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BGD/80/001—RDA
Support for Tubewell Comand Area
Devopment, Northwest Bangiadesh

UNDERGROUND LOW PRESSURE PIPE SYSTEM (NARHATTA)

(USAID Funded Project)

Rural Development Academy
Sherpur, Bogra
Bangladesh.

August 1983

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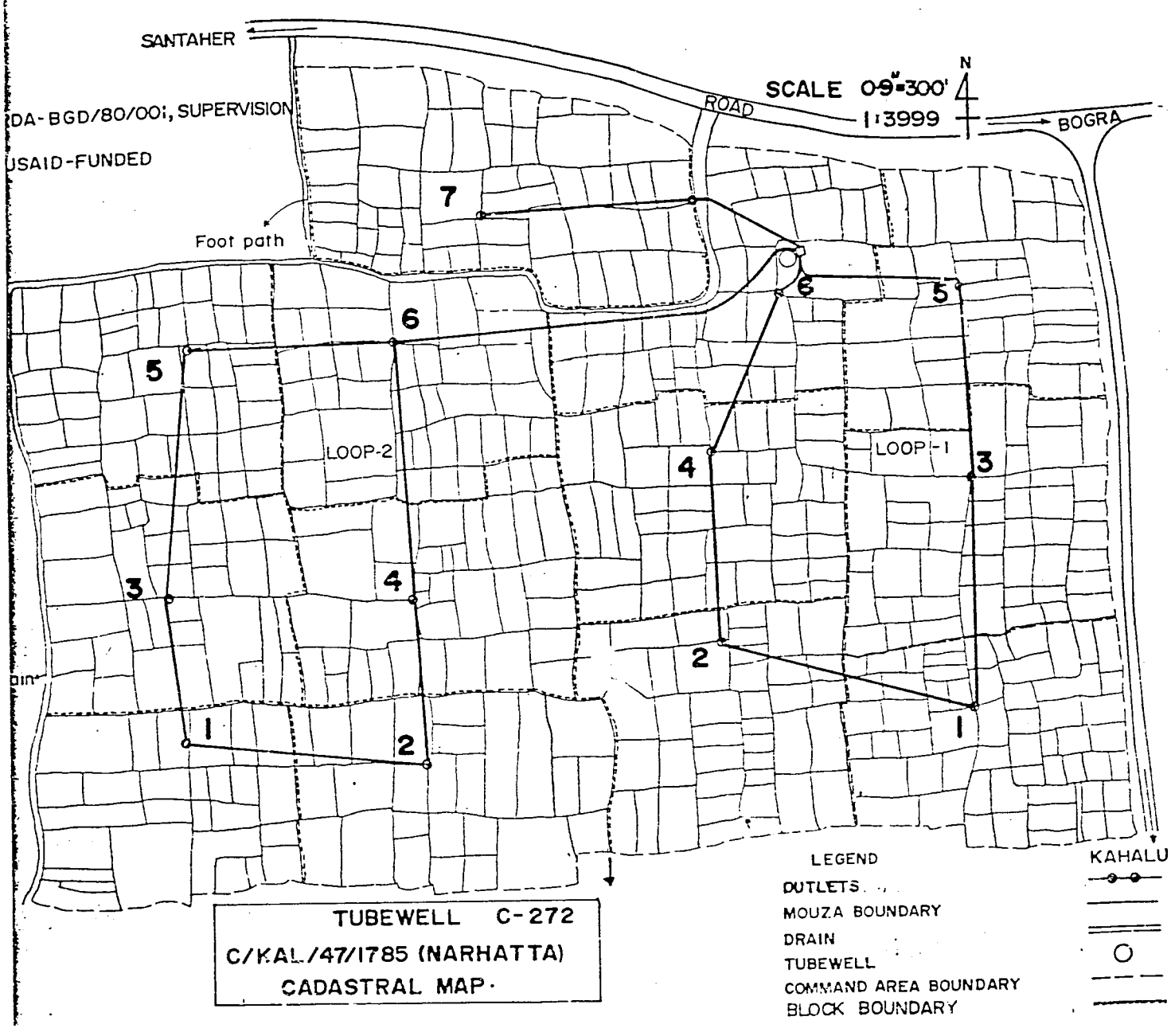
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TUBEWELL
COMMAND AREA BOUNDARY
BLOCK BOUNDARY
TUBEWELL C-272
C/KAL/47/1785 (NARHATTA)
CADASTRAL MAP

NARHATTA UNDERGROUND LOW PRESSURE PIPE SYSTEM FOR IRRIGATION WATER DISTRIBUTION

Introduction

Irrigation, with an adequate water supply, suitable soil and good management, should ensure sustained high yields of crops per unit area of land. When the water supply is less than adequate or costly, the aim must be to obtain the best possible yields per unit of water in combination with carefully selected agronomic and managerial practices. The success of an irrigation project in meeting these requirements depends, to a large extent, on the proper functioning of its water conveyance and distribution system. Proper funtioning is essentially identified with correct operation of the system, so that equitable and reliable arrangement of water amongst users and the conveyance of water with minimum losses can be ensured; its effectiveness is basically dependent on a well planned, designed and constructed network from the source of water supply down to the farmer's field.

Because of the importance of irrigation to the Bangladesh development plan and concern regarding the future availability of adequate ground water for irrigation, a series of studies are being made of how to best utilize fully the resources already available.

In 1982 RDA assisted by FAO/UNDP in conjunction with and funded by USAID installed an underground Low Pressure Pipe System on a Command Area in the District of Bogra, Bangladesh and, with the first harvest results now recorded, a report on the planning, installation, implementation and economic viability is presented. 1/

Planning

In mid-1980 during the preparation stage for project BGD 80/001, a start was made with the development of an underground low pressure pipe system for irrigation water distribution. Due to conflicting

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1/ See attached Buried Pipe Irrigation for Command Area Development An Economic Analysis preparaed by USAID.

opinions regarding the installation costs of such systems, a desk exercise was undertaken to compare the construction costs of pipe systems and brick lined channel systems on two command areas in the Bogra District. This included design of alternate layouts for both types of systems; hydraulic calculations to find pipe diameters and channel cross sections; estimates of materials required and total costs. Also, some of the advantages of the pipe system were elaborated on; an estimate of the land area taken up by channels and a construction workplan with an indication of the construction manday requirement were developed.

For this exercise two DTW areas in the Bogra District were selected from the topographical and other data which were available, Gordaha in Gabtali Thana and Narhatta in Kahalu Thana, For both systems, layouts were designed assuming a minimum discharge of the pump at 2 cusec. Because of the configuration this resulted in a two spur system for Gordaha area whilst for Narhatta. a system was chosen with loops plus an additional straight line supply.

When this is completed, between 15 and 20 DTW command areas were visited and evaluated with the assistance of BADC and IRDP (BRDB) to select a suitable area for the first of these installations. Criteria requirements for selection of the demonstration area were:

a. Accessibility even in relatively adverse climatic conditions.

b. The area should be reasonably developed and show good possibilities for expansion.

c. Availability of a reasonably well maintained pumping plant having a discharge of at least 2 cusec.

d. Occurrence of problems with the distribution of irrigation water due to topographical and or soil conditions.

e. Existence of an organized irrigation group willing to cooperate.

f. Potential to cover not less than 100 acres.

Successful irrigation ultimately depends to a large extent on the response of the farmers and therefore, the irrigation facilities made available to him must be designed and maintained with a view to meeting his requirements and aptitude. Whenever possible, farmers and the staff operating the irrigation network should be encouraged to participate at all relevant stages particularly during planning.

From these investigations it soon became clear that the command area of DTW C-272 in Narhatta, which had been selected for the desk exercise, was the most suitable area.

Discussions were held with the farmers envolved in the already existing Deep Tubewell Organization and, with the farmers, who, through expansion of the irrigable area, would also become involved. Both parties showed positively their wish to join in the experiment.

In the original discussion the Narhatta DTW Scheme Management Committee was involved. This committee was disbanded and a new controlling body viz. Narhatta Buried Pipe System (NBPS) Management Committee was formed, with an increase in the number of directors from seven to nine. This allowed additional farmers who were joining the scheme, to elect their own representatives.

The implementation procedure recommended to the NBPS Management Committee was that as suggested in the Manual, Irrigation Management Programme (CAD Section) and the paper; 'Recommendation for the Operation of a Closed Pipe System at Narhatta DTW Area' (Annex 1).

Checking of the topography of the area and the discharge of the pump were the first activities undertaken after the area was selected so as to ascertain whether design changes would have to be made. The topography proved to be correct and no changes in the layout were necessary, but the assumption that the DTW gave a standard discharge

of 2 cusec was incorrect. Measurements showed that the DTW gave a discharge of a little over 3 cusecs making new hydraulic calculations necessary in order to find the correct pipe diameter. In the same way as in the desk study (using friction loss data provided by the manufacturer), the friction losses and pipe diameter which should be used if the system was to be made of asbestos pipes, were calculated.

At the same time, other materials such as reinforced concrete and PVC pipe were studied with respect to quality, availability and costs. The spun R.C.C. pipes were unsuitable because of the quality difference from pipe to pipe. There was also uncertainty as to whether the pipes could be manufactured in large quantities in time once the decision was made to construct the system.

The manufacturing capacity of PVC pipes, which would have been preferred because of handling characteristics and ease of joining, is inadequate in Bangladesh and the manufacturers do not have the capacit to be able to absorb extra orders and produce only diameters up to 4 inches.

Importation of PVC pipes from India was contemplated and quotations of 3 manufacturers were studied, but orders were not placed as taxes and transport cost would make the pipes much more expensive than the asbestos cement pipes made in Bangladesh. The decision was made to use asbestos cement for both pipes and accessories which could be made locally in the diameters required.

For the discharge valves, models of alfalfa valves from India were obtained and adapted to fit the risers. The valves were then made in Bangladesh.

Design and Layout of the System

The layout of the system consists of two closed loops which are each connected by a main line with the header tank and two additional

lines serving an area of 18 acres, and separated from the body of the command area by a natural drain. Each loop has six outlets, each outlet serving blocks of between 12 and 13 acres whilst the additional lines each have one outlet which together serve the separate 18 acres block.

The discharge from the tubewell is divided in the overhead pressure tank into two streams, each of approximately 1.5 cusec, and delivered into one discharge point at a time in each loop or line. By designing the system in this way the necessary pressure-head that is needed to provide the driving force for the water in the pipes, could be kept to 10 feet. The maximum available pressure-head is determined by the total dynamic head of the pump. Normally the DTWs have a total dynamic head of about 60 feet and with a maximum drawdown of about 40 feet. The maximum available pressure head is in the order of 20 feet.

With the valve for the pressure head set and the length of the system known, it was possible to calculate the pipe diameters using graphs giving friction losses for different pipe sizes at a specific discharge. Assuming there were no grains in the pressure head, as the command area is almost flat, the calculations showed that 8 inches diameter pipes for the loops and 10 inches diameter pipes for the main and additional lines, the total friction losses in each part of the system were less than the total available pressure head. A safety factor of more than 10 percent had been incorporated in the calculations in the form of extra length of the system. The loops are 4040' (Loop I) and 4070' (Loop II), the main lines 90' (Main I) and 1200' (Main II) and the additional lines 300' (Line I) and 750' (Line II) respectively.

Design and Construction of the Header Tank

The header tank has been designed as a monolith reinforced concrete structure with a free floating foundation. The tank, which is supported by four columns, has three main functions:

- to provide a pressure head for the water in the system
- to divide the DTW discharge into two streams of about 1.5 cusecs
- to prevent entry of sand into the pipe system.

To achieve these aims the tank has been divided into three compartments i.e. into the first one the DTW pumped water is discharging through a pipe over the top of the tank wall. From there the water runs at a velocity over a solid baffle into the second compartment which is separated from the discharge area in which the stand pipes are fitted by a plate with two half 90°V-notch weirs to divide the discharge equally. This area is again divided into smaller areas around each standpoint which are separate by a joint overflow.

Provision for Gate Valves

For standpipes, two 14" diameter M.S. steel housing pipes have been used, each at the lower end fitted with a horizontally fitted piece of the same pipe which again was provided on each side with a reducer to bring down the diameter from 14" to 10". Flanges were welded onto the reducers so as to be able to bolt on the steel connection pipes. The connection pipes were made in two pieces for two reasons, viz:

- to fit them into the asbestos cement pipes
- for further insertion of hand operated gate valves to close off one part of the system in case of damage.

The tank and inspection walls around the connections between standpipes and asbestos pipes were built by a construction firm from

Bogra, whilst the welding on standpipes connection pipes and extension of the discharge pipe was done by a metal workshop also in Bogra. The construction of the tank, including the setting of the weir plate and standpipes took 4 weeks and, inspection wells and setting of the first asbestos cement pipes, which were done at the time of pipe laying, took about 10 days.

The option of closing off any part of the system with gate valves from the rest of the system created a number of extra problems. Firstly, the connection necessitated the construction of M.S. steel pipes with bends as the standpipes and asbestos cement pipes could not be brought into line. Secondly, the steel pipes had to be made in two pieces for ease of installation and to replace one piece with the gate valves when they became available. The construction and installation of these pipes delayed the testing of the system considerably, as extra care had to be taken to ensure the connections did not leak. Whenever leaks were detected after testing, the water in part of the system had to be removed and the metal pipes taken out to be adapted, replaced and tested again, To prevent any movement of the metal pipe and further damage to the asbestos cement pipes, the whole connection plus part of both pipes was cast in a block on concrete.

For future pipe systems, a direct connection between asbestos cement pipe and standpipe would be preferably in case the same tank design is used. This can be realized by providing the standpoints with a piece that has the same outer diameter as the asbestos cement pipe and can be fitted with a standard rubber sealing ring into the socket of the asbestos cement pipe.

Another possibility would be to design and construct a header tank more or less along the lines of the type used in India. The tank for this system would consist of three cells with concrete walls

built up to the desired height. The middle cell would receive the discharge of the DTW simply by extending the discharge pipe through the wall and it could function at the same time as a sand trap. The outer ones would be the standpipes and receive water over weirs or orifices in the separation walls with the middle cell, so as to divide the discharge into two equal streams.

Construction of the System of Irrigation Pipe Delivery

The construction of the system, more than six months after the tank was completed, started with the digging of the trenches for the loops and lines. Because the top of the pipes had to have a soil cover of at least 2.5 feet, the trench had to be dug to about 3.5 feet below field level. The trench digging proceeded according to schedule notwithstanding the fact that the clay subsoil was very sticky and hard to dig out. On average, over a hundred men were involved in this trench digging every day.

During the digging one problem was apparent, the heavy clay soil removed from the trench and necessary to backfill the trench again after the pipe laying, became stone-hard under the drying influence of sun and wind and was unsuitable for bedding and backfilling around the pipes. As the bringing in of sand for bedding purposes was too costly, a solution was found by using top soil from fields near the trench.

Ten days after the commencement of trench digging, the trenches for Main I, Loop I, Main II and part of Loop II were finished and the pipe laying commenced. Assistance was given for this work by ARAMIT who made a technician available.

Initially, the pipes were laid with the sockets pointing down stream, as this would, according to information received from the manufacturer, facilitate the joining of the pipes and have no influence

on the sealing of the joint. Joining the pipes in this way is relatively easy, and damage, especially to the sockets, can be prevented as the open-end can be correctly positioned in front of the socket opening before and during the joining of the pipes. If the pipes are joined with the socket facing upstream the chances of damage to the socket are greater and also correct joining is more difficult.

During a visit of the USAID engineer (USAID through the counterpart agency RDA was funding the project), a discussion developed regarding the positioning of the pipes in the line, mainly respect to the opening between the pipes and rubber ring functioning as an air trap, and the effect of this on the tightness of the seal. It was therefore decided to construct part of the system with the pipe socket pointing upstream. This was subsequently done on the additional Lines I and II.

Joining of the pipes posed no problems but care had to be taken to obtain a good sealing effect of the rubber ring and to prevent damage to the socket. Several groups of village people mastered these skills quickly and worked during the rest of the construction as pipe laying teams.

Pipes were cut to length with a handsaw after indication of the required length.

Special care had to be taken when joining pipes of asbestos cement and metal accessories, also the asbestos fittings are liable to damage because they are of hand moulded construction and their strength is somewhat lower than that of the pipes. When joining pipes after bends, extra precautions were necessary to keep the bends in place and prevent damage to sockets.

One feature of the hand moulded accessories that caused concern was the deviation in the diameter of the sockets from the exact value,

more specifically a greater diameter, especially at point where changes in direction were necessary as after-bends, dividers and in-risers. Sealing of the rubber rings was insufficient and grouting with a 1:1 cement-sand mortar had to be applied to get a complete seal.

At several points in the system reductions in diameter were necessary for which two methods were applied. (a) One made use of local metal reducer pieces produced from M.S. sheet, with one end having an outside diameter equal to that of the 10" and the other equal to the outside diameter of the 8" pipe. These reducers were fitted in the same way with rubber rings as the pipes. (b) The other method took advantage of the fact that the inside diameter of the 10" pipe was the same as the inside diameter of the socket from the 8" pipe. The reduction was achieved by pushing an 8" diameter pipe with a ring over a length of 4" to 5" into the 10" diameter pipe.

This same technique was also used when joining 8" diameter pipes to close the loops and at points where after laying of the pipes, due to damage, a pipe had to be replaced. For this purpose a piece of 10" diameter pipe about a foot long was cut and one 8" diameter pipe fitted with a rubber over which the 10" pipe socket was pushed till the end of the pipe and socket were flush; the other pipe was then provided with a rubber ring and the 10" pipe socket pushed back until it covered both pipe ends to the same extent and bridged the opening between the pipe ends.

Outlets were made at selected locations along the line by inserting a T-piece and coupling a riser pipe long enough to be 6" over field level. The cast iron alfalfa valves were then placed over the pipe and a platform with side walls and stilling pool was constructed from lightly reinforced concrete.

Surge relief structures were provided at the mid-point of the loops and at the end of the longest additional line the same

procedure of joining to the pipe was used except that the riser pipe was in excess of 6' and on top of which a 2" diameter galvanized iron pipe was fitted. In this way the total height of the pressure relief structure was made the same as the maximum pressure head that can be applied to the standpipe.

At ground level, a concrete slab was made on top of of which a brick wall was constructed around the riser to protect the asbestos cement pipe and to fix the metal part of the riser firmly. The opening between the pipe and the wall was filled with concrete.

Backfilling started as soon as possible after a considerable part of the line was laid. The trench was not completely filled, the area around the sockets being kept free to observe them during testing. As stated previously, the soil coming out of the trench was unsuitable for backfilling and friable top soil from nearby fields which were already harvested had to be used. This soil was brought in in carrying baskets to the trenches and spread in thin layers alonside the pipe, where it was then compacted with small wooden rammers; when a soil cover of more than 4" was reached, other soil was used for backfilling, and compacting was then able to be done with heavier concrete hand rammers.

Because of extra work in transporting the soil needed for backfill and the laborious process of compacting the soil, more mandays were required than originally estimated.

Through visual inspection prior to testing, cracks were detected in the sockets of three pipes. These were dug out and the socket sawn off; two short pieces, one with a socket on one side, the other with two open ends, with a total length of about ½ to 1" less than the original pipe, were then joined to the remaining pipe line parts in the normal way with the use of 10" diameter pipe socket. When the

pipe line is filled with water this procedure can only be used after pumping out all the water from that part of the system at the lowest placed outlet.

Another possiblity is to repair the cracked pipe by tightening galvanized wire netting around the damage part of the pipe and packing this in a strong mortar mix or concrete. When a socket is cracked, the joint may be grouted and packed in concrete to prevent leakage and further damage.

Two special features have been provided in the Narhatta system (a) first is a reinforced concrete culvert built to protect the pipes where they cross the natural drain and (b) the second is the set of extra tapping points, one in each of the additional lines. From here the system could be extended to include the area to the north of the Bogra - Santaher road which belongs mainly to the same group of farmers. This is only possible when the farmers in the existing command area are irrigating efficiently and with the rearranging and increasing of the existing blocks to make a 7 day rotation on the extended area possible.

Testing the System

Testing of the system proved a laborious and time consuming operation, for each time defects appeared the test had to be broken off and the defect repaired before the testing could be continued. During the filling of the system, it became apparent that the connection between the standpipes and the asbestos pipes will always be a weak point in this system and an improved method of connecting the system to the standpipes should be used in future.

When these problems were rectified, pressure testing was able to recommence under full pressure. The section of the system where the pipes were laid with sockets pointing upstream performed slightly

better than the rest of the system where the pipes were reversed. In Main II and Loop II particularly, there were several joints showing leaks. This was partly due to the escape of the air trapped through the inside configuration of the socket between the walls and the rubber ring, caused partly by minor irregularities in the walls of the socket.

Construction Costs

When analyzing the construction cost, it should be kept in mind that this is the first system of its kind in Bangladesh and that certain safety factors were applied to ensure trouble free operation. These extra provisions provided, increased the cost of this installation, but the cost of future projects of this type is expected to be reduced by 20%.

A breakdown of the costs under major headings is as follows:

ITEMS		BTK
Header tank and weir plate		37,050
Standpipes and reducers		24,400
Inspection wells		23,700
Accessories: standpipes connections and discharge pipe, pipe, acessories and tranport (10% of material cost)		731,200
Weir, netting, cement, sand, bricks etc		21,500
Alfalfa valves		4,550
Labour cost (estimated)		75,000
Total	BTK	939,950
1 US $ = 22.50 BTK	US$	41,776

Cost per acre	BTK	5696.66	say	5697
Command area 165 acres	US$	253.19	say	253

From the above calculation it can be seen that the cost of construction is high. However, with an improved connection between

standpipes and asbestos pipes, which would do away with the inspection wells and most of the accessories necessary for this connection, it would save around Tk. 35,000.

In all phases of design and construction, safety factors were applied and as a result, certain costs did increase. Furthermore, a cost increase was incurred due to the fact that the header tank and the rest of the system, including inspection wells, could not be constructed in one operation.

The labour costs are higher than estimated because of unforeseen problems in trench digging and backfilling, pipe laying etc. Many things could only be learned the hard way as there was no previous experience in developing an underground low pressure pipe system for water distribution. Labour costs of approximately half those paid are more realistic.

In discussion with ARAMIT, Bangladesh Asbestos Cement Industries Ltd., they indicated that in future when a greater number of systems were being built, prices of pipes and accessories would be reduced by 10% to 20% This would make a big difference in the total cost of the system as these items make up about 75 percent of the costs.

SEASON CROPPING PLAN

Land Preparation

The land preparation for irrigation for the 1983 Boro Season commenced on the 4th February 1983, using as a basis the block system as proposed in the original design. True rotation was not always followed, but a system convenient to the irrigating participants through discussionsdid emerge. These changes from the planned rotation were more evident during the early crop establishment period and were the result of the farmers' wishes, some of which were as follows: Optimum planting dates, seedling availability, advance payment of water charges, completion of harvest of wheat and potatoes.

Crop Planting

The first Boro rice was planted on the 12th February 1983 and 55 ha. were completed on the 20th March 1983.

The principal rice varieties used during this Boro season were BR4, China/Purbach, Kalembong (improved local variety).

Harvest Results

The Boro harvest commenced on the 20 May and was completed on 25 June 1983, for a result average of 4,140 kg. paddy per hectare.

General Factors

1. Cropped area increase for Boro over 1982: 25 hectare
2. Per hectare yield increase over 1982: 370 kg.
3. Land preparation irrigation for Aus rice cropping: 10 hectare.
4. Reduction of farmer conflict through improved control in water distribution
5. Management improvement has been made but much more assistance is needed to improve the book-keeping aspects and avoid conflict over payments. The introduction of receipts for water payments did assist in this matter.

Conclusions

The Underground Low Pressure Pipe System for irrigation water distribution shows great potential for Bangladesh:

1. Through its high distribution efficiency a much larger area can be irrigated with the same amount of water discharge rate.
2. Spread the benefits of irrigated agriculture over the total command area by ensuring a uniform discharge at all points.
3. Problems regarding right of way, land acquisition and compensation are minimized.
4. Topographic variations which pose problems to conventional systems can be overcome and command areas with incorrectly situated DTWs can be successfully developed.
5. Permits close control of the prescribed rotational schedules and it prevents water pilferage conflict.
6. Necessary to investigate the state of the pump and engine.
7. To perform a topographical survey to secure cooperation of the farmers.
8. Improved header tank along the lines of the standard Indian design is required.
9. Joining asbestos cement pipes with the sockets pointing in an upstream direction gives less problems.
10. Bedding of A/C pipes to be supported along their whole length to avoid fracturing.
11. The skills necessary to construct the pipelines are not very difficult to learn and the village people mastered these quickly and adapted the techniques freely as and when necessary during the construction.
12. The cost of the system may appear high, especially when compared with the present built farmer systems, or even with the improved earthen channel systems, but preliminary calculations on a discounting basis indicate that costs for pipe systems are in the same order

as those for concrete lined channel systems.

13. CAD managerial aspects require improvement.

14. Technical inputs through Thana Officers require strengthing.

Recommendations

For the development of underground low pressure pipe systems for irrigation water distribution, it is recommended that:

- A topographical survey is carried out to find the optimal design and situation of outlets at the highest points in the blocks.
- A design for the header tank is used which is simple and will avoid construction of additional works and accessories that may later on cause operational and maintenance problems.
- When laying the pipes, they are positioned with the socket pointing in an upstream direction so as to avoid construction of air traps between socket, pipe and rubber ring, which may increase leakage problems.
- The use of too many accessories (bends, dividers) following each other should be avoided, due to the deviations in dimensions which tend to cause leakages and also, because the strength is lower than that of the pipes as they are hand moulded.
- When diversions in flow have to be made, then where possible, equal 90° tees are used as the bends are not required, this gives less joining problems.
- Proper care is exercised in bedding the pipes to ensure support along the full length and an excavation for the socket is made to prevent any damage.
- For backfilling, the soil is carefully chosen to get full support for the pipes on all sides and that compaction is carried out in such a way that no pipes will be damaged.
- At points where the direction of the pipe line changes or where there are bifurcations, these bends and bifurcations are supported

with blocks of concrete to prevent movement. The same applies for end-stops in case provisions are made for extension of the system.

- Instruction of the users should take place to help them utilize the system to the maximum extent. Attention should be paid to management and operation, with the view to reduce field water losses; increase in cropping intensity and production by introduction of improved varieties and new crops; reduction of production costs; supply of inputs and marketing of produce; and post harvest activities.
- The experimental systems to be studied and monitored to find suitable solutions that help the country to increase the agricultural production in order to feed its population.
- Thorough economic analyses are made of the costs and benefits of the different distribution systems.

RECOMMENDATIONS FOR THE OPERATION OF A CLOSED PIPE SYSTEM AT NARHATTA DIW AREA

I. Basic Information

1. The Command Area

- Area served by Loop A - - - - - - -	29.92 hectares
- Area served by Loop B - - - - - - -	30.32 hectares
- Area served by Loop C - - - - - - -	7.06 hectares
Total:	67.30 hectares

2. The Block Formation

It is important to have a strong Block Organization to operate the system effectively.

The following block formation is recommended:

Loop A - - - - - - -	6 Blocks
Loop B - - - - - - -	6 Blocks
Loop C - - - - - - -	1 Block

II. Work Implementation

In order to administer the planned improvement systematically, the following steps were recommended:

Step 1. Thana CAD Committee

The Thana Cooperative Officer Kahalu should work with the TPO/BRDB Kahalu and the TEO/DAES Kahalu to discuss how the three officers will cooperate in giving advice regarding the operation of the buried pipe system at Narhatta Manual pages 7,8,9.

Step 2. Reorganization of the Irrigation Management Committee

The existing Management Committee was reorganized in

order to cope with the expanded area of the command area. The CAD served approximately 30.36 hectares before the pipe system became operative. On completion of the buried pipe system, it is expected to be expanded to 67.20 hectares for winter crops.

Step 3. Function of the Existing Irrigation Management Committee

Before the new Management Committee came into being and assumed the operation, the existing management committee continued to function and implement the work.

Step 4. Formation of Blocks

As the block system is new to the Marhatta farmers, it is important they understand that the formation of blocks is the key to the buried pipe system. The Thana Officers concerned will assist the present Management Committee to organize the blocks according to the IMP manual page 96 & 97.

Step 5. Election of the Block Leaders

After the constituents of the blocks are identified then a leader will be elected or selected - IMP manual p 99.

Step 6. Organization of a New Irrigation Management Committee

After the election of block leaders, a new irrigation management committee will be organized. Follow the suggestion as recommended in the IMP manual page 81.

Step 7. Transfer of Business from the Existing IMC to New IMC

When the new Irrigation Management Committee is properly organized, the Thana Cooperative Officer, in cooperation with the TPO/TCCA, will assist in the smooth transfer of business including books and records, assets & liabilities.

Step 8. New Irrigation Management Committee

After its official inauguration, the Irrigation Management Committee will not lose any time in performing its functions - IMP manual pages 81 - 87, 96 - 148.

Step 9. Decide the Cropping Plan

Firstly, it has to be decided which crops to grow and how to make improvements year by year - IMP manual pages: 46-57, 72 - 75 and particularly page 99.

Step 10. Decide the Water Distribution Plan

There are two plans to be made, viz:

- Block Distribution Plan - IMP manual page 137 - 138
- Within the Block Distribution Plan - IMP manual page 98.

The management committee will took an active role in coordinating and deciding the above two plans and have each member correctly informed through their Block Leader.

Step 11. Decide the Water Rate

The water charge must be commonly discussed and decided upon, based on the actual requirement, refer IMP manual pages 102, 105, 153 and 158.

Step 12. Decide the Operation Budget

The operation budget includes:

- Plan of income
- Plan of expenditure

Refer IMP manual page 102 - 104

Step 13. Hold Members' General Assembly (MGA)

The members are kept well informed regarding the plan and operation of the entire irrigation scheme. There are two MGA's to be held for each crop season. One before the season and the other one after the season.

Before the season MGA - - - IMP manual pages 99-105 & 137 - 139.

After the season MGA - - - IMP manual pages 161-162.

Step 14. Training of Water Users and Leaders

The Chain Officers assist the Management Committee to conduct the training of the followings:

- Farmers' Training - IMP manual pages 91, 110 - 123.
- Leaders' and Workers' Training - IMP manual pages 92, 139-144.

Step 15. Maintenance and Book Keeping

- The irrigation pump and irrigation channel will be properly maintained - IMP manual pages 106 - 111.
- Books and record will be correctly kept - IMP manual p 140-145.

Step 16. Construction of Irrigation Channels

Though we did not have to build the main channel as it is served by the buried pipes, we still need to construct channels within the blocks for the water flow from the outlet - IMP manual pages 37 - 44.

Step 17. Evaluation

The operation of the scheme should be evaluated each season so as to make continuous improvement - IMP manual pages 149 - 160.

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BURIED PIPE IRRIGATION FOR COMMAND AREA DEVELOPMENT

AN ECONOMIC ANALYSIS

BY

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BURIED PIPE IRRIGATION FOR COMMAND AREA DEVELOPMENT

AN ECONOMIC ANALYSIS

Bangladesh is in short supply of food, and new agricultural strategies are being explored. Government policies aim to devise better techniques for increasing agricultural production. Studies indicate that irrigation is one of the most important constraints on agricultural production.[1/] Agriculture can be made more productive either through an expansion of irrigated area or by an improvement in water efficiency within existing command areas.

The Government of Bangladesh and a number of donor agencies are concentrating their efforts on removing the irrigation constraint. An experimental underground low pressure pipe system developed by FAO with USAID assistance at Narhatta village of Bogra District is aimed at evaluating promising techniques of water conveyance and distribution. Concern regarding future availability of ground water for irrigation is one of the reasons for developing this system. At present, the country's existing irrigation facilities, utilizing earthen channels for water conveyance are inefficient[2/] and it was felt highly necessary to study ways to increase their efficiency. The Narhatta deep tubewell (DTW) area previously using earthen channel was selected for conducting experiments relating to buried pipe adoption.

1/ See Report of IDA President: Report No. P-2709-BD, World Bank, Washington, February, 1980.

2/ Deep tubewell utilization is limited to 50-60 acres compared to the potential of 165-170 acres. Losses are due to seepage, percolation and evaporation.

The new buried pipe system gives a very high conveyance and distribution efficiency besides yielding other economic and non-economic advantages.[3/] However a conversion from earthen channel to buried pipe requires a large additional investment. An assessment of the comparative cost and benefits from earthen channel and buried pipe system is essential to determine the destrability of these additional invesements.

DESCRIPTION OF PROJECT

General

The project area is located in Narhatta area, Kahalu Thana of Bogra District and is about 8 miles from Bogra. The area has had a deep tubewell since 1977 with a command area of 70-75 acres. Rice is the principal crop grown in the area and average size of farms is around 0.3 acres. As with other areas of Bangladesh, the project has three main seasons: the monsoon from June to October, during which about 80% of annual rainfall is recorded; the dry season from November to February which has very little rainfall and the lowest temperatures and humidities, and the pre-monsoon from March to May, which has the highest temperatures and evapporation rates with occasional heavy rain storms.

The proposed engineering lay out of the underground system (Figure 1) consists of two closed loops which are each connected by a main line with the header tank and two additional lines. Each loop has six outlets, each serving blocks of between 12 and 13 acres, and the additional lines each have one outlet which together serve on 18 acre

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3/ Irrigation efficiency as measured by proportion of pumped water reaching farmers fields for buried pipe system is calculated to be 80 - 85 percent, while for earthen channel it is 40 - 50 percent (source FAO Report, BDG/80/001 FAO Bogra).

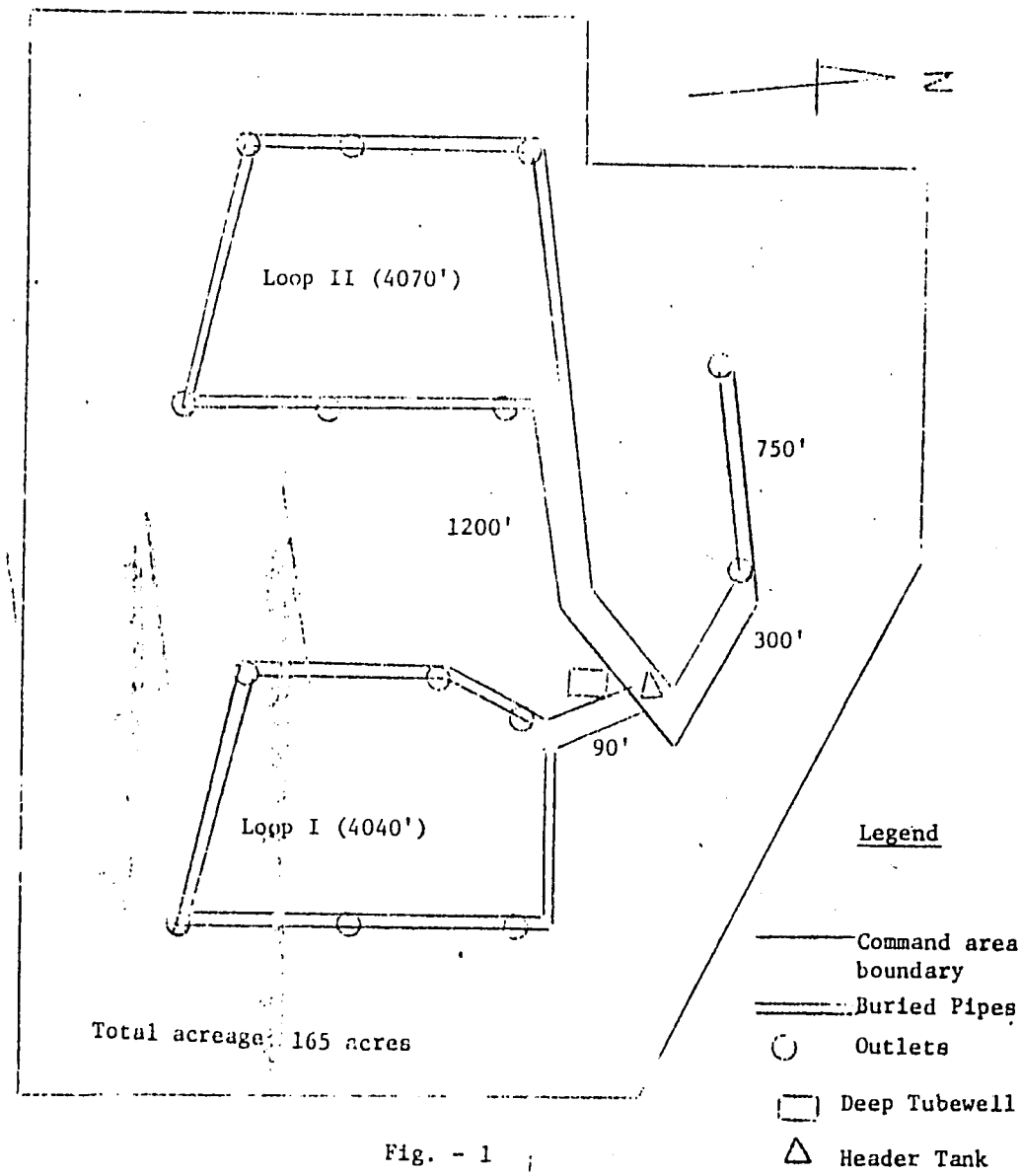

Fig. - 1

Sketch of Pipe Layouts: Buried Pipe Irrigation Project at Narhatta, Bogra.

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block. The loops are 4040 feet (loop I) and 4070 feet (loop II), the main lines 90 feet (main I) and 1200 feet (main II), and the additional lines 300 feet (line I) and the 750 feet (line II), respectively. Two 14 inches mild steel stand pipes are used to connect the header tank with asbestos pipes. The buried asbestos pipes are dug to about 3.5 feet below field level.

Topography and Soil

The area is a part of the high elevation Barind tract region ranging in elevation from about 60 to 80 feet above sea level. This is a flood free area with 80-90 inches annual rainfall. Soils are of sandyclay type and rice grows well if soils have adequate moisture. Rain water is used to grow rice in the wet season, however, irrigation is needed for dry season rice production. The absence of rivers and canals make shallow and deep tubewells the only alternatives for irrigation. The ground water table is at a reasonable level and the area is a flat plain making it suitable topographically for channel and low pressure pipe distribution.

Agricultural Production and Cropping Patter

Basic data on agricultural production and cropping pattern observed in the project area as well as some assumptions on future cropping pattern are set forth in table 1. Before DTW irrigation, transplanted local aman was the main crop in the project area. The average yield was around 20 maunds per acre and nearly all farmers grew the crop during the rainy season in June/July. After the harvest of aman in October/November, the land remained mostly fallow during the

winter months. Again with the start of early rains in March/April, a few farmers (around 5 percent) grew local aus with an average yield of 12 maunds per acre. Ninety-five percent of the land remained fallow during the period. The cropping intensity was only 105 percent.

With the introduction of the DTW utilizing earthen channel in an area previously unirrigated production and cropping patterns show a remarkable change in the command area of 75 acres. Transplanted HYV aman, with average yields of 40 maunds, replaced the local variety. HYV boro, wheat and potatoes began to be cultivated in the land previously remaining fallow. Local aus gave way to HYV aus during the months of March/April to June/July. The cropping intensity rose to 194%.

In March 1983, the area began to be irrigated by buried pipes. The data on crop yield, command area and cropping intensity are available for the first year (table 1). Command area has increased from 75 acres to 136 acres in the first year. It is assumed to rise to 156 acres in the second year and to 165 acres in the years hereafter. With an assured and uniform discharge of water over an increased command area of 90 acres, higher gross production and income should result. HYV varieties of aus and aman have replaced their local counterparts and larger acreages of boro, potato and wheat will be cultivated during the coming dry season in the project area. 4/ The cropping intensity in the first year is 265% and is expected to rise to 300% in the third year

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4/ This is the first year of buried pipe project and the farmer's intention were known by interview.

and years thereafter. The project would also eliminate crop area losses arising from construction of earthen channels.[5/] It's other advantages relate to (a) less problems of right of way, land acquisition, and compensation, (b) solution of problems arising from topographic variation and poor siting of pumps in conventional systems, (c) permission of close control of the prescribed rotational schedules, etc.

Methodology of Analysis

The method of economic analysis used here is a comparison of costs and benefits that result overtime with: (a) DTW irrigation using earthen channel compared to no prior irrigation, (b) DTW irrigation using buried pipe system compared to earthen channel, and (c) DTW irrigation using buried pipe system compared to no prior irrigation.

The measurement of costs relate to expenditures on construction for earthen channels and buried pipe systems as well as for operation of the DTW under each of the above systems. The measurement of benefits require calculation of increased production in the project area due to higher yield, increased cropping intensity, and expanded command area under earthen channel and buried pipe system.

Three measures of project feasibilities are used, the net present value (NPV), benefit-cost ration (B/C) and the internal rate of return (IRR). The first is arrived at by subtracting present cost from present value calculated over the project life, the second by dividing the discounted value of net benefit by the discounted value of costs calculated

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5/ The area lost over a command area of 165 acres for a channel of 5 feet width is calculated to be 4 acres.

over project life and the last is a calculated rate of compound interest that just makes the net present work of the cash flow equal to zero. The formula used for their calculation are shown in appendix table. The first is an absolute measure and estimates project's net present worth. The second is a relative measure and compares benefits per unit of cost. The third is also a relative measure and in a sense represents the average earning power of the money used in the project over the project life. Project feasibilities are judged by whether the benefit-cost ratio is greater than one, and/or, the net present values is greater than zero and/or the internal rate of return (IRR) is higher than the cost of money/capital. The three measures have their relative advantages and disadvantages. The difficulty with with benefit-cost ratios and Net Present Values is that they require determination of a suitable discount rate, generally the opportunity cost of capital, which is often difficult to properly determine. Furthermore, the value of B/C ratio changes depending on where the meeting out in the cost and benefit streams occur. Though the internal rate of return does not require the use of discount rate nevertheless the determination of opportunity cost of capital is required to use as a cut-off rate.

In case of mutually exclusive alternatives[6/] there are some advantages of using NPV criteria[7/] compared to the B/C ratio and IRR: The NPV gives correct ranking of projects so that alternative with highest NPV discounted at opportunity cost of capital should be used. This is accounted by the fact that NPV is an absolute measure and since in mutually exclusive alternatives only one project can be done, it makes sense to go with the one promising the greatest absolute net benefits, (even though the unit-for-unit efficiency represented by B/C ratio and IRR are greater for other alternatives). Furthermore, since the two relative measures, e.g. B/C ratio and IRR fail to take into account the scale effect, they may lead

6/ Mutually exclusive alternatives are competing projects of which only one can be implemented.

7/ J. Price Gittinger (1981), Economic Analysis of Agricultural Projects, IBRD, Washington (Revised Edition).

to erroneous investment choice. B/C ratio and IRR have inherent bias against large projects with relatively high gross returns and cost.[8/]

In the analysis, all of the three measures of project feasibility are calculated and estimated. The current market prices for the project and farmer's input and output are assumed to remain constant throughout the project life. The assumption is consistent with any rate of inflation over the project life so long the relative prices of input and output remain constant. Indirect costs and benefits of the infrastructure investment are not considered.

Cost of Construction for Earthen Channel and Buried Pipe System

Various components of investment, operation and maintenance costs of earthen channel and buried pipe system were identified. Cost of construction for earthen channel was calculated by using FAO furnished data of Tk.10/feet for a total command area of 75 acres for a discharge of 2 cusec.[9/] Construction cost of buried pipe system was obtained from FAO team working in Regional Development Academy of Bogra. Cost figures are shown in table 2. Buried pipe systems require a repair cost of Tk.2,500 for correcting probable damages in pipes and fixtures, and earthen channels are assumed to require a cost of Tk.3,000 per annuam mainly for channel widening, removing grass and silts, and repairing leaks and weak points The salary or opportunity cost of the manager was the same for both systems.[10/] The buried pipe system is assumed to have a working life of 40 years and has no salvage value.The earthen channels, annually maintained and repaired, are assumed to have an infinite life span. But for this analysis, a 40 year project life is assumed for both the buried pipe and open channel systems.

8/ See McKean, R.N., "Efficiency in Government through Systems Analysis with Emphasis on Water Resources Development. New York, Wiley, 1958 (pp 107-116) for discussion of the point with illustrative example.

9/ Length of earthen channel over the entire command area of 75 acres is calculated to be 9,870 feet.

10/ Manager basically performs the function of a clock man. His task is to schedule and routing water delivery for each block in a day.

Cost of Installation and Operation of DTW with Earthen Channel and Buried Pipe System (Table 2)

The investment costs of the DTW for the two water conveyance systems were the same at Tk.380 thousand. This includes the cost of pump, engine, well components and drilling. The operation and maintenance cost of DTW under the two water conveyance systems were different. The difference arose because the DTW engine has had to work for extra hours to cover the expanded command area under the buried pipe system. The O & M cost included expenditures on diesel, lubricant oil, repair and spare parts and operator's wage. Annual O&M cost for DTW with earthen channel and buried pipe system were calculated to be Tk.26.6 thousand and Tk.33.5 thousand respectively. The pump and engine are assumed to have a useful life of 15 and 12 years under earthen channel and buried pipe respectively while well components have 20 years in both systems. Replacement costs are charged as project costs whereas salvage values were credited against project costs.

Benefit Estimates

Benefits were measured at net revenues to the farmers, e.g. after deducting total farm costs from farmer's gross revenue. The cost incurred by the farmer were different from those of the project cost and included costs on seed, fertilizer, manure, pesticide, animal power, and hired labor. Farmer's cost of irrigation is excluded from his budget to avoid double counting. Figures on annual gross benefit before and after DTW irrigation appear in table 3. Crop input requirements and farmer's cost per acre are shown in table 4. Finally table 5 shows net product from farming both before and after DTW irrigation.

Benefit Before Irrigation (table 3-5)

Local aman grown on the entire project area of 165 acres and local aus grown on 5% of the area (8.25 acres) were the two crops existing before irrigation. During this time cropping intensity was 105% (table 1). Annual gross value of production on the entire project area amounted to Tk.474.4 thousand; annual total production costs were Tk.266.0 thousand; and annual total net revenue were Tk.208.4 thousand.

Benefit with DTW Irrigation and Earthen Channel (table 3-5)

With DTW irrigation, local varieties of aman and aus have given way to HYV varieties in 75 acres of the command area, while local varieties continued to be grown in the residual project area of 90 acres. HYV boro, wheat and potatoes were grown during winter months in 50, 15 and 10 acres respetively of the command area which previously remained fallow. Cropping intensity increased from 105% to 194% (table 1). Annual gross value of production in the entire project area amounted to Tk.1308.5 thousand; annual total production costs to Tk.[illegible]9.4 thousand, and annual total net revenue to Tk.523.3 thousand.

Benefit with DTW Irrigation and Buried Pipe System (table 3-5)

The conversion of earthen channel to buried pipes is expected to result in an increased command area of 90 acres. Command area development is assumed to be phased over 3 years in the following manner:

Year	0	1	2	3-40
Acre	0	136	150	165
Benefit as Percentage of Full Benefit	0	82	91	100

With DTW irrigation using buried pipes acreages alloted to HYV aus, aman and boro as well as those for wheat and potato did either increase or are expected to increase in the entire command area. Cropping intensity is estimated to rise from 265% in the first year to 300% in the third and final year (table 1). Annual gross value of production in the entire project area amounted to Tk.2037.2 thousand, annual total production cost to Tk.1153.5 thousand, and annual total net revenue to Tk.782.4 thousand.

Results

A discount rate of 14 percent in real term is assumed[11] to find present value of cost and benefit. In the analysis, cost and benefit streams are expressed in current (May, 1983) prices.

[11] This is the interest rate charged by commercial bank for medium term loans. Probably this rate also reflects the opportunity cost to farmers of capital in Bangladesh.

Change Examined	NPV	B/C	IRR
A. DTW irrigation using earthen channel compared to no irrigation	2118	3.97	68.7%
B. DTW irrigation using buried pipe system compared to earthen challen	977	1.99	30.1%
C. DTW irrigation using buried pipe system compared to no irrigation	3093	2.84	43.9%

Summary and Conclusion

This paper reports an economic analysis of the investment in buried pipe systems for water conveyance. Three measures of project feasibilities, namely, net present value (NPV), benefit-cost ratio(B/C), and the internal rate of return (IRR) are used to shed light on the feasibility of investing in buried pipes instead of earthen channels. Three alternative options are considered, namely (1) transformation of non-irrigated land to DTW using earthen channel conveyance; (2) conversion of a DTW area using earthen channel to one using buried pipes and; (3) transformation of non-irrigated land into a DTW irrigated area directly using buried pipes.

The preference for using one feasibility measure over another for judging economic viability of alternative options would depend on whether we regard the projects to be mutually exclusive or independent. If earthen channels are converted by phases to become a buried pipe system they can be treated as independent; whereas if construction of earthen channel preempt a buried pipe project, they are to be regarded as mutually exclusive. Both are likely possibilities and consequently all the three project feasibility measures are useful.

Looking at each one of the project singly, all are economically viable, e.g. benefit-cost ratios are all greater than one, net present benefits are positive, and internal rate of returns are higher than the likely cost of capital. The problem of selection among these projects depends on whether there is capital limitation or not. In a situation of no budgetary constraint, all three independent projects that have been found feasible can be implemented. Under the more normal conditions of budgetary limitations, however, use of NPV criterion for project selection is recommended, and the decision rule is to select the projects which yield the highest aggregate NPV within the capital constraint. Under this rule, the set of projects (A and B) that first proposes a transformation of non-irrigated land into DTW irrigated area using earthen channel conveyance and then suggesting its conversion to buried pipes are recommended. The decision rule for selecting among mutually exclusive projects in situations of no capital limitation is to select the project with the highest NPV, B/C or IRR. Where there is capital limitation, however, selection would obviously have to be confined to those alternatives whose investment requirements fall within the capital constraint. Under this rule, our three projects give conflicting results. If the investment decisions are based purely on the magnitude of the computed B/C ratio and IRR, then projct A (DTW irrigation using earthen channel compared to no irrigation) is the best alternative. Based on the NPV's, however, project C (DTW irrigation using buried pipe system compared to no irrigation) is

to be selected. One way to resolve the conflict would be to use NPV as the preferred selection criterion[12/]

The analysis used in the report does not incorporate indirect benefits of an intensive irrigation method such as that of a buried pipe system. For a modernizing agriculture relying on manufacturing sectors for supply of inputs and consumer items, these linkages are likely to be substantial and can modify the results upward. Secondly, there might be important non-economic benefits of the project which may justify the expansion of the buried pipe system. Finally, a reduction of the cost of asbestos pipes, which constitute a major portion of total project cost would make the system more profitable.

12/ See arguments given in methodology section and additinally, National Economic Development Authority (1977), A Guide to Project Development, Manila, Philippines (pp. 135-137).

Benefit-Cost Ratio

Present value of incremental benefit is estimated by using the formula:

$$PV = \frac{B_1}{(1+r)^1} + \frac{B_2}{(1+r)^2} + \text{----} + \frac{B_{40}}{(1+r)^{40}}$$

and the present value of incremental cost by

$$PC = \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \text{------} + \frac{C_{40}}{(1+r)^{40}}$$

where PV = Present value of benefits

PC = Present value of costs

B_i = Incremental benefit in the ith year

C_i = Incremental cost in the ith year

r = rate of discount

Benefit-cost ratio (B/C) is thus PV/PC.

Net Present Value

Net present value (NPV) is PV-PC.

Internal Rate of Return

Internal Rate of Return (IRR) is simply the rate of interest that equates the discounted present value of incremental benefits and the present value of the incremental costs. In terms of symbols used previously, the rate of return is the rate of interest at which the present value of incremental benefits $\sum_{t=1}^{\infty} \frac{B_t}{(1+r)^t}$, and the present

value of incremental costs $\sum_{t=1}^{n} \frac{C_t}{(1 + r)^t}$ are equal, or in other words the rate of interest at which the difference between discounted incremental benefits and costs is zero, that is, $\sum_{t=1} \frac{B_t - C_t}{(1 + r)^t} = 0$

TABLE 1

AREA CULTIVATED AND CROPPING INTENSITY

CROP	AREA (ACRES) W	WE	WB	$\overline{WB}$
Aus (Local)	8.25 a/	4.5 b/	1.4 c/	0
Aus (HYV)	0	75	136	165
Aman (Local)	165 d/	90 e/	29 f/	0
Aman (HYV)	0	75	136	165
Boro	0	50 g/	95 g/	115 g/
Wheat	0	15 h/	26 h/	32 h/
Potato	0	10 i/	15 i/	18 i/
Total All Crops	173.25	319.5	438.4	495
Net Cultivated Area	165	165	165	165
Cropping Intensity	105%	194%	265%	300%

W = Without irrigation, WE = With DTW irrigation and earthen channel, WB = With DTW irrigation and present buried pipe command area of 136 acres, $\overline{WB}$ = With DTW irrigation and future buried pipe command area of 165 acres.

a/ Grown before DTW irrigation in 5 percent of total command area of 165 acres (8.25 acres).
b/ Grown after DTW irrigation in 5% of 90 acres (165-75) not covered by DTW with earthen channel (4.5 acres).
c/ Grown in 5% of 29 acres (165-136) not presently covered by DTW with buried pipe system (1.4 acres).
d/ Grown in the entire command area of 165 acres.
e/ Grown in 90 acres (165-75).
f/ Grown in 29 acres (165-136).
g/ Grown after DTW irrigation in 70% of command area (50, 95, 115 acres).
h/ Grown after DTW irrigation in 20% of command area (15, 26, 32 acres).
i/ Grown after DTW irrigation in 10% of command area (10, 15, 18 acres).

TABLE 2

COST OF WATER CONVEYANCE SYSTEM AND DEEP TUBEWELLS

	Water Conveyance System		Deep Tubewell Using	
	Earthen Channel	Buried Pipe	Earthen Channel	Buried Pipe
Fixed Investment Cost (Tk.)	98,700 c/	1,003,156	380,000 e/	380,000 e/
Operation and Maintenance Cost (Tk.)				
Maintenance Cost	3,000 c/	2,500 d/	-	-
Diesel f/	-	-	21,065	27,015
Lubricant Oil g/	-	-	2,950	3,765
Repair and Spares h/	-	-	600	770
Manager's Wage i/	1,600	1,600	-	-
Operator's Wage j/	-	-	2,000	2,000
SUB TOTAL	4,600	4,100	26,615	33,550

Source: FAO Team working at Regional Development Academy, Bogra.

a/ Earthen Channel cost is calculated @ Tk. 10/ft for a command area of 75 acres.

b/ Buried pipe cost refers to the total command area of 165 acres.

c/ For channel widening, removing grass and soils, and repplishing leaks.

d/ For repairing damages in pipes, fixtures, and header tanks and replacement of parts.

e/ Cost is measured as of May 1983 assuming DTW is 200 feet deep, have submergible turbine pump, 21.5 hp. diesel engine and rated discharge of 2 cusec. Cost includes expenditures on pump, engine, materials and accessories, drilling and instillation.

f/ @ .7 gallon/hour and Tk. 34/gallon.

g/ @ 2 gallon/72 hour and Tk. 120/gallon.

h/ For 885 hours annual operation with earthen channel and 1130 hours annual operation with buried pipe system. Working life of DTW pump and engine are assumed to be around 15,000 hours.

i/ 4 months at monthly rate of Tk. 400/month.

j/ 4 months at monthly rate of Tk. 500/month.

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TABLE 3

BURIED PIPE IRRIGATION PROJECT
(ANNUAL GROSS BENEFIT (MAY 1983 PRICES)

ITEM	PRICE (TK./MD.)	GROSS PRODUCTION (MD) W	WE	WB	WB	GROSS VALUE ('000 TK) W	WE	WB	WB
Aus Local	125	99	54	17	0	12.4	6.8	2.1	0
Aus HYV	120	-	2190	4080	4950	-	262.8	489.6	594.0
Aman Local	140	3300	1800	580	0	462.0	252.0	81.2	0
Aman HYV	110	-	2920	5440	6600	0	321.2	598.4	726.0
Boro HYV	130	-	2272	4284	5198	-	295.3	557.0	675.7
Wheat	130	-	480	870	1056	-	62.4	113.1	137.3
Potato	90	-	1200	2176	2640	-	108.0	195.8	237.6
TOTAL GROSS VALUE:						474.4	1308.5	2037.2	2370.6

W = Without irrigation WE = With DTW irrigation and earthen channel, WB = With DTW irrigation and present buried pipe command area of 136 acres, WB = With DTW irrigation and future buried pipe command area of 165 acres.

TABLE 4

BURIED PIPE IRRIGATION PROJECT
CROP INPUT REQUIREMENTS PER ACRE

Item	Aus Local	Aus HYV	Aman Local	Aman HYV	Boro	Wheat	Potato	Price May 1983(Tk.)
Seed (Md.)	1	.4	.4	.4	.5	1.5	30	1/ 280/md.
Fertilizer(Md.) 2/	.1	2.7	.3	3.5	4	3	5.5	3/ 140/md.
Manure(md.)	30	100	100	150	150	125	150	2/md.
Pesticide Cost (Tk.)	0	110	50	110	110	0	70	-
Animal Power/ a-d	12	14	12	14	14	12	12	25/a-d
Hired Labor / m-d 4/	25	40	33	40	48	30	66	20/m-d
Total Cost	1129	1710	1364	2162	2420	2040	7260	
Yield (Md.)	12	30	20	40	45	32	145	

Source: FAO survey data of region.
Authors interview of farmers.

1/ Price of Potato seed is Tk. 150/maund, and Tk. 200/maund for wheat.

2/ Includes urea, T.S.P and MP.

3/ Weighted average price.

4/ Hired labor only.

TABLE 5

BURIED PIPE IRRIGATION PROJECT
ANNUAL CROP PRODUCTION COSTS

Item	QUANTITY USED W	WE	WB	$\overline{WB}$	PRODUCTION COST ('000) W	WE	WB	$\overline{WB}$
Seed (Md)	74.2	385.5	660.2	785.5	20.9	107.9	184.8	219.9
Fertilizer (Md)	50.3	793	1396.9	1684.1	7.0	111.0	195.6	235.8
Manure (Md)	16,748	34,374	56871	65382	33.5	77.7	113.7	130.8
Pesticide Cost	-	-	-	-	8.3	27.3	42.9	50.3
Animal Power (a-d)	2,409	4248	6012	6851	60.2	106.2	150.3	171.3
Hired Labor (m-d)	6,806	12179	18248	20937	136.1	243.5	364.9	418.7
Total Cost					266.0	729.4	1153.5	1349.6
TOTAL GROSS VALUE					474.4	1308.5	2037.2	2370.6
NET PRODUCT					208.4	523.3	782.4	898.2

W = Without irrigation.
WE = With DTW irrigation and earthen channel.
WB = With DTW irrigation and present buried pipe command area of 136 acres.
$\overline{WB}$ = With DTW irrigation and future buried pipe command area of 165 acres.

Table 7: COST AND BENEFIT STREAM FOR DTW IRRIGATION USING EARTHEN CHANNELS AND BURIED PIPE SYSTEM

Year	Cost (000 Tk)		Benefit (000 Tk)			Incremental Cost (000 Tk)			Incremental Benefit (000 Tk)		
	With DTW Irrigation and Earthen Channel	With DTW Irrigation and Buried Pipe System	Without Irrigation a,b/	With DTW c/ Irrigation and Earthen Channel	With DTW d/ Irrigation and Buried Pipe System	DTW Earthen Channel Compared to No Irrigation	DTW Buried Pipe Compared to Earthen Channel	DTW Buried Pipe Compared to No Irrigation	DTW Earthen Channel Compared to No Irrigation	DTW Buried Pipe System Compared to Earthen Channel	DTW Buried Pipe System Compared to No Irrigation
0	478.7	1383.2	208.4	208.4	208.4	478.7	904.5	1383.2	0	0	0
1	31.2	37.7	208.4	523.3	782.4	31.2	6.5	31.7	314.9	259.1	574.0
2	31.2	34.6	208.4	557.8	862.2	31.2	6.5	34.6	349.4	304.4	653.8
3	31.2	37.7	208.4	628.0	898.2	31.2	6.5	37.7	419.6	270.2	689.8
4-12	280.8	339.3	1875.6	5652.0	8083.8	280.8	58.5	339.3	3776.4	2431.8	6208.2
-	-	(25.4)	-	-	-	-	(25.4)	(25.4)	-	-	-
13	31.2	164.4	208.4	628.0	898.2	31.2	133.2	164.4	419.6	270.2	689.8
14-15	62.4	75.4	416.8	1256.0	1796.4	62.4	13.0	75.4	839.2	540.4	1379.6
-	(25.4)	-	-	-	-	(25.4)	-(25.4)	-	-	-	-
16	158.2	37.7	208.4	628.0	898.2	158.2	-120.5	37.7	419.6	270.2	689.8
17-20	124.8	150.8	832.6	2512.0	3592.8	124.8	26.0	150.8	1678.4	1080.8	2759.2
-	(19.8)	(19.8)	-	-	-	(19.8)	-	(19.8)	-	-	-
21	130.2	103.1	208.4	628.0	898.2	130.2	-27.1	103.1	419.6	270.2	689.8
22-24	93.6	113.1	625.2	1884.0	2694.6	93.6	19.5	113.1	1258.8	810.6	2069.4
-	-	(25.4)	-	-	-	-	(25.4)	(25.4)	-	-	-
25	31.2	164.6	208.4	628.0	898.2	31.2	133.4	164.6	419.6	270.2	689.8
26-30	156.0	188.5	1042.0	3140.0	4491.0	156.0	32.5	188.5	2098.0	1351.0	3449.0
-	(25.4)	-	-	-	-	(25.4)	-(25.4)	-	-	-	-
31	158.2	37.7	208.4	628.0	898.2	158.2	-120.5	37.7	419.6	270.2	689.8
32-36	156.0	188.5	1042.0	3140.0	4491.0	156.0	32.5	188.5	2098.0	1351.0	3449.0
-	-	(25.4)	-	-	-	-	(25.4)	(25.4)	-	-	-
37	31.2	164.4	208.4	628.0	898.2	31.2	133.2	164.4	419.6	270.2	689.8
38-40	93.6	114.6	625.2	1884.0	2694.6	93.6	21.0	114.6	1258.8	810.6	2069.4
-	(41.9)	(83.8)	-	-	-	(41.9)	41.9	(83.8)	-	-	-

a/ Benefit is in net terms, e.g. gross benefit minus cost.
b/ Calculated for the total command area of 165 acres.
c/ Includes loss of production (equivalent to 2 acres) due to channel construction on the 75 acre command area (proportion to crop production).
d/ Buried pipe command area is assumed to increases to 150 acre in second year and to 165 acre in third year and thereafter.

TABLE 6

COST STREAM FOR WATER CONVEYANCE SYSTEM AND DEEP TUBEWELL

	COST: WATER CONVEYANCE SYSTEM ('000 Tk.)						COST: DEEP TUBEWELL (000 TK.)					
	EARTHEN CHANNEL			BURIED PIPE SYSTEM			EARTHEN CHANNEL			BURIED PIPE SYSTEM		
Year	Investment Cost	O&M Cost	Total Cost	Investment Cost	O&M Cost	Total Cost	Investment Cost	O&M Cost	Total Cost	Investment Cost	O&M Cost	TOTAL Cost
0	98.7	0	98.7	1003.2	0	1003.2	380.0	0	380.0	380.0	0	380.0
1	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	0	27.6	27.6
2	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	0	30.5	30.5
3	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	0	33.6	33.6
4-12	0	41.4	41.4	0	36.9	36.9	0	239.4	239.4	0 h/	302.4	302.4 h/
–	–	–	–	–	–	–	–	–	–	(25.4)	–	(25.4)
13	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	127.0 i/	33.6	160.5 i/
14-15	0	9.2	9.2	0	8.2	8.2	0 a/	53.2	53.2 a/	0	67.2	67.2
–	–	–	–	–	–	–	(25.4)	–	(25.4)	–	–	–
16	0	4.6	4.6	0	4.1	4.1	127.0b/	26.6	153.6 b/	0	33.6	33.6
17-20	0	18.4	18.4	0	16.4	16.4	0	106.4	106.4	0	134.4	134.4
–	–	–	–	–	–	–	(19.8)c/	–	(19.8)c/	(19.8)c/	–	(19.8)c/
21	0	4.6	4.6	0	4.1	4.1	99.0d/	26.6	125.6d/	99.0d/	33.6	99.0d/
22-24	0	13.8	13.8	0	12.3	12.3	0	79.8	79.8	0	100.8	100.8
–	–	–	–	–	–	–	–	–	–	(25.4)j/	–	(25.4)h/
25	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	127.0k/	33.6	160.5k/
26-30	0	23.0	23.0	0	20.5	20.5	0	133.0	133.0	0	168.0	168.0
–	–	–	–	–	–	–	(25.4)e/	–	(25.4)e/	–	–	–
31	0	4.6	4.6	0	4.1	4.1	127.0f/	26.6	153.6	0	33.6	33.6
32-36	0	23.0	23.0	0	20.5	20.5	0	133.0	133.0	0	168.0	168.0
–	–	–	–	–	–	–	–	–	–	(25.4)l/	–	(25.4)l/
37	0	4.6	4.6	0	4.1	4.1	0	26.6	26.6	127.0m/	33.6	160.5m/
38-40	0	13.8	13.8	–	12.3	12.3	0	79.8	79.8	0	100.8	100.8
–	–	–	–	–	–	–	(41.9)g/	–	(41.9)g/	(83.8)n/	–	(83.8)n/

a/ 20% salvage value for pump and engine after 15 years. b/ Replacement cost of pump and engine. c/ 20% salvage value of well components after 20 years. d/ Replacement cost of well components. e/ 20% salvage value of pump and engine after 30 years. f/ Replacement cost of pump and engine. g/ 33% salvage value of pump and engine. h/ 20% salvage value for pump and engine after 12 years. i/ Replacement cost of pump and engine. j/ 20% salvage value for pump and engine after 24 years. k/ Replacement cost of pump and engine. l/ 20% salvage value for pump and engine after 36 years. m/ Replacement cost of pump and engine. n/ 66% salvage value of pump and engine.