of installation of shallow tubewell was 1983 and since then traditional earthen canal distribution system was used upto 2006 - 07 irrigation season. The pump is run by diesel engine. In 2007 - 08 irrigation season, distribution system of the scheme was improved.

For improvement of the system, bottom of the earthen canal was compacted properly with 8 – 12 cm of earth filling (clay soil) by two steps. Then a sand layer of 2.5 cm was given on the canal bottom. Before setting the slab in the canal, alignment as well as slope was maintained properly. Bottom of the canal was higher than the side land. The size of the side slab was 60cm × 18cm × 4 cm whereas for bottom slab the size was 60cm × 28cm × 5cm. Standard type cement, medium size sand and 0.25 inch size khoa were used for making precast slab. The ratio used for making cement concrete was 1:2:4. The slab was kept two weeks for curing. The cement mortar of ratio 1: 4 (cement: sand) was used for joining the slabs. The canal was rectangular in shape. The length of the canal improved was 200m of the total canal length 310m. So the distribution system improved was 65% of the total irrigation canal. There are 16 outlets and 7 checks in the canal which are made of CC block and wood. A typical cross section of a rectangular lined canal is shown in fig. 3.2. A photograph of lined canal in Agarghata scheme is shown in fig. 3.4.

Fig. 3.4: Lined Canal in Agarghata Scheme

**3) Haridhali Scheme**

The Haridhali scheme is located in Haridhali union of Paikgacha upazila. The design command area is 4.35 ha. Land is medium high and soil is clay loam. The scheme is managed by the pump owner. The basic information on the shallow tubewell is given in table 3.1. After harvesting, the pump owner collected the irrigation charge as one-fourth of the total crop. Year of installation of shallow tubewell was 2005 and since then traditional earthen canal distribution system was used upto 2006 - 07 irrigation season. The pump is run by diesel engine. In 2007 - 08 irrigation season, distribution system of the scheme was improved.

For improvement of the system, bottom of the earthen canal was compacted properly with 8 – 12 cm of earth filling (clay soil) by two steps. Then a sand layer of 2.5 cm was given on the canal bottom. Before setting the slab in the canal, alignment as well as slope was maintained properly. Bottom of the canal was higher than the side land. The size of the side slab was 60cm × 18cm × 4 cm whereas for bottom slab the size was 60cm × 28cm × 5cm. Standard type cement, medium size sand and 0.25 inch size khoa were used for making precast slab. The ratio used for making cement concrete was 1:2:4. The slab was kept two weeks for curing. The cement mortar of ratio 1: 4 (cement: sand) was used for joining the slabs. The canal was rectangular in shape. The length of the canal improved was 200m of the total canal length 320m. So the distribution system improved was 63% of the total irrigation canal. There are 13 outlets and 6 checks in the canal which are made of CC block and wood. A typical cross section of a rectangular lined canal is shown in fig. 3.2. A photograph of lined canal in Haridhali scheme is shown in fig. 3.5.

Fig. 3.5: Lined Canal in Haridhali Scheme

**4) Birashi More Scheme**

The Birashi More Scheme is situated in Kapilmuni union of Paikgacha upazila. The design command area is 4.30 ha. Land is medium high and soil is clay. The scheme is managed by the pump owner. The basic information on the shallow tubewell is given in table 3.1. After harvesting, the pump owner collected the irrigation charge as one-fourth of the total crop. Year of installation of shallow tubewell was 2005 and since then traditional earthen canal distribution system was used upto 2006 - 07 irrigation season. The pump is run by diesel engine. In 2007 - 08 irrigation season, distribution system of the scheme was improved.

For improvement of the system, bottom of the earthen canal was compacted properly with 8 – 12 cm of earth filling (clay soil) by two steps. The sides of the canal were also compacted and the side slope was maintained as 1:1. Finally a layer of clay with cowdung was placed on the bottom and sides of the canal. Bottom of the canal was higher than the side land. The canal was trapezoidal in shape. The length of the canal improved was 400m of the total canal length 425m. So the distribution system improved was 94% of the total irrigation canal. There are 26 outlets and 14 checks in the canal which are made of wood. A typical cross section of a trapezoidal compacted earthen canal is shown in fig. 3.6. A photograph of compacted earthen canal in Birashi More scheme is shown in fig. 3.9.

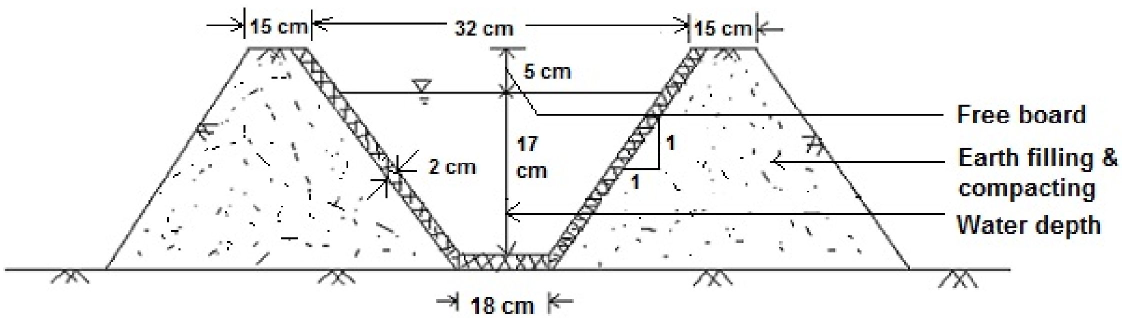



Fig 3.6: Typical cross section of a trapezoidal compacted earthen canal

Fig. 3.7: Improved Earthen Canal in Birashi More Scheme

**5) Ganesher More Scheme**

The Ganesher More Scheme is located in Raruli union of Paikgacha upazila. The design command area is 3.95 ha. Land is medium high and soil is clay. The scheme is managed by the pump owner. The basic information on the shallow tubewell is given in table 3.1. After harvesting, the pump owner collected the irrigation charge as one-fourth of the total crop. Year of installation of shallow tubewell was 2004 and traditional earthen canal distribution system was used upto 2006 - 07 irrigation season. The pump is run by electric motor. In 2007 - 08 irrigation season, distribution system of the scheme was improved.

For improvement of the system, bottom of the earthen canal was compacted properly with 8 – 12 cm of earth filling (clay soil) by two steps. The sides of the canal were also compacted and the side slope was maintained as 1:1. Finally a layer of clay with cowdung was placed on the bottom and sides of the canal. Bottom of the canal was higher than the side land. The canal was trapezoidal in shape. The length of the canal improved was 400m of the total canal length 410m. So the distribution system improved was 98% of the total irrigation canal. There are 22 outlets and 12 checks in the canal which are made of wood. A typical cross section of a trapezoidal compacted earthen canal is shown in fig. 3.6. A photograph of compacted earthen canal in Ganesher More scheme is also shown in fig. 3.8.

Fig. 3.8 Compacted Earthen Canal in Ganesher More Scheme

**6) Shamnagar Scheme**

The Shamnagar Scheme is situated in Kapilmuni union of Paikgacha upazila. The design command area is 4.00 ha. Land is medium high and soil is clay. The scheme is managed by the pump owner. The basic information on the shallow tubewell is given in table 3.1. After harvesting, the pump owner collected the irrigation charge as one-fourth of the total crop. Year of installation of shallow tubewell was 1995 and traditional earthen canal distribution system was used upto 2006 - 07 irrigation season. The pump is run by electric motor. In 2007 - 08 irrigation season, distribution system of the scheme was improved.

For improvement of the system, bottom of the earthen canal was compacted properly with 8 – 12 cm of earth filling (clay soil) by two steps. The sides of the canal were also compacted and the side slope was maintained as 1:1. Finally a layer of clay with cowdung was placed on the bottom and sides of the canal. Bottom of the canal was higher than the side land. The canal was trapezoidal in shape. The length of the canal improved was 400m of the total canal length 420m. So the distribution system improved was 95% of the total irrigation canal. There are 32 outlets and 17 checks in the canal which are made of wood. A typical cross section of a trapezoidal compacted earthen canal is shown in fig. 3.6. A photograph of compacted earthen canal in Shamnagar scheme is shown in fig. 3.9.

Fig. 3.9: Improved Earthen Canal in Shamnagar Scheme

Chapter 4

# DATA COLLECTION AND ANALYSIS

The data that were collected during the field study include: actual pump discharge, daily pump operating hours, actual area irrigated and climatic parameters. In order to collect data under "pre and post" project situations, the similar ecological and socio-economic conditions were assumed. Data on cost of production, yield, price of output etc. were collected from the pump owners during the field study.

## 4.1 Data collection

**Discharge measurement:**

Actual pump discharge of each scheme was measured by volumetric method. By storing the water in the pump house in a given time, the volume of water was measured from the multiplication of length, width and height of the pump house. The actual time was recorded from the time of pump starting to fill up the pump house. The volume of water thus obtained was divided by the actual time to obtain discharge of the pump. The discharge was measured three times during beginning, middle and end of the season and the average discharge was taken for the study.

**Seasonal operating hours:**

Daily operating hours of pump are important data for determining duty of water. Data of daily operating hours were collected from the record of the pump manager. Seasonal operating hours were calculated from the daily operating hours and the operating days of the pump.

**Production cost:**

The crop production costs - seed, manure and fertilizer cost, insecticide and pesticide cost, rent of power tiller and labor costs (including family labor) were collected from the local farmers of the study area. Yield data were collected from five selected farmers under each of the schemes. Then the average yield (ton/ha) was taken for the study. To compare with the farmers collected crop yield data, it was also collected from the Sub Assistant Agriculture Officer (SAAO) who is responsible for the respective block/union. The SAAO obtained average yield (kg/$m^2$) from the crop – cut samples. A crop area of 4m × 5m in a plot was cut and it was taken at three locations in the same plot. Then the average yield was obtained. The price of crop and straw was collected from the local farmers under the scheme and the local markets. The irrigation charge was one – fourth of the total crop. The initial cost of the shallow tubewell, lined canal and improved earthen canal was collected from the pump owners. The variable cost such as fuel and oil cost or electric bill, repair and maintenance cost and operator's wage were also collected from the pump owners.

**Climatic data:**

The climatic parameters- maximum and minimum temperatures, relative humidity, sunshine hours, wind speed, rainfall were collected from the nearest meteorological station, Khulna for the study period (December to March) in the years of 2007, 2008 and 2009 as shown in table 4.1.

Table 4.1: Mean monthly maximum and minimum temperatures, relative humidity, sunshine hours, wind speed and rainfall of the meteorological station, Khulna:

| Type of data | 2006 | 2007 | | | | 2008 | | | | 2009 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dec | Jan. | Feb. | Mar | Dec | Jan. | Feb. | Mar | Dec | Jan. | Feb. | Mar |
| Max. Tem. ($^0$C) | 25.7 | 24.9 | 27.6 | 30.2 | 26.1 | 25.1 | 26.8 | 32.3 | 26.2 | 26.2 | 29.8 | 33.2 |
| Min. Tem. ($^0$C) | 14.4 | 12.3 | 16.9 | 19.2 | 16.4 | 13.8 | 15.3 | 22.4 | 14.2 | 15.2 | 16.9 | 21.1 |
| Relative humidity,% | 81 | 77 | 78 | 71 | 85 | 80 | 74 | 77 | 79 | 82 | 74 | 72 |
| Wind speed, m/s | 1.11 | 2.50 | 3.06 | 3.06 | 1.67 | 1.67 | 1.94 | 1.67 | 1.94 | 1.94 | 2.22 | 2.50 |
| Sunshine hours | 5.6 | 5.2 | 6.1 | 8.5 | 5.1 | 5.9 | 7.3 | 6.7 | 6.8 | 6.5 | 8.8 | 7.7 |
| Rainfall, mm | 00 | 00 | 54 | 37 | 00 | 67 | 36 | 48 | 00 | 11 | 06 | 20 |

## 4.2 Data analysis

**Performance Indicators:**

The indicators used for performance evaluation are: Duty of water (D), water use efficiency (WUE), overall irrigation efficiency (Ei), and benefit-cost ratio. The indicators are described below:

### 4.2.1 Duty of water (D):

It is the relationship between the volume of water and the area of the crop it matures. Duty is generally expressed in hectares per cubic meter per second. The area irrigated (ha) was divided by the discharge of the pump. Then the value was converted for the whole day by multiplying 24 hours and dividing by average seasonal operating hours (10 hrs) in a day. The duty of water for each scheme for each year of the study period was determined from actual irrigated area, pump discharge and average operating hours. The detail calculation of duty of water is shown in table 5.1.

### 4.2.2 Water Use Efficiency (WUE):

It is the ratio of yield of the crop to the total amount of water supplied to the field. The volume of water ($m^3$) lifted was determined by the multiplication of seasonal operating hours and the average discharge ($m^3$/sec) of the pump. Total production was obtained by the multiplication of area irrigated (ha) and the average yield (kg/ha) of the crop. The water use efficiency (kg/$m^3$) was thus obtained by dividing the volume of water ($m^3$) lifted to the yield (kg) of the scheme. The detail calculation of water use efficiency of schemes during the study is shown in tables 5.2 - 5.4.

### 4.2.3 Overall Irrigation Efficiency (Ei):

Seasonal overall irrigation efficiency can be defined as the ratio of the amount of water required for the crop to the total amount of water supplied. The amount of water supplied includes irrigation water as well as rain water. (Meriam and Keller, 1978; Merriam *et. al*., 1983 and Perry, 1996):

$$Ei = \frac{\text{Evapotranspiration}}{\text{Irrigation + Effective Rainfall}}$$

Evapotranspiration is the combination of soil evaporation and crop transpiration. Weather parameters, crop characteristics, management and environmental aspects affect evapotranspiration. The evapotranspiration rate from a reference surface is called the reference evapotranspiration and is denoted as ETo. A short uniform grass (or alfalfa) field is considered worldwide as the reference surface. The reference grass crop completely covers the soil, is kept short, well watered and is actively growing under optimal agronomic conditions.

ETo values measured or calculated at different locations or in different seasons are comparable as they refer to the evapotranspiration from the same reference surface. The only factors affecting ETo are climatic parameters. Consequently, ETo is a climatic parameter and can be computed from weather data. ETo expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors (Allen *et al.*, 1998).

Owing to the difficulty of obtaining accurate field measurements, ETo is commonly computed from weather data. A large number of empirical or semi-empirical equations have been developed for assessing reference evapotranspiration from meteorological data. Numerous researchers have analysed the performance of the various calculation methods for different locations. As a result of an Expert Consultation held in May 1990, the FAO Penman-Monteith method is now recommended as the standard method for the definition and computation of the reference evapotranspiration ETo.

Evapotranspiration of Boro rice ($ET_c$) was obtained from multiplication of Kc values and ETo. The Kc values were taken as 1.1, 1.1, 1.25 and 1.0 during the study period December to March (Doorenbos & Pruitt). ETo was calculated by using the software FAO ETo Calculator (FAO, 2009). Monthly maximum and minimum temperatures, relative humidity, wind speed and sunshine hours collected from Meteorological station, Khulna were used to calculate $ET_0$ (mm/day). The values of $ET_0$ are given in table 4.2.

Table 4.2: The output values of $ET_0$

| Ir. season \ Month | December | January | February | March |
|---|---|---|---|---|
| 2006 - 07 | 2.2 | 2.6 | 3.8 | 4.7 |
| 2007 - 08 | 2.2 | 2.7 | 4.0 | 4.8 |
| 2008 - 09 | 2.2 | 2.7 | 3.9 | 4.9 |

Depth of irrigation water (mm) was determined by dividing the area irrigated of the scheme to the volume of water ($m^3$) lifted for that scheme. The total rainfall of the study area during the Boro season was assumed effective rainfall. In 2007 - 08 irrigation season, 70% of the total rainfall has been assumed effective.

### 4.3 Economic analysis

An economic analysis was conducted to determine the cost effectiveness of the works implemented in each scheme. For this, the profitability of the pump owners under post improvement condition was compared with that of pre improvement condition.

#### 4.3.1 Profitability of the pump owners

$$\text{Profitability of the pump owners} = \frac{\text{Total irrigation charges collected}}{\text{Total annual cost of the scheme}}$$

**Benefit**

The benefit of the pump owners was the total irrigation charges (one - fourth of crop cut) collected from the farmers under the scheme. The benefit of the pump owners in the years of 2007, 2008 and 2009 are given in the table 5.9.

**Cost**

The annual cost of both compacted earthen canal and lined canal distribution system includes fixed cost (depreciation and interest on investment both for STW and distribution system) and variable cost (fuel & oil cost or electric bill, repair & maintenance cost and operators' wage). The depreciation was calculated using the following equation (Michael, 1981):

$$D = (P - S)/L$$

Where, D = Depreciation, Tk. /year

P = Initial cost, Tk.

S = Salvage value, Tk.

L = Useful life, year

The salvage value is considered 10% of the initial cost for STW and nil for distribution systems (Singh, 1977). The life of a STW is considered 15 years and that of lined canal and compacted earthen canal systems are taken as 10 years and 50 years (Ahammed, 1984 and Gisselquist, 1989).

The interest on investment was calculated by the following equation (Singh, 1977):

$$I = (P + S)/2 \times i$$

Where,

I = Interest on investment, Tk. /year

i = Bank interest rate,

P = Initial cost, Tk.,

S = Salvage value, Tk.

In this analysis, the bank interest rate is taken as 12 percent. The fuel and oil cost or electric bill, repair and maintenance cost and operator's wage were collected from the records of the pump owners. Total annual cost of the scheme and benefit under pre and post - improvement situations are given in the tables 5.7 - 5.9. The detail calculation of fixed cost (depreciation & interest on investment) and variable cost (fuel & oil cost or electric bill, repair & maintenance cost and operators' wage) is shown in tables 5.7 - 5.9.

**Benefit - Cost ratio**

It is the ratio of the total irrigation charges collected to the total annual cost of the scheme. The values of BCR are given in the table 5.10.

$$\text{Benefit - Cost ratio} = \frac{\text{Total irrigation charges collected}}{\text{Total annual cost of the scheme}}$$

### 4.3.2 Profitability of the farmers

$$\text{Profitability to grow irrigated Boro} = \frac{\text{Gross return}}{\text{Total cost of production}}$$

**Return**

The gross return includes the price of output and straw. The output price was calculated from the multiplication of yield (ton/ha) and unit price (tk./ton). The gross returns under pre and post - improvement situations are presented in the tables 5.11 - 5.13

**Cost**

Total cost of production includes input cost and land rent. Input costs - seed, manure and fertilizer cost, rent of power tiller, insecticide and pesticide cost and labor cost (including family labor). Land rent was assumed same for all the schemes. The cost per hectare in the years of 2007, 2008 and 2009 are given in the tables 5.11 - 5.13

**Benefit – Cost ratio**

It is the ratio of the total irrigation charges collected to the total annual cost of the scheme. The BCR values are given in the tables 5.11 - 5.13

$$\text{Benefit – Cost ratio} = \frac{\text{Gross return}}{\text{Total cost of production}}$$

Chapter 5

# RESULTS AND DISCUSSION

## 5.1 Duty of Water

Duty of water as a performance indicator was used to assess the impact of improved distribution system for six schemes. Three of six schemes- Ramchandranagar, Agarghata and Haridhali have lined canal distribution system and the remaining schemes - Birashi More, Ganesher More and Shamnagar have improved earthen canal distribution system. All these schemes had traditional earthen distribution systems under pre - improvement situation. From the pre and post - improvement situations, percent change for the improvement of duty was determined. The results for duty of water are given in table 5.1.

Table 5.1: The values of duty of water under pre and post improvement situations

| Scheme no. | Pre-improvement | | | Post-improvement | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2006-07 irr. season | | | 2007-08 irr. season | | | 2008-09 irr. season | | |
| | Area, ha | dis. (l/s) | Duty (ha/lps) | Area, ha | dis. (l/s) | Duty (ha/lps) | Area, ha | dis. (l/s) | Duty (ha/lps) |
| 1 | 5.05 | 17.50 | 0.693 | 5.10 | 16.00 | 0.765 | 5.20 | 17.00 | 0.734 |
| 2 | 4.10 | 15.00 | 0.656 | 4.20 | 14.00 | 0.720 | 4.25 | 14.00 | 0.729 |
| 3 | 4.35 | 17.00 | 0.614 | 4.45 | 15.50 | 0.689 | 4.50 | 15.50 | 0.697 |
| Average | 4.50 | 16.50 | 0.654 | 4.58 | 15.17 | 0.725 | 4.65 | 15.50 | 0.720 |
| 4 | 4.30 | 16.00 | 0.645 | 4.40 | 15.00 | 0.704 | 4.45 | 15.00 | 0.712 |
| 5 | 3.95 | 14.50 | 0.654 | 4.05 | 14.00 | 0.694 | 4.10 | 14.50 | 0.679 |
| 6 | 4.00 | 16.50 | 0.582 | 4.00 | 16.00 | 0.600 | 4.05 | 15.00 | 0.648 |
| Average | 4.08 | 15.67 | 0.627 | 4.15 | 15.00 | 0.666 | 4.20 | 14.83 | 0.680 |

The above table shows that the values of duty of water under the pre improvement situation for the selected lined canal distribution system vary from 0.614 (ha/lps) to 0.693 (ha/lps) with an average value of 0.654 (ha/lps). Under the post improvement situation, the values vary from 0.689 (ha/lps) to 0.765 (ha/lps) with an average value of 0.722 (ha/lps). Duty of water was increased by 10% for the lined canal distribution system.

From the above table it also shows that the values of duty of water under the pre improvement situation for the selected compacted earthen canal distribution system vary from 0.582 (ha/lps) to 0.654 (ha/lps) with an average value of 0.627 (ha/lps). Under the post improvement situation, the values vary from 0.600 (ha/lps) to 0.712 (ha/lps) with an average value of 0.673 (ha/lps). Duty of water was increased by 7% for the compacted earthen canal distribution system.

Results show that due to reduction of the loss of irrigation water in the distribution system; duty of water was increased for the improved distribution systems with respect to traditional earthen canal distribution system. It was greater for lined canal distribution system than compacted earthen canal distribution system.

### 5.2 Water Use Efficiency (WUE)

The term water use efficiency expresses water used per kg of rice production. Water use efficiency as a performance indicator was used to assess the impact of improved distribution system for six schemes.

Percent change of water use efficiency was determined from the corresponding values under pre and post improvement conditions. The results for water use efficiency are given in tables 5.2 – 5.4.

Table 5.2: The values of water use efficiency in 2006 - 07 irrigation season:

| Scheme no. | Area, ha | Yield ( kg/ha) | Discharge ($m^3/s$) | Operating hours | Volume ($m^3$) | WUE (kg/ $m^3$) |
|---|---|---|---|---|---|---|
| 1 | 5.05 | 5200 | 0.018 | 1127 | 71001 | 0.370 |
| 2 | 4.10 | 5270 | 0.015 | 975 | 52650 | 0.410 |
| 3 | 4.35 | 5150 | 0.017 | 980 | 59976 | 0.374 |
| Avg. | 4.50 | 5207 | 0.017 | 1027 | 61209 | 0.385 |
| 4 | 4.30 | 5100 | 0.016 | 1050 | 60480 | 0.363 |
| 5 | 3.95 | 5200 | 0.015 | 945 | 49329 | 0.416 |
| 6 | 4.00 | 5110 | 0.017 | 985 | 58509 | 0.349 |
| Avg. | 4.08 | 5137 | 0.016 | 993 | 56106 | 0.376 |

Table 5.3: The values of water use efficiency in 2007 - 08 irrigation season:

| Scheme no. | Area, ha | Yield ( kg/ha) | Discharge ($m^3/s$) | Operating hours | Volume ($m^3$) | WUE (kg/ $m^3$) |
|---|---|---|---|---|---|---|
| 1 | 5.10 | 5950 | 0.016 | 1140 | 65664 | 0.462 |
| 2 | 4.20 | 6050 | 0.014 | 1115 | 56196 | 0.452 |
| 3 | 4.45 | 5970 | 0.016 | 1100 | 61380 | 0.433 |
| Avg. | 4.58 | 5990 | 0.015 | 1118 | 61080 | 0.449 |
| 4 | 4.40 | 5530 | 0.015 | 1085 | 58590 | 0.415 |
| 5 | 4.05 | 5500 | 0.014 | 1020 | 51408 | 0.433 |
| 6 | 4.00 | 5440 | 0.016 | 1020 | 58752 | 0.370 |
| Avg. | 4.15 | 5490 | 0.015 | 1042 | 56250 | 0.406 |

Table 5.4: The values of water use efficiency in 2008 - 09 irrigation season:

| Scheme no. | Area, ha | Yield ( kg/ha) | Discharge ($m^3/s$) | Operating hours | Volume ($m^3$) | WUE (kg/ $m^3$) |
|---|---|---|---|---|---|---|
| 1 | 5.20 | 5770 | 0.017 | 1080 | 66096 | 0.367 |
| 2 | 4.20 | 5300 | 0.014 | 1010 | 50904 | 0.469 |
| 3 | 4.50 | 5540 | 0.015 | 1045 | 56430 | 0.455 |
| Avg. | 4.63 | 5537 | 0.015 | 1045 | 57810 | 0.430 |
| 4 | 4.45 | 5340 | 0.015 | 1035 | 55890 | 0.392 |
| 5 | 4.10 | 5500 | 0.014 | 935 | 47124 | 0.473 |
| 6 | 4.05 | 5020 | 0.015 | 980 | 52920 | 0.398 |
| Avg. | 4.20 | 5287 | 0.015 | 983 | 51978 | 0.421 |

From the above table it shows that the values of water use efficiency under pre improvement situation for the selected lined canal distribution system vary from 0.370

($kg/m^3$) to 0.410 ($kg/m^3$) with an average value of 0.385 ($kg/m^3$). Under the post improvement situation, the values vary from 0.394 ($kg/m^3$) to 0.487 ($kg/m^3$) with an average value of 0.440 ($kg/m^3$). Water use efficiency was increased by 14% for the lined canal distribution system.

The values of water use efficiency under the pre improvement situation for the selected compacted earthen canal distribution system vary from 0.349 ($kg/m^3$) to 0.416 ($kg/m^3$) with an average value of 0.376 ($kg/m^3$). Under the post improvement situation, the values vary from 0.370 ($kg/m^3$) to 0.473 ($kg/m^3$) with an average value of 0.414 ($kg/m^3$). Water use efficiency was increased by 10% for the compacted earthen canal distribution system.

Results reveal that less amount of water used per kg of rice production due to reduction of the loss of irrigation water in the distribution system. It was less for the lined canal distribution system comparison to compacted earthen canal distribution system. But for traditional earthen canal distribution system, it required large amount of water for per kg of rice production.

### 5.3: Overall irrigation efficiency

Overall irrigation efficiency as a performance indicator was used to assess the impact of improved distribution system for six schemes. From the pre and post - improvement situations, percent change for the improvement of overall irrigation efficiency was determined. The results for overall irrigation efficiency are given in the table 5.5.

Table 5.5: Depth of irrigation water and overall irrigation efficiency (Ei)

| Irrigation season | Name of the items | Scheme no. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Avg. | 4 | 5 | 6 | Avg. |
| 2006-07: | Depth of irrigation, mm | 1406 | 1284 | 1379 | 1360 | 1407 | 1249 | 1463 | 1375 |
| | ET, mm/day | 3.68 | 3.68 | 3.68 | 3.68 | 3.68 | 3.68 | 3.68 | 3.68 |
| | Rainfall, mm | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 |
| | Ei = | 28 | 31 | 29 | 29 | 28 | 32 | 27 | 29 |
| 2007-08: | Depth of irrigation, mm | 1321 | 1194 | 1367 | 1298 | 1332 | 1269 | 1469 | 1355 |
| | ET, mm/day | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| | Rainfall, mm | 151 | 151 | 151 | 151 | 151 | 151 | 151 | 151 |
| | Ei = | 31 | 34 | 30 | 31 | 30 | 32 | 28 | 30 |
| 2008-09: | Depth of irrigation, mm | 1183 | 1194 | 1236 | 1204 | 1256 | 1149 | 1307 | 1238 |
| | ET, mm/day | 3.79 | 3.79 | 3.79 | 3.79 | 3.79 | 3.79 | 3.79 | 3.79 |
| | Rainfall, mm | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 |
| | Ei = | 36 | 35 | 34 | 35 | 34 | 37 | 32 | 34 |

$$\text{Overall Irrigation Efficiency, Ei} = \frac{\text{ET}}{\text{I + Re}} = \frac{3.79 \times 115}{1183 + 37} = 36\%$$

* Crop season was taken 115 days (from transplanting to harvesting)

Table 5.6: The percent increase in value of overall irrigation efficiency due to improvement work.

| Name of the Scheme | Overall irrigation efficiency (%) | | | | |
|---|---|---|---|---|---|
| | Pre-improvement (2006 – 07) | Post-improvement | | | (%) Change |
| | | 2007 - 08 | 2008 - 09 | Average | |
| Ramchandranagar | 28 | 31 | 36 | 33 | 5 |
| Agarghata | 31 | 34 | 35 | 35 | 4 |
| Haridhali | 29 | 30 | 34 | 32 | 3 |
| Average | 29 | 31 | 35 | 33 | 4 |
| Birashi More | 28 | 30 | 34 | 32 | 4 |
| Ganesher More | 32 | 32 | 37 | 34 | 2 |
| Shamnagar | 27 | 28 | 32 | 30 | 3 |
| Average | 29 | 30 | 34 | 32 | 3 |

From the above table it shows that the overall irrigation efficiency under pre improvement situation for the selected lined canal distribution system vary from 28% to 31%  with an average value of 29%. Under the post improvement situation, the values vary from 30% to 36% with an average value of 33%. Overall irrigation efficiency was increased by 4% for the lined canal distribution system.

The values of overall irrigation efficiency under the pre improvement situation for the selected compacted earthen canal distribution system vary from 27% to 32% with an average value of 29%. Under the post improvement situation, the values vary from 28% to 37%with an average value 32%. Overall irrigation efficiency was increased by 3% for the compacted earthen canal distribution system.

Results show that overall irrigation efficiency was higher for lined canal distribution system due to reduction of loss of irrigation water in the distribution system comparison to compacted earthen canal distribution system. But for traditional earthen canal distribution system, the overall irrigation efficiency was less due to more loss of irrigation water in the system.

## 5.4 Economic analysis

### 5.4.1 Profitability of the pump owners

It was determined from the ratio of total irrigation charges collected to the total annual cost of the scheme. From the pre and post improvement situations, percent change for the profitability of the pump owners was obtained. The values of benefit - cost ratio (BCR) are given in table 5.10.

Table 5.7: Total annual cost of the scheme in 2006 - 07 irrigation season:

| Scheme no. | Shallow tubewell | | | | Distribution system | | | | F. cost | F & oil/elec. | R & M | O' wage | V. cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | S | D | I | P | S | D | I | | | | | |
| 1 | 22000 | 2200 | 1320 | 1452 | 32000 | 0 | 640 | 1920 | 5332 | 5200 | 2270 | 3000 | 10470 |
| 2 | 22000 | 2200 | 1320 | 1452 | 32000 | 0 | 640 | 1920 | 5332 | 5100 | 2150 | 3000 | 10250 |
| 3 | 22000 | 2200 | 1320 | 1452 | 32000 | 0 | 640 | 1920 | 5332 | 5350 | 2200 | 3000 | 10550 |
| 4 | 22000 | 2200 | 1320 | 1452 | 32000 | 0 | 640 | 1920 | 5332 | 5000 | 2100 | 3000 | 10100 |
| 5 | 22000 | 2200 | 1320 | 1452 | 32000 | 0 | 640 | 1920 | 5332 | 5200 | 2000 | 3000 | 10200 |
| 6 | 22000 | 2200 | 1320 | 1452 | 32000 | 0 | 640 | 1920 | 5332 | 3200 | 2200 | 3000 | 8400 |

Table 5.8: Total annual cost of the scheme in 2007 - 08 irrigation season:

| Scheme no. | Shallow tubewell | | | | Distribution system | | | | F. cost | F & oil/ elec. | R & M | O' wage | V. cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | S | D | I | P | S | D | I | | | | | |
| 1 | 22000 | 2200 | 1320 | 1452 | 40000 | 0 | 4000 | 2400 | 9172 | 3650 | 550 | 3000 | 7200 |
| 2 | 22000 | 2200 | 1320 | 1452 | 40000 | 0 | 4000 | 2400 | 9172 | 3500 | 500 | 3000 | 7000 |
| 3 | 22000 | 2200 | 1320 | 1452 | 40000 | 0 | 4000 | 2400 | 9172 | 3700 | 600 | 3000 | 7300 |
| 4 | 22000 | 2200 | 1320 | 1452 | 36000 | 0 | 720 | 2160 | 5652 | 4100 | 1600 | 3000 | 8700 |
| 5 | 22000 | 2200 | 1320 | 1452 | 36000 | 0 | 720 | 2160 | 5652 | 4050 | 2000 | 3000 | 9050 |
| 6 | 22000 | 2200 | 1320 | 1452 | 36000 | 0 | 720 | 2160 | 5652 | 2500 | 1800 | 3000 | 7300 |

Table 5.9: Total annual cost of the scheme in 2008 - 09 irrigation season:

| Scheme no. | Shallow tubewell | | | | Distribution system | | | | F. cost | F & oil/ elec. | R & M | O' wage | V. cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | S | D | I | P | S | D | I | | | | | |
| 1 | 22000 | 2200 | 1320 | 1452 | 40000 | 0 | 4000 | 2400 | 9172 | 3500 | 500 | 3000 | 7000 |
| 2 | 22000 | 2200 | 1320 | 1452 | 40000 | 0 | 4000 | 2400 | 9172 | 3450 | 500 | 3000 | 6950 |
| 3 | 22000 | 2200 | 1320 | 1452 | 40000 | 0 | 4000 | 2400 | 9172 | 3600 | 600 | 3000 | 7200 |
| 4 | 22000 | 2200 | 1320 | 1452 | 36000 | 0 | 720 | 2160 | 5652 | 4100 | 1800 | 3000 | 8900 |
| 5 | 22000 | 2200 | 1320 | 1452 | 36000 | 0 | 720 | 2160 | 5652 | 4200 | 2000 | 3000 | 9200 |
| 6 | 22000 | 2200 | 1320 | 1452 | 36000 | 0 | 720 | 2160 | 5652 | 2400 | 1800 | 3000 | 7200 |

Table 5.10: The benefit-cost ratio (BCR) and percent change under pre and post - improvement situations.

| Scheme no. | Pre-improvement ( 2006 – 2007) | | | Post-improvement | | | | | | (%) Change |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2007 – 2008 | | | 2008 - 2009 | | | |
| | Total cost | Benefit | BCR | Total cost | Benefit | BCR | Total cost | Benefit | BCR | |
| 1 | 15802 | 19063 | 1.21 | 16372 | 21406 | 1.31 | 16172 | 20844 | 1.29 | 8 |
| 2 | 15582 | 19281 | 1.24 | 16172 | 21719 | 1.34 | 16122 | 19375 | 1.20 | 3 |
| 3 | 15882 | 18906 | 1.19 | 16472 | 21469 | 1.30 | 16372 | 20125 | 1.23 | 6 |
| Avg. | 15755 | 19083 | 1.21 | 16338 | 21531 | 1.32 | 16222 | 20114 | 1.24 | 6 |
| 3 | 15432 | 18750 | 1.22 | 14352 | 20094 | 1.40 | 14552 | 19500 | 1.34 | 13 |
| 4 | 15532 | 19063 | 1.23 | 14702 | 20000 | 1.36 | 14852 | 20000 | 1.35 | 10 |
| 5 | 13732 | 18781 | 1.37 | 12952 | 19813 | 1.53 | 12852 | 18500 | 1.44 | 9 |
| Avg. | 14899 | 18865 | 1.27 | 14002 | 19969 | 1.43 | 14085 | 19333 | 1.38 | 10 |

From the above table it shows that the values of BCR under pre improvement situation for the selected lined canal distribution system vary from 1.19 to 1.24 with an average value of 1.21. Under the post improvement situation, the values vary from 1.20 to 1.34 with an average value of 1.28. The pump owners' BCR was increased by 6% for the lined canal distribution system.

The values of BCR under the pre improvement situation for the selected compacted earthen canal distribution system vary from 1.22 to 1.37 with an average value of 1.27. Under the post improvement situation, the values vary from 1.35 to 1.53 with an average value of 1.40. The BCR of the pump owners' was increased by 10% for the compacted earthen canal distribution system.

Results show that the values of BCR for shallow tubewells with lined canal were found to be lower than that for shallow tubewells with compacted earthen canal. This was mainly due to higher initial cost of the lined canal compared to compacted earthen canal. Though the BCR values were greater for compacted earthen canal compared to lined canal but lined canal should be recommended for the adoption. Because it was more sustainable in the field and it required less area compare to compacted earthen canal. So it is evident that adopting improved distribution systems, the pump owners will be benefited more.

### 5.4.2 Profitability of the farmers

It was determined from the ratio of gross return to the total cost of production. From the pre and post improvement situations, percent change for the profitability of the farmers was obtained. The values of benefit cost ratio (BCR) are given in tables 5.11 - 5.13. .

Table 5.11: Per hectare total cost of production and gross return in 2006 - 07 irr. season.

| Scheme Name | Input cost, tk./ha | Land rent, tk./ha | Total cost | Yield t/ha | Unit price, tk./ton | Output price | Straw | Gross return | BCR |
|---|---|---|---|---|---|---|---|---|---|
| Ramchandranagar | 25000 | 12000 | 37000 | 5.20 | 12500 | 65000 | 11250 | 76250 | 2.06 |
| Agargata | 24500 | 12000 | 36500 | 5.27 | 12500 | 65875 | 11250 | 77125 | 2.11 |
| Haridhali | 24000 | 12000 | 36000 | 5.15 | 12500 | 64375 | 11250 | 75625 | 2.10 |
| Average | | | | | | | | | 2.09 |
| Birashi More | 24500 | 12000 | 36500 | 5.10 | 12500 | 63750 | 11250 | 75000 | 2.05 |
| Ganesher More | 24200 | 12000 | 36200 | 5.20 | 12500 | 65000 | 11250 | 76250 | 2.11 |
| Shamnagar | 24300 | 12000 | 36300 | 5.11 | 12500 | 63875 | 11250 | 75125 | 2.07 |
| Average | | | | | | | | | 2.08 |

Table 5.12: Per hectare total cost of production and gross return in 2007 - 08 irr. season.

| Scheme Name | Input cost, tk./ha | Land rent, tk./ha | Total cost | Yield t/ha | Unit price, tk./ton | Output price | Straw | Gross return | BCR |
|---|---|---|---|---|---|---|---|---|---|
| Ramchandranagar | 27200 | 12000 | 39200 | 5.95 | 12500 | 74375 | 11250 | 85625 | 2.18 |
| Agargata | 27500 | 12000 | 39500 | 6.05 | 12500 | 75625 | 11250 | 86875 | 2.20 |
| Haridhali | 27100 | 12000 | 39100 | 5.97 | 12500 | 74625 | 11250 | 85875 | 2.20 |
| Average | | | | | | | | | 2.19 |
| Birashi More | 24000 | 12000 | 36000 | 5.53 | 12500 | 69125 | 11250 | 80375 | 2.23 |
| Ganesher More | 24200 | 12000 | 36200 | 5.50 | 12500 | 68750 | 11250 | 80000 | 2.21 |
| Shamnagar | 24300 | 12000 | 36300 | 5.44 | 12500 | 68000 | 11250 | 79250 | 2.18 |
| Average | | | | | | | | | 2.21 |

Table 5.13: Per hectare total cost of production and gross return in 2008 - 09 irr. season.

| Scheme Name | Input cost, tk./ha | Land rent, tk./ha | Total cost | Yield t/ha | Unit price, tk./ton | Output price | Straw | Gross return | BCR |
|---|---|---|---|---|---|---|---|---|---|
| Ramchandranagar | 24200 | 12500 | 36700 | 5.77 | 12500 | 72125 | 11250 | 83375 | 2.27 |
| Agargata | 23200 | 12500 | 35700 | 5.20 | 12500 | 65000 | 11250 | 76250 | 2.17 |
| Haridhali | 22400 | 12500 | 34900 | 5.15 | 12500 | 64375 | 11250 | 75625 | 2.31 |
| Average | | | | | | | | | 2.25 |
| Birashi More | 23300 | 12500 | 35800 | 5.34 | 12500 | 66750 | 11250 | 78000 | 2.18 |
| Ganesher More | 24200 | 12500 | 36700 | 5.50 | 12500 | 68750 | 11250 | 80000 | 2.18 |
| Shamnagar | 23100 | 12500 | 35600 | 5.02 | 12500 | 62750 | 11250 | 74000 | 2.08 |
| Average | | | | | | | | | 2.15 |

From the above table it shows that the values of BCR for the selected lined canal distribution system vary from 2.06 to 2.31 with an average value of 2.18. The values of BCR for the selected compacted earthen canal distribution system vary from 2.05 to 2.23 with an average value of 2.15

The price of rice straw is high in this area and the farmers earn more profit in addition to rice grain.

Chapter 6

# CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

For this study, six shallow tubewell irrigation schemes were selected to assess the impact of improved distribution systems. Three of the shallow tubewell irrigation schemes has compacted earthen canal and the rest has lined canal. The impact of improved distribution system was assessed by comparing the performance of the schemes under pre and post - improvement situations. The indicators used for performance comparison are- duty of water, water use efficiency, overall irrigation efficiency and cost effectiveness of the improvement works.

The following conclusions can be made from the study:

1. Duty of water increased by 10% for lined canal distribution system and 7% for compacted earthen canal distribution system with respect to traditional earthen canal distribution system.

2. Water use efficiency increased by 14% for lined canal distribution system and 10% for compacted earthen canal distribution system compare to traditional earthen canal distribution system.

3. The average overall irrigation efficiency under pre and post improvement situations for the selected lined canal distribution system were 29% and 33%, respectively. It was increased by 4% with respect to traditional earthen canal distribution system. The average overall irrigation efficiency under pre and post improvement situations for the selected compacted earthen canal distribution system were 29% and 32%, respectively and it was increased by 3% compare to traditional earthen canal distribution system.

4. The benefit - cost ratio of the pump owners increased by 6% for lined canal distribution system and 10% for compacted earthen canal distribution system with respect to traditional earthen canal distribution system. The average value of benefit -

cost ratio for lined canal under post improvement situation 1.28 was found to be less than the value for compacted earthen canal 1.40. This is due to higher initial cost of the lined canal system compare to compacted earthen canal system. The improvement of the system does not have any impact on the profitability of the farmers. This is because the farmers pay the same rate of irrigation charge both before and after the improvement of the systems.

## 6.2 Recommendations

The following recommendations can be made for the further study:

1. The present study focused only the improvement of distribution system for shallow tubewell irrigation schemes. A future study should be undertaken to evaluate the impact of improved water management practices.

2. The impact of improved distribution system was evaluated only for six schemes in this present study. A future study should be undertaken to cover more shallow tubewells.

3. Cost effectiveness of the improvement works was conducted using only one year's of pre project and two year's of post project data. Study should be taken to use long term data.

4. Conveyance loss was not measured in this study. A future study should be undertaken to measure the conveyance loss in the irrigation canal.

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