Development of Irrigated Agriculture in East Pakistan : Some Basic Considerations*

by

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INTRODUCTION

East Pakistan is characterized by a heavy monsoon rainfall accompanied by inundation of vast areas during the summer season. The inundation is caused by high flood levels of two of the largest rivers of the world, the Brahmaputra-Jamuna and the Ganges-Padma and by the influx of such major tributaries as the Meghna within the deltaic area. Probably nowhere else in the world is there such a confluence of great rivers as in East Pakistan.

The heavy precipitation and extensive inundation create difficulties for most crops other than rice. Thus, rice is grown on 23 million acres or 112 per cent of the 20.5 million acres of the net area sown[1]. The area of all other crops is 5 million acres, raising the total cropped area[2] to 28 million acres. This gives an intensity of cropping[3] of 137 per cent.

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*This is one of the two related articles on the possibilities of a rapid development of agriculture in East Pakistan. The second article which deals with the "Role of Nitrogen-Responsive, High Yielding Varieties of Rice, and the Use of Fertilizer in the Development of Agriculture in East Pakistan" will appear in a subsequent issue of this *Review*.

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[1]*Net area sown* represents the area actually used for cropping purposes during a year, regardless of number of crops raised on it.

[2]*Total cropped area* represents the aggregate area of all crops raised on the same land during different seasons of the year. East Pakistan has three growing seasons, namely, the summer or *aus* season from March to July, the *bhadoi* or *aman* season from July to November and the *rabi* season from November to March.

If one acre of land is used for growing an *aus* crop as well as an *aman* crop and a *rabi* crop, the net area sown will be one acre, whereas the total cropped area will be three acres.

[3]*Intensity of cropping* represents the ratio between the total cropped area and the net area sown. It is usually shown as a percentage. Thus, the cropping intensity of rice in East Pakistan is $23/20.5 \times 100 = 112$ per cent whereas the total cropping intensity is $28/20.5 \times 100 = 137$ per cent.

From November to March, the rainfall is insufficient for crop production and less than four million acres are grown to winter crops. These crops depend upon the remaining soil moisture, with hoped for assistance from uncertain showers. The months of October, April and May also frequently have insufficient rainfall for good crop yields. Some crops also suffer from drought for short period during the monsoon.

In the absence of large funds for investment and advanced engineering and agricultural technology, the cultivators have had to adapt themselves to naturally occurring conditions of land and water rather than modify these conditions so that both land and water could be fully used around the year. The long dry period from October to April, the inundation due to floods and the uncertainty of the monsoon, which determines the pattern of agriculture in East Pakistan, point to the development of irrigation, flood control and drainage as the means for a rapid development of agriculture in East Pakistan.

Master Plan for Water Resources Development

The East Pakistan Government has been working on the problem during the last seven years. A "Master Plan" has been prepared by the International Engineering Company of San Francisco (IECO) for the East Pakistan Water and Power Development Authority (EP-WAPDA) [24 and 25]. The water development projects included in this Master Plan are estimated to cost Rs. 9,960 million including Rs. 2,882 million in foreign exchange upto 1985 [24, p. 4]. Out of the total cost, about Rs. 4,226 million are proposed to be spent by 1970 and Rs. 7,846 million by 1975 [24, p. 6].

The major emphasis in the IECO Master Plan is on *flood control* measures. The Master Plan is basically a massive scheme for empoldering[4] large parts of East Pakistan into 50 projects which would provide flood protection and drainage facilities to about 12.1 million acres and irrigation facilities to about 7.9 million acres by 1985 [24, p. 2].

About Rs. 8,810 million or 88 per cent of the total estimated cost is proposed to be spent on flood control and multipurpose projects (which include flood control, drainage and irrigation facilities). Only Rs. 1,150 million or 12 per cent of the total cost is proposed for purely irrigation projects [24, pp. 120-121].

Under the IECO Master Plan, the *flood control* works would be provided in the *first stage*. This is because every year, large areas (estimated at about ten million acres) are flooded by the three major rivers, the Ganges-Padma, the

[4] Empoldering means division of area into units called polders which are provided with embankments on all sides to prevent inundation.

Brahmaputra-Jamuna, the Meghna and their tributaries. The farmers of East Pakistan have learned to live with these normal floods over the centuries [24, p. 87]. However, when the floods are abnormal either in their date of arrival, rapidity of rise or magnitude of duration, the losses of crops, livestock and property are generally severe[5].

Flood protection is to be obtained by building some 2,000 miles of embankments along the major rivers and their tributaries. Embankments on both sides of the three main rivers, the Brahmaputra-Jamuna, the Ganges-Padma and the lower Meghna, are proposed to be completed by 1975. The protecting embankments would be designed with regulators for admitting flood waters to the project areas when required and for evacuating excess quantities of water by gravity or by pumping.

The Master Plan envisages the development of *irrigation* at the *second stage*. Within the total protected area of 12.1 million acres, irrigation is to be provided for about 1 million acres by 1975 and to about 3.9 million acres by 1985. In addition, in areas not requiring flood protection, irrigation would be provided to about 1.5 million acres by 1975 and to about 4 million acres by 1985 [24, p. 119 and 27, pp. B VII 48-49].

In flood protected areas, surface water would be brought by gravity canals through regulators in the embankments when rivers are full and by pumping from the rivers when they are low. Within the project areas, the fields would be supplied with water by a gravity canal system with distributaries and water courses. Relift pumps would be provided in some areas to supply land not commanded by gravity canals.

Maximum annual diversions from the main rivers would be about 41.7 million acre-feet (MAF) for irrigation of about 6.8 million acres by 1985 [24, p. 112]. This would mean an average annual diversion of about 6.2 acre-feet per acre irrigated.

Groundwater is available in many parts of the province. However, the IECO states that because of the high cost of development and operation of wells, groundwater projects would be limited to a small area in the Rangpur, Dinajpur, Mymensingh and Comilla districts where recharge is assumed to be adequate and which lack an adequate supply of surface water [24, p. 111].

Although low-lift pumps of the Agricultural Development Corporation are mentioned in the Master Plan, there is no reference to small low-lift pumps which

[5] In 1955, an area of 12.6 million acres or 38 per cent of total land area of East Pakistan was inundated. Similarly, there were severe floods in 1954, 1956, 1962 and 1964.

In 1962, the loss of crops alone was estimated at Rs. 1,100 million [24, p. 87]. Comparable detailed estimates of loss of crops for other years are not available.

can be purchased and used by the farmers themselves. Similarly, there is no reference to private tubewells which have proved so successful in West Pakistan during the Second Plan period.

The IECO states that the flood-control projects of the type recommended by them are seldom able to retire the capital investment directly from benefits in any part of the world. Rather, the investment in such projects is viewed as prudent use of public resources for indirect as well as direct returns. In this connection the IECO refers to flood-protection works on the Mississippi which presumably have not been able to retire the capital cost [24, p. 137].

The IECO further states that if direct cash flow from the completed Master Plan projects are not enough to cover interest on capital costs and operation and maintenance, then new capital must be raised for each step of the total development. The IECO also points out that general and special taxes on the entire province may be the best means of accumulating improvement capital, but they consider that it will prove one of the more difficult and complicated aspects of the implementation of the Master Plan [24, p. 137].

The recoveries of charges from the beneficiaries will be less than the interest on capital and the cost of operation and maintenance. The sum outstanding against the Master Plan projects in 1985 for capital cost plus the annual deficit on operation of these projects is estimated to amount to a total of Rs. 12,162 million as against the capital cost of Rs. 9,960 million [24, p. 138].

The IECO Master Plan evisages an increase in the gross crop value at constant prices from Rs. 3,059 million in 1964 to Rs. 6,694 million in 1958 [24, p. 174]. This means an annual rate of increase of 3.8 per cent in agricultural production during the 21-year period.

Rice production is expected to increase from 9.5 million tons in 1964 to 19.6 million tons in 1985. The IECO assumes that an increase of 4.3 million tons can result from the use of fertilizers, improved seed, plant-protection measures and improved farming practices [27, p.B Vii-II]. This would raise rice production in East Pakistan from 9.5 million tons in 1964 to 13.8 million tons by 1985 without water development projects. The balance of 5.8 million tons of rice can be obtained, according to the IECO, only by major *flood-control* and drainage projects provided in the *first stage* with *irrigation* projects provided in a *second stage*.

Planning Commission Proposals

While The IECO takes the position that *flood-control* is the *prerequisite* of agricultural development in East Pakistan, the Planning Commission seems to have taken a stand that covers both positions. Although they state that small irrigation schemes without flood-control works are more important, they make a smaller allocation for small irrigation schemes than for flood-control works. Thus, in the *Third Five-Year Plan,* the Planning Commission states: "It is apparent, however, that the extent to which the agricultural potential of the province can be realized depends *on* great measure on the additional *water* that can be made available during the winter months. Conditions are ideal during this period for intensive irrigated agriculture and a large segment of the Province can eventually grow two or even three complete crops per year" [38, p. 304]. The Planning Commission further states "that in most years supplemental winter irrigation is possible for about 11 million acres including 4 million acres of *boro* rice and 7 million acres of other crops such as fruits, vegetables, oilseeds and livestock fodder. Thus...a large and vigorous low-lift pumps and surface irrigation programme during the Third Plan period is practicable" [38, p. 305]. However while making allocations for the Third Plan schemes, the Planning Commission provided only Rs. 390 million for "irrigation schemes" out of total allocation of Rs. 2,268 million for "water development schemes". Against this, a sum of Rs. 1,746 million is provided for "flood regulation schemes" and for "multipurpose development schemes" most of which include flood control and drainage works [39, pp. 21-22].

Strategy Proposed in this Paper

After an examination of the existing irrigation schemes in East Pakistan, the author considers that the IECO has investigated the possibilities of large gravity canals fed by large pumping plants installed on the rivers and protected by flood-control works in considerable detail. They do not, however, appear to have investigated fully the possibilities of greatly expanded use of low-lift pumps and small tubewells which can be used without a costly gravity canal system and a costly flood-control system. An examination of the current irrigation schemes and cropping patterns in East Pakistan indicates that a very large increase in agricultural production can be realized by concentrating on small low-lift pumps and small tubewells. These can provide supplemental winter irrigation to about eleven million acres including four million acres of *boro* paddy and seven million acres of other *rabi* crops such as fruits, vegetables, potatoes, oilseeds, wheat and maize and other fodder crops as estimated by the Planning Commission [38, p. 305].

At present the *aus*[6] paddy, jute and sugarcane crops suffer from drought

[6] There are three rice crops in East Pakistan. These are: *aus* paddy grown on some seven million acres; *aman* paddy grown on about fifteen million acres and *boro* paddy grown on about one million acres. Out of fifteen million acres under *aman* crop, about six million acres are sown by broadcasting and about nine million acres by transplanting.

The term *aus* is derived from the Bengali word 'ashu' and means early. The origin of the words *aman* and *boro* are not well established.

The *aus* crop is adapted to relatively dry conditions. It is also sown in March to May and harvested in June to August.

The *broadcast aman* is sown in areas where depth of flooding ranges between three to twelve feet. It is sown in March-April and harvested in November-December.

The *transplanted aman* is grown in areas where depth of flooding is zero to three feet. The seed of this *aman* is sown in June-July, the seedlings are transplanted in July-August and the crop is harvested from November to January.

The *boro* crop is grown as a winter crop in areas which are too deeply flooded during the summer to permit growing any other crop. The seed of *boro* is sown in November-December, the transplanting is done in December-January and the crop is harvested in April-May.

during March, April and May. The *aus* paddy also suffers flood damage in June and July. The low-lift pumps and tubewells can enable a large part of the nine million acres under *aus* paddy, jute and sugarcane to be sown early and escape the damage from drought as well as floods.

Similarly, at present the *aman* crop suffers from delayed transplanting due to lack of sufficient rainfall or due to late harvesting of the *aus* crop. Also, droughts in October and November, at the critical flowering and maturing stage, cause considerable reduction in yields. The low-lift pumps and tubewells can enable high yields to be obtained from *aman* paddy by providing supplemental irrigation at the time of transplanting but more particularly at the time of flowering and maturity. The author, therefore, recommends that the strategy proposed by the IECO be modified and most *irrigation* projects be executed in the *first stage* and most *flood-control* and drainage projects be executed in the *second stage*. For this purpose, part of the funds should be diverted from multipurpose and flood-control schemes to winter irrigation schemes during the next 5 to 10 years. With the introduction of high-yielding rice varieties, expanded use of fertilizers, and other improved agricultural practices it should be possible to reach the rice production target of 19.6 million tons with small irrigation schemes during the winter, early summer, and late autumn seasons without executing major flood-control schemes.

Hypotheses Enunciated in this Paper

The above strategy is based on a number of hypotheses which are enunciated in the following paragraphs. These hypotheses will be tested against the working of existing irrigation projects in East Pakistan in Sections II and III of this paper.

Total cultivated area of East Pakistan is 21.6 million acres, including 20.5 million acres as net area sown and 1.1 million acres of current fallow[7]. Out of this, only 2 million acres is above flood level. A major part of the remaining area of 19.6 million acres is subject to flooding of varying depths (Appendix Table A-1). The *first* hypothesis of this paper is that small irrigation schemes, such as low-lift pumps and tubewells, can be executed in a large part of East Pakistan without providing major flood-protection works. A system of large gravity canals, fed by diversion or pumping from the rivers, as proposed in the IECO Master Plan, would need complete flood-protection works. Flood-protection works are likely to be exceedingly costly in East Pakistan because of the sheer magnitude of the flood water. The maximum combined discharge of Ganges-Padma-Brahmaputra-Jamuna between 1956 and 1962 was 5.1 million cusecs [24, p. 88]. By comparison, the maximum discharge of the Mississippi River in the

[7] *Cultivated* area consists of *net area sown* plus *current fallow*. *Current-fallow* is that part of the cultivated area which is not cropped during a particular year, but was cropped in the previous year.

United States was only 2.1 million cusecs in 1927 which is considered as the maximum on record [24, p. 92]. The cost of small irrigation schemes based on small low-lift pumps and small tubewells is, therefore, likely to be only a small fraction of the cost of large gravity canals supported by a system of flood-control works.

Our *second* hypothesis is that water requirements of crops for supplementary irrigation are likely to be small. East Pakistan receives about 60 to 120 inches of rainfall in a major part of the province and large areas are inundated by floods every year. The mean annual evaporation is only about 45 to 50 inches [28, plate AII-6]. Most of the low and intermediate lands (which constitute 72 per cent of the total cutivated area of East Pakistan) have relatively high watertables even during the dry season. The depth of the watertable seldom exceeds 10 to 15 feet, and in many places is within 3 to 4 feet of the soil surface. At the end of the monsoon it comes to within 1 to 2 feet of the surface in most places. Under these conditions, with predominantly silty soils, considerable moisture is supplied to the plant root zone by capillarity. With the advent of irrigation, it is likely that watertables will be even closer to the soil surface and requirements for supplementary irrigation will be small [27, p.B-VII-32].

Our *third* hypothesis is that although *large pumps* are technically more efficient compared to small pumps, insofar as utilization of fuel and the cost of pumping per unit volume of water is concerned, they are *more costly* insofar as the cost of water delivered to the fields is concerned. This is because they need a costly canal distribution system and a large part of the pumped water is lost by seepage in the distribution system before it reaches the cropped land to be irrigated. The benefits from large gravity canals are also reduced because of the long gestation period of these projects.

A *fourth* hypothesis, which is an extension of the *third* hypothesis, is that although the cost of installation and operation of *tubewells* for each unit of water pumped is high, the actual cost of delivery of water is less than that in the case of large gravity canals fed from large pumping plants installed on the rivers. The tubewell water can be used where it is pumped without providing for a costly canal distribution system and practically no seepage losses are involved in the distribution system. Another reason for the low cost of water delivered to the fields by tubewells is that practically no gestation period is involved.

The *fifth* hypothesis is that although small *private* low-lift pumps and small *private* tubewells may be *less efficient* in the utilization of fuel and pumping of water as compared to large *government* low-lift pumps and large *government* tubewells, they are *more economical* because of their very low capital cost, extreme care with which they are worked by the farmers and the great economy in the use of irrigation water brought about by the farmers when they have to pay for the pump, the tubewell, and the fuel.

Our *sixth* hypothesis is that *irrigation* schemes in a country like East Pakistan, where there is practically no rainfall and practically no cropping for about six months of the year, are likely to be *highly produetive* and would fully retire the capital cost from the direct benefits. The cash flow from these schemes would not only cover the interest on capital cost and operation and maintenance cost, but would also leave considerable income to pay for the cost of flood-control projects proposed for second stage of development.

The *seventh*, and the last hypothesis, which is an extension of the sixth hypothesis, is that *irrigation* lays a firm ground, technically and economically, for improved farm practices, most particularly for the rapid introduction of *high-yielding varieties* and greatly expanded use of *fertilizer*. As high-yielding varieties and fertilizer spread with expansion of irrigation, a chain-reaction is set up; irrigation supporting the expansion of high-yielding varieties and fertilizer use, and high-yielding varieties and fertilizer use supporting the rapid expansion of irrigation. The farmers are, therefore, likely to take up, on a private basis, small low-lift pumps and small tubewells along with the high-yielding varieties and fertilizers.

The above hypotheses are tested against the working of the existing irrigation projects in East Pakistan. Some of the surface-water development projects are discussed in Section II whereas some of the groundwater development projects are discussed in Section III. The benefit-cost estimates of all projects studied in this paper are compared in Section IV and a summary of conclusions is given in Section V.

II. SURFACE WATER DEVELOPMENT

Two projects dealing with surface water development in East Pakistan will be considered in this section. One of these deals with the large gravity canal system fed by large pumping plants installed on the rivers, which is the major type of irrigation recommended by the IECO for East Pakistan. The second deals with low-lift pumps which are recommended for large-scale use by the author.

A typical example of the first type is the Ganges-Kobadak project which is in the most advanced stage of development. A typical example of the second type is the "Mechanical Cultivation and Power Pump Irrigation" scheme operated by the Agricultural Development Corporation (ADC).

1. GANGES-KOBADAK PROJECT

The Kushtia Unit of the Ganges-Kobadak project is located south of the Ganges-Padma and the Gorai river and covers most of the Kushtia District.

The project provides for a gravity canal system fed by large pumping plants installed on the river Ganges to serve about 3,30,000 acres of land.

Work on Kushtia Unit of the Ganges-Kobadak project was started in 1955 following approval of the project by the government in 1954. A power-house to provide electricity for the pumping of water from the Ganges river into large gravity canals to serve the area was completed in 1958. A number of difficulties arose in the construction of the main pumping plant to house three large pumps with a total capacity of 3,000 cusecs. An auxiliary pumping plant with 12 medium sized pumps, having a total capacity of 1,400 cusecs, was completed in 1961. The main pumping plant is still under construction, 12 years after the project was approved [25, pp. 320-321].

The twelve medium-size pumps installed in the auxiliary pump-house get frequently out of order, but cannot be repaired until the water level in the river and in the intake channel falls in November [18, p. 4]. Any breakdown of the pumps during the summer thus results in loss of pumping throughout the summer season.

Maintenance of the intake channel has also presented problems due to formation of shoals. The intake channel is excavated by dredgers every winter but is filled up with silt during the next monsoon season [18, p. 4].

The Kushtia Unit is divided into two phases. Irrigation canals have been laid out in 94,000 acres included in phase one of the unit. The canal system includes 46 miles of main canal, 133 miles of secondary canals, 310 miles of tertiary canals and 500 hydraulic structures. From these canals 1,770 outlets were planned for the irrigation of 94,000 acres by constructing field channels which were to be dug by the farmers. The farmers have so far refused to construct the field channels except in small areas. The project authorities have, therefore, increased the number of outlets to 3,055 [18, p. 6]. Even then each outlet will have to irrigate an average of about 31 acres and field channels will have to be constructed if the entire area of 94,000 acres is to be irrigated.

In order to understand the behaviour of the farmers it is pertinent to remember that the project was started in 1955 but that no water was made available upto 1962. On the contrary, the project authorities, in protecting the area from floods by embankments shut off the flood waters which had been used for natural flood irrigation by the farmers for centuries before. The rainfall in this area is low: about fifty to sixty inches a year, compared to the provincial average of over eighty inches a year. The flood water was essential for raising a rice crop and the cutting off of this flood water turned the farmers against the WAPDA authorities.

Even after 1962, when pumping was started, canals have been run at below the full supply level. Therefore, irrigation water could not have reached the fields of all the farmers even if they had constructed the field channels. It was, therefore, only natural that the farmers refused to construct the field channels. In August and September 1965, most (though not all) channels were run to full supply level [18, Annexure 6]. The farmers did use the incoming water for irrigation of 28,600 acres during September 1965 (*see*, Table I) by flooding their fields from plot to plot, a practice which they had used for centuries with natural flood waters before the Ganges-Kobadak Project was started.

TABLE I

WATER PUMPED, AREA IRRIGATED, AND DEPTH OF WATER USED ON EACH ACRE IRRIGATED ON THE GANGES-KOBADAK PROJECT IN 1965

Month	Fortnight	Water requirement based on area for which indent was placed by the extension staff on the engineering staff	Actual water supplied by the engineering staff	Total area irrigated	Average depth of irrigation per acre irrigated
(1)	(2)	(3)	(4)	(5)	(6)
		(......*cusecs*.........	)	(*acres*)	(*inches*)
June	Second	65	427	6,800	23
July	First	18	137		
	Second	56	315	3,400	49
August	First	229	471		
	Second	248	740	10,700	42
September	First	293	1,085		
	Second	264	983	28,600	26
October	First	314	1,027		
	Second	220	882	7,000	100
Total June to October					240

Source: Columns (1) to (4) from [18, p. 5]. Column (5) from [19].
Column (6): the actual quantity of water given in cusecs converted into acre-inches by multiplying cusecs in Column (4) with the number of days in each fortnight and then multiplying the resultant cusec-days with 24 (each cusec-day assumed to be equal to 24 acre-inches).

The method of flood irrigation from plot to plot is an exceedingly costly and wasteful method for use of the pumped water. Total depth of water pumped for each acre of crop grown in 1965/66 was about 240 acre-inches (Column (6) of Table I). It has been assumed by the IECO that about half of the pumped water is lost in the canal system [24, p. 184]. The irrigation water used for each crop grown was, therefore, about 120 acre-inches. Water use of 120 acre-inches is exceedingly high particularly when compared to the irrigation water used in areas served by low-lift pumps of the ADC (discussed in the next section) where the farmers raised a *boro* crop with only 21 acre-inches of pumped water. It appears that either more than half of the pumped water was lost in the canal system *or* that much of the water put on the fields was removed by the farmers on to unsown land and then put into drains.

Capital Cost

In December 1964, the IECO estimated the capital cost of Kushtia Unit at Rs. 232 million out of which Rs. 28.9 million or 12.5 per cent was allocated to the Jessore Unit [25, p. 230]. The Project Director of the Ganges-Kobadak Project estimates the cost of the Kushtia Unit at Rs. 333.9 million (Appendix Table A-2). Out of this, about 12.5 per cent or Rs. 41.6 million may be allocated to the Jessore Unit. The net capital cost of the Kushtia Unit would be about Rs. 292.3 million for a total irrigatable area of 330 thousand acres. The per acre capital cost thus comes to over Rs. 886. The capital cost of canals and hydraulic structures to be provided on these canals account for nearly one half of the total cost, that is, about Rs. 153 million or Rs. 460 per acre (Appendix Table A-2).

A sum of Rs. 221.5 million had been spent on the Ganges-Kobadak Project by March 1966 and the remaining sum of Rs. 112.4 million is required for completion of the work during the Third-Plan period.

Annual Cost

The annual cost of the Kushtia Unit was estimated by the IECO, in December 1964, at Rs. 15.0 million for 330 thousand acres or Rs. 45.4 per acre irrigated. This is based on the following assumptions:

i) The total capital cost of the Kushtia Unit would be Rs. 232 million out of which Rs. 28.9 million (or 12.5 per cent) would be allocated to the Jessore Unit and Rs. 203.1 million to the Kushtia Unit [25, p. 320].

ii) Interest will be charged at the rate of 4 per cent [25, p. 185].

iii) The life of the project will be 50 years, therefore repayment of the capital cost has been based on a sinking fund contribution and interest payment, both at 4 per cent interest for 50 years [25, p. 185].

iv) Replacement reserves were established as a sinking fund contribution at 4 per cent interest. The life of replaceable items was assumed as varying from 20 years for culverts, 25 years for mechanical equipment, 35 years for electrical equipment and 40 years for substations [25, p. 185].

v) The annual cost of maintenance and operation of irrigation, flood control and drainage features was set at 2 per cent of the capital cost [25, p. 186].

vi) The price of electricity was assumed to be Rs. 0.05 per kilowatt hour for pumping purposes [25, p. 186].

The author considers that most of the above assumptions by the IECO are incorrect or unjustified and need modification. For example:

i) The capital cost of the Kushtia Unit is estimated at Rs. 334 million by the Project Director of the Ganges-Kobadak Project as against Rs. 232 million estimated by the IECO [*see*, Table III].

ii) A 4 per cent rate of interest is very low for Pakistan as a measure of opportunity cost. According to Mahbubul Haq: "It would seem that a shadow price of capital between 8 to 10 per cent would be...appropriate..." [17, p. 47]. The author has used a rate of interest of 8 per cent for *all* projects discussed in this paper.

iii) The life assumed for some of the items appear to be excessive. The mechanical equipment, such as the pumping plants, are not likely to last for twenty-five years in East Pakistan. The twelve medium-size pumps installed in 1961 had to be completely overhauled in 1965. It is unlikely that they will last upto 1986. A ten-year life would be more appropriate for such items.

iv) The average price of electricity in East Pakistan according to the IECO Master Plan works out to be Rs. 0.18 per kwh in 1965/66, Rs. 0.15 in 1974/75 and Rs. 0.125 per kwh in 1984/85 [28, p. D I-7]. While it is perfectly legitimate to subsidize the sale of electricity for use in agriculture in initial years, for the purpose of benefit-cost analysis, the full cost must be taken into consideration. In this paper, the price of electricity has been assumed to be Rs. 0.125 per kwh for estimating the benefit-cost ratio.

The author has recalculated the annual operation cost on the basis of the revised assumptions, points *i*), *ii*) and *v*) above, and the results are presented in Table II below.

The total annual cost increases to Rs. 31.7 million and cost per acre comes to Rs. 96 per acre against Rs. 45.4 per acre as estimated by the IECO.

Benefit-Cost Ratio

The present value of crop production is estimated by the IECO at Rs. 91.8 million from 330 thousand acres, or Rs. 278 per acre [25, p. 320]. The value of crop production is expected to rise to Rs. 233.6 million or Rs. 700 per acre at the time of full development. The increase will result from higher yields per acre

TABLE II

ANNUAL COST PER ACRE AS ESTIMATED BY IECO AND AS ESTIMATED BY THE AUTHOR FOR THE KUSHTIA UNIT OF GANGES-KOBADAK PROJECT

(*in million rupees*)

Item (1)	Estimate by IECO (2)	Estimated by the author (3)
Interest and amortization	10.8[a]	23.9[b]
Operation and maintenance	2.4	3.4[c]
Replacement reserve	0.1	0.1
Power	1.7	4.3[d]
Total annual cost	15.0	31.7
Cost per acre (*rupees*)	45.4	96.0

Source: Column (2) from [25, p. 320].
Column (3) from estimates by the author, *see* text.

Notes: *a*) On the basis of capital cost of Rs. 203 million and interest rate of 4 per cent.
b) On the basis of capital cost of Rs. 292 million and interest rate of 8 per cent.
c) Increase in proportion to capital cost.
d) Price of electricity assumed to be Rs. 0.125 per kwh against Rs. 0.05 assumed by the IECO.

and from increases in the intensity of cropping from the present 140 per cent to 228 per cent [25, p. 320].

The gross annual benefit would amount to Rs. 141.7 million. The cost of production of crops is estimated at 50 per cent of the gross value. The net benefit would, therefore, be Rs. 70.9 million or Rs. 215 per acre. The benefit-cost ratio was, thus, worked out by the IECO as 215/45 = 4.7. If the full annual cost of Rs. 96 per acre, estimated by the author, is taken into account, the benefit-cost ratio falls to 215/96 = 2.2.

Proposals for Increasing the Efficiency of Water Use on the Ganges-Kobadak Project

It was shown in Table I that the present cropping on the Ganges-Kobadak Project means a water use of 120 acre-inches per acre which is an exceedingly high figure particularly when compared to the ADC low-lift pumps where twenty-one acre-inches were used to raise a *boro* crop in 1964/65 (*see*, Table V) and the cooperative villages of the Pakistan Academy for Rural Development

A considerable loss of water is inevitable in the early stages of development of irrigation on *all* large canal systems when the area cropped is small in relation to the available water supply. This loss can be reduced by extending the area under irrigated crops by constructing field channels. There must, however, be some strong incentive for the farmers to shift from flood irrigation to controlled irrigation which is possible with field channels. The new high-yielding rice varieties evolved at the International Rice Research Institute (IRRI), Manila, and introduced in East Pakistan in 1966 are expected to provide this incentive. The difference that an early sown and transplanted irrigated IRRI rice, with the proper application of fertilizer would make to the production of a crop in the *aus* season is likely to be quite spectacular so that once the farmers see the effect of this transplanted-irrigated-fertilized crop, they will begin to construct their field channels and may complete them in a few years. For this purpose, it would be necessary to lay out fertilizer demonstration trials on IRRI rice on each tertiary canal in the project area in the 1966 *aman* season, if the farmers have to grow the IRRI rice in the 1967 *aus* season, when seed would be available for considerable part of the area that can be grown with the IRRI varieties. At present, *aus* rice is grown on about 50 per cent of the total cultivated area in the project [25, p. 320]. A large part of the 47,000 acres can be put under irrigated transplanted *aus* with IRRI seed during the 1967 or 1968 *aus* season, if all the canals are run at full-supply level from February to June 1967. It would be desirable to run all the canals at full-supply level from now onward so that the farmers will develop confidence in the availability of water when they need it.

Summary: Ganges-Kobadak Project

The first unit of the Ganges Kobadak Project, known as the Kushtia Unit, provides for a gravity canal distribution system fed by large pumping plants installed on the Ganges river to irrigate about 330 thousand acres of land in the Kushtia district. The capital cost of the project is estimated at Rs. 292 million or Rs. 886 per acre. The annual operating cost is estimated at Rs. 96 per acre. The benefits are estimated at Rs. 215 per acre and the benefit-cost ratio works out to be 2.2.

Work on the project was started in 1955 but serious difficulties have been encountered in the construction of the main pump-house which is to house 3 large pumps of a total capacity of 3,000 cusecs. The pump-house is still under construction 12 years after the project was approved. An auxiliary pump-house was constructed to house 12 medium-size pumps with a total capacity of 1,400 cusecs. These pumps were installed in 1961 but have frequently gone out of order during the last two years. These cannot be repaired until the water level in the river and the intake channel falls in November. The intake channel also presents serious problems. It gets silted up during the monsoon and has to be excavated by dredgers every winter.

The canal system has been completed for a total area of 94,000 acres but the farmers have so far refused to construct the field channels. Water is being used by flooding from plot to plot with the result that 240 acre-inches of water were pumped for each acre irrigated during 1965/66. About 120 acre-inches were actually put on each acre irrigated.

The efficiency of water use on the Ganges-Kobadak Project can be greatly increased by the introduction of high-yielding IRRI rice varieties combined with optimum use of fertilizer. This will provide an incentive to farmers to construct the field channels and to make use of controlled irrigation water required for the IRRI rice varieties.

The following factors regarding the Ganges-Kobadak Project lead us to the conclusion that further work on such large gravity canals fed by large pumping plants installed on the rivers should be delayed till alternative methods of irrigation have been more thoroughly investigated:

i) The high capital cost involved, *ii*) the difficulties encountered in the construction of the main pump-house to house the large pumps, *iii*) frequent breakdown of the medium-size pumps housed in the auxiliary pump-house, *iv*) inability to repair the medium-size pumps so long as the water level in the river and in the intake channel remains high, *v*) difficulties involved in the maintenance of the intake channel, *vi*) failure to utilize the irrigation water by the farmers by refusing to construct field channels, and *vii*) comparatively low benefit-cost ratio of the project.

2. LOW-LIFT POWER PUMPS

The IECO has given details of a large number of surface-water development projects involving gravity canals fed by diversions from rivers or by pumping plants installed on the rivers. However, only a passing reference has been made to the low-lift pump programme of the Agricultural Development Corporation (ADC). The low-lift pump programme of the ADC is not included in the IECO Master Plan and is not discussed in detail.

As low-lift pumps are likely to make a greater contribution to agricultural production in East Pakistan during the Third-Plan period than all the surface-water development projects of the WAPDA, these will be discussed in somewhat greater detail in this paper.

The ADC Programme

In the districts of Sylhet, Mymensingh, Dacca and Comilla there are large areas of very low lands which are deeply flooded during the summer season. No crops can be raised in these areas until the flood waters have receded in October or November. Most of these lands are fertile and have been brought under *boró* paddy which is grown from December to April. As rainfall is very scanty during the winter, supplemental irrigation is required. Supplementary irrigation has been applied over the centuries by lifting water from low-lying places and from small streams and drainage channels onto the fields by crude ccuntry methods.

In order to provide irrigation facilities to the *boro* crop on a large scale, a scheme for the "Mechanical Cultivation and Power Pump Irrigation" was introduced in East Pakistan in 1951/52 and expanded in 1955/56. The number of power pumps increased sharply from 40 in 1955/56 to 1,345 in 1959/60 and the area irrigated increased from less than 3,000 acres in 1955/56 to over 47,000 acres in 1959/60 [23]. The scheme was further expanded during the Second-Plan period (Appendix Table A-3) and the maximum acreage of 1,57,000 acres was irrigated with 2,300 pumps in 1963/64.

The ADC has proposed to expand this scheme by purchasing 16,000 two-cusec pumps during the Third-Plan period and to reach a target of irrigation of 750,000 acres of *boro* paddy by 1969/70 (Appendix Table A-4).

Capital Cost

The capital cost of a two-cusec pump is estimated at about Rs. 7,500 by the ADC [5, p. 5]. The ADC had 1,100 one-cusec pumps, which were purchased in 1956/57 and 1957/58, at an average price of about Rs. 5,000 each [8]. No additional one-cusec pumps have been purchased since then.

The capital cost of a two-cusec pump has now increased to Rs. 8,650 [7, p.12]. We have assumed a proportionate increase in the capital cost of a one-cusec pump from Rs. 5,000 to Rs. 5,770.

Annual Operating Cost

The ADC estimates the cost of irrigation of one acre of *boro* paddy at Rs. 57.5 per acre with a two-cusec pump [5, p. 5]. No estimates are presented for a one-cusec pump by the ADC.

We have collected information on hours worked, fuel consumed, and area irrigated by two-cusec pumps and by one-cusec pumps during the last three years. The results are presented in Appendix Table A-3 and are summarized in Table III below.

TABLE III

HOURS WORKED AND AREA IRRIGATED BY TWO-CUSEC AND ONE-CUSEC PUMPS OF ADC: 1962/63 to 1964/65

Year	Hours worked per pump		Area irrigated per pump		Fuel consumed per pump	
	Two-cusec pump	One-cusec pump	Two-cusec pump	One-cusec pump	Two-cusec pump	One-cusec pump
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	(......*hours*... ..)		(......*acres*......)		(......*rupees*......)	
1962/63	928	687	63	69	700	520
1963/64	707	729	64	60	800	610
1964/65	639	756	60	42	1030	680
Average for three years	733	717	62	59	840	610

Source: [Appendix Table A-5].

During the last three years, 1962/63 to 1964/65, the two-cusec pumps irrigated on the average, 62 acres of crops and used an average of Rs. 840 worth of fuel. The one-cusec pumps irrigated almost as much area (59 acres) as the two-cusec pumps and used an average of Rs. 610 worth of fuel.

On the basis of the capital cost of Rs. 8,650 and Rs. 5,770 for two-cusec and one-cusec pumps, respectively, average irrigated area of 62 acres and 59 acres, and average fuel consumption as shown in Table III, the author has calculated the annual operating cost of the two types of pumps. These are shown in Columns (2) and (3) of Table IV. Other items like cost of operating staff, ADC overhead charges, *etc.*, are taken from the calculations provided by Mr. Hobbs [23].

The annual operating cost comes to Rs. 60 per acre for two-cusec pumps and Rs. 50 per acre for one-cusec pumps. The ADC has been charging Rs. 37 per acre but has not been able to realize the whole of this hire charge. It has so far been able to realize about Rs. 10 million out of Rs. 20 million [10, p. 16]. The total area irrigated to-date is about 700 thousand acres. The recoveries have therefore, averaged about Rs. 14 per acre. A subsidy of about 71 per cent has, therefore, been involved in the use of one-cusec pumps and 77 per cent in the use of two-cusec pumps.

Benefit-Cost Ratio

The ADC estimates the yield of *boro* paddy raised on low-lift pumps at 25 maunds per acre [10, pp. 16-17]. Although no crop-cutting experiments have been done by the ADC, the work carried out by the Pakistan Academy of Rural Development (PARD), Comilla indicates that the estimates obtained by the ADC are reasonable. The price of *boro* paddy in 1964/65 was about Rs. 16 per maund [45, pp. 48 and 66][8]. The gross income from one acre of *boro* paddy was, thus, Rs. 400 per acre (25×16). The cost of production of all crops raised with the aid of irrigation is estimated as 50 per cent of the gross value on IECO-WAPDA projects [25, p. 186]. If the same rate is adopted for the ADC pumps, the net income would be Rs. 200 per acre, against the estimated expenditure of Rs. 60 and Rs. 50 per acre respectively on two-cusec and one-cusec pumps. The benefit-cost ratio is thus 3.3 for two-cusec pumps and 4.0 for one-cusec pumps.

TABLE IV

ESTIMATED ANNUAL OPERATIONAL COST OF TWO-CUSEC AND ONE-CUSEC PUMP UNDER THE EXISTING ADC SYSTEM AND WHEN FARMERS HAVE TO PAY FOR FUEL PLUS ANNUAL RENTAL CHARGES

Item	When ADC pays for the fuel and charges flat per acre rate		Whe farmers pay for fuel plus annual rental charges	
	Two-cusec pump	One-cusec pump	Two-cusec pump	One-cusec pump
(1)	(2)	(3)	(4)	(5)
1) Interest and amortization at 8 per cent in 10 years (8650 × .149 and 5770 × .149)	1,289	860	1,289	860
2) Interest and amortization on building and equipment	82[a]	55[b]	82[a]	55[b]
3) Fuel consumption	840[c]	610[c]	1,080[e]	840[f]
4) Spares, travelling, transport and contingencies	270[a]	180[b]	220[g]	147[g]
5) Pay of staff	1,197[a]	1,197[d]	750[h]	750[h]
6) ADC's overhead charges	65[a]	43[b]	65[a]	43[b]
	3,743	2,945	3,486	2,695
Area irrigated (*acres*)	62	59	90	70
Cost per acre irrigated (*rupees*)	60	50	39	39

Notes: *a*) Estimates by Mr. Hobbs [23]. *Source* : See text.
b) In proportion to the capital cost of Rs. 8,650 and Rs. 5,770 respectively.
c) From Table III.
d) Pay of staff for one-cusec pump assumed the same as that for two-cusec pump.
e) For 90 acres at Rs. 12 per acre against Rs. 11 per acre incurred in 1962/63. One rupee extra for increased price of diesel oil in 1966/67.
f) For 70 acres at Rs. 12 per acre.
g) Some reduction due to less staff to be supervised.
h) Assistant pump drivers and most of the unit staff engaged on collection of hire charges not required.

[8] Mahmoodur Rahman, Research Specialist at the Pakistan Academy of Rural Development, Comilla, estimated the yield of irrigated *boro* paddy at 24 maunds per acre in 1964/65 [45, p. 48].

The price of *boro* paddy was Rs. 17 per maund [45, p. 48], whereas price of *shaita* paddy was Rs. 15 per maund [45, p. 66]. An average price of Rs. 16 per maund has been taken for the two varieties combined.

Proposal for Raising the Efficiency of ADC Pumps

The question of increasing the efficiency of the ADC pumps has been dealt with at length by Mr. Richard H. Patten of the Harvard Advisory Group, Dacca. In a paper on "Pilot Projects in Irrigation" involving cooperation between the Basic Democracies, the Agricultural Development Corporation, the Agricutural Directorate and the Water and Power Development Authority [40]. It has been pointed out that the present system of per acre charge for low-lift pumps has three main disadvantages. *First,* it gives no incentive to the farmers to economise on use of water. *Second,* there is no incentive for the farmers to assist the ADC in an assessment of the acreage irrigated or to assist in the actual collection of the payment. The ADC must, as a consequence, maintain a large staff to make recoveries and even then not more than half of the hire charges are recovered. *Third,* the pump driver and the local people are given an incentive to falsify the records on the amount of fuel used and sell part of the fuel in the market [40, p. 12].

The actual working results of the ADC pumps (Table V) during the last three years confirm these points. Columns (2) and (4) of Table V show that the number of hours taken to irrigate one acre of *boro* paddy by a two-cusec pump was reduced from fifteen in 1962/63 to eleven in 1964/65.

However, the cost of fuel consumed by the pumps increased from eleven rupees per acre in 1962/63 to seventeen rupees per acre in 1964/65. This was inspite of the fact that the cost per gallon of diesel oil for the ADC remained the same[9].

TABLE V

HOURS WORKED, WATER USED AND FUEL CONSUMED PER ACRE IRRIGATED BY A TWO-CUSEC ADC PUMP

Year (1)	Hours worked (2)	Water used (3)	Fuel consumed (4)
	(hours)	*(acre-inches)*	*(rupees)*
1962/63	15	29	11
1963/64	11	22	13
1964/65	11	21	17

Source: Calculated from Appendix Table A-5.

It has been proposed [40] that the Basic Democracies and Local Government Department through the Thana Councils and the Union Councils organize groups of farmers for use of low-lift pumps and use the works programme funds to pay the first year's hire charges of Rs. 1,000 for those organized groups of farmers who

[9] Though an excise duty of Rs. 0.20 per gallon was levied on diesel oil in 1964/65 and another Rs. 0.20 in 1965/66, this did not affect the ADC, as a rebate equal to the excise duty was allowed for the use of diesel oil in agriculture.

agree to pay Rs. 100 in advance. In the second and third years, the charges by Thana Council would be gradually reduced and those by farmers increased while in the fourth year the farmers groups would pay the entire Rs. 1,100 in advance [40, p. 14].

The cost of fuel would be borne by the farmers groups from the very first year.

The ADC has agreed to this system of a fixed hire charge of Rs. 1,100 for a two-cusec pump plus cost of fuel from 1966/67 onward. It is anticipated that this will lead to the following significant changes:

i) considerably increase the area irrigated by the pumps
ii) considerably reduce the cost of operation of the pumps, and
iii) increase the recoveries of hire charges.

The change in the system of realization of hire charges in the Comilla Kotwali Thana caused an increase of over 50 per cent in the area irrigated by each tubewell in 1965/66 (*see*, Col. (5), Table IX). The change in system of collecting hire charges may be expected to cause a similar increase in the area irrigated by the ADC pumps from 64 and 60 acres in 1963/64 and 1964/65 to about 90 acres or more for a two-cusec pump during 1966/67.

An average area of ninety acres per two-cusec pump is not excessive. An irrigation of sixty-nine and sixty acres was actually achieved with the one-cusec ADC pumps throughout East Pakistan during 1962/63 and 1963/64 (*see*, Table VI). Some of the two-cusec pumps in the Mymensingh and Sylhet districts have irrigated between seventy and ninty acres in recent years under the old system of realization of hire charge (*see*, Table VI). They may, therefore, be expected to reach an average irrigation of ninety acres per pump with the change in the system of hire charges.

The change in the system of collecting hire charges may be further expected to reduce the cost of fuel from seventeen rupees per acre in 1964/65 to the 1962/63 level of about eleven rupees per acre in 1966/67, when the farmers have to pay for the amount of water actually used. Charging for the fuel will mean metering water itself. Under the old system, a flat fee regardless of quantity of water used was levied so that water was used till the marginal product was equal to zero.

Annual Operating Cost When Farmers Pay For Water Used

The annual operating cost for a two-cusec pump irrigating 90 acres of *boro* paddy, when the farmers pay for quantity of water used by buying their own fuel, is shown in Columns (4) and (5) of Table IV. It is assumed that no assistant pump driver will be appointed and that much of the staff, which is used for collection of hire charges, will not be required. It is further assumed that the ADC will continue to maintain workshops and provide repairs and spares for the pumps. It is also assumed that the ADC will maintain the fuel depots but will no longer issue any fuel to the pump drivers. The farmers will purchase their own fuel from the ADC depots or from the local market for operation of the ADC pumps. Under the new system the total annual operating cost of a two-cusec pump is likely to be reduced from Rs. 3,743 for 62 acres at present to about Rs. 3,486 for 90 acres of *boro* irrigation by farmers or Rs. 39 per acre. Out of the total annual cost, the farmers will pay about Rs. 2,180 or Rs. 24 per acre. They will spend Rs. 1,080 on fuel and pay Rs. 1,100 as annual hire charges to the ADC. The balance of Rs. 1,300 (or 37 per cent of the cost) will be borne by the government as a subsidy on the ADC pump operations. The subsidy of 37 per cent compares with the present subsidy of about 75 per cent borne by the government on the ADC operations.

The annual operation cost of a one-cusec pump is likely to be reduced from Rs. 2,945 for 59 acres at present to about Rs. 2,695 for 70 acres when farmers have to buy their own fuel. It may be appropriate to fix the annual rental charges for one-cusec pump at two-thirds of the rental charges of two-cusec pumps, that is, in proportion to the capital cost of the two. This would mean an annual rental charge of about Rs. 700 per pump. The farmers will then pay in all Rs. 1,540 (Rs. 840 for fuel and Rs. 700 as annual rental charges). The balance of Rs. 1,155 or 43 per cent of the annual cost will be borne by the government as a subsidy.

Benefit-Cost Ratio Under the Proposed Programme

Under the new system proposed, the gross income and the net income would be the same as under the old system, that is, Rs. 400 and Rs. 200 per acre respectively.

The annual cost of operation would however be reduced to only Rs. 39 per acre against Rs. 60 and Rs. 50 per acre under the old system. The benefit-cost ratio would, thus, be 200/39 = 5.1 against 3.3 and 4.0 under the old system.

Introduction of high-yielding IRRI rice varieties, combined with the optimum use of fertilizer, would greatly increase the yield of *boro* paddy on the ADC pumps. According to Chandler [4, p. 21], these varieties should yield a minimum of about 75 maunds per acre during the *boro* season with good irrigation facilities and with 100 pounds of nitrogen, 40 pounds of phosphate and 40 pounds of potash. All the farmers are not likely to apply the optimum dose of fertilizer. The author has assumed that the farmers will apply an average of about 60 pounds of nitrogen, 30 pounds of phosphate and 20 pounds of potash. With this level of fertilizer application they would probably get about 50 maunds of paddy per acre, giving a gross return of Rs. 800. The cost of production is not likely to increase in the same proportion. The cost of production (excluding cost of fertilizer and irrigation) may go up from Rs. 200 with the old varieties to about Rs. 300 with the new IRRI varieties. The net income would, therefore, rise to Rs. 500 per acre. The cost of fertilizer, at an unsubsidized rate, comes to about Rs. 55 per acre[10]. Water requirements of IRRI rice would also be higher. These may be 50 per cent higher than those of ordinary *boro*. The fuel consumption will, therefore, increase from Rs. 12 to Rs. 18 per acre and total cost of irrigation from Rs. 36 to Rs. 42 per acre.

Total cost of fertilizer and water would then come to Rs. 97 per acre. The benefit-cost ratio would be 500/97 = 5.2. The net income for the farmers would increase from Rs. 164 (= 200 − 36) with *boro* paddy to Rs. 403 (= 500 − 97) per acre by growing IRRI rice.

TABLE VI

AVERAGE AREA COVERED BY TWO-CUSEC AND ONE-CUSEC PUMPS OF ADC IN DIFFERENT ZONES OF EAST PAKISTAN: 1962/63 to 1964/65

Year	Capacity	Average area irrigation per pump in							Average East Pakistan
		Sylhet	Kuliar-char	Chitta-gong	Dacca	Brahman baria	Naogaon	Jessore	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1962/63	Two-cusec	96	77	35	55	52	43	—	63
	One-cusec	53	70	38	40	111	36	—	69
1963/64	Two-cusec	76	71	42	48	81	44	—	64
	One-cusec	68	40	36	33	82	62	—	60
1964/65	Two-cusec	77	62	36	50	71	53	46	60
	One-cusec	35	32	53	53	22	—	124	42
3-year average	Two-cusec	82	68	38	51	70	46	46	62
	One-cusec	54	52	41	46	86	43	124	59

Source: Calculated from statements supplied by the Agricultural Development Corporation with their letter No. ADC/ENG/DEVB/IP-33/65/3225, dated 7 December, 1965.

Acquisition of Pumps during Third-Plan Period: One-cusec Versus Two-cusec

The ADC has proposed the acquisition of 16,000 two-cusec pumps during the Third-Plan period (Appendix Table A-4). Figures in Table VI indicate that the

10 Urea 1.6 maunds at Rs. 20 per maund (Rs. 32), triple-super-phosphate 0.8 maunds at Rs. 20 per maund (Rs. 16) and muriate of potash 0.5 maund at Rs. 14 per maund (Rs. 7)

actual area irrigated by the two-cusec pumps in Chittagong, Dacca, Naogaon and Jessore zones during the Second-Plan period justified the use of one-cusec pumps instead of two-cusec pumps.

As the number of pumps increases during the Third-Plan period, the area available at each site would probably become smaller and smaller. It would, therefore, be more economical to purchase 24,000 one-cusec pumps instead of 16,000 two-cusec pumps during the Third-Plan period. The cost of both would be the same. The one-cusec pumps can be used in Chittagong, Dacca, Naogaon and Jessore zones and in all other parts of East Pakistan. The presently available two-cusec pumps can be concentrated in Sylhet, Kuliarchar and Brahmanbaria zones where larger blocks of land are available.

The ADC does not want any one-cusec pumps even when the size of block available is just enough for a one-cusec pump and not for a two-cusec pump. The ADC states: "In similar conditions, *i.e.*, if a two-cusec set is used in a one-cusec block, there will be saving of approximately Rs. 400 per set" [8, p. 4]. The "saving" of Rs. 400 claimed by the ADC results because two pump drivers are supposed to be required for a one-cusec pump and only one pump driver is supposed to be required for a two-cusec pump. An additional pump driver is claimed for one-cusec pump because the pump has to be worked for 1,000 hours in the season whereas the two-cusec pump has to work only 500 hours in the season.

Two questions arise in this connection:

i) does a one-cusec pump need two-drivers?

ii) does Pakistan have so much extra capital that it can afford to purchase equipment costing Rs. 8,650 to do the work which can be done by an equipment costing Rs. 5,570?

Regarding *i*) the ADC pumps working for 1000 hours in 5 months or 200 hours a month would need the services of the pump driver for about 8 hours a day. The tubewells installed in the cooperative villages of the PARD, Comilla, worked for 12 hours a day on an average during the *boro* season in 1965/66 and only one-pump driver was appointed. There is no reason why one ADC pump operator should not be able to work for 8 hours a day.

Regarding the second point, the 16,000 two-cusec pumps proposed for the Third-Plan period by the ADC would cost Rs. 138 million. If 16,000 one-cusec pumps are purchased, these would cost about Rs. 92 million. Pakistan can use the extra Rs. 46 million in some other development project rather than lock them up in two-cusec pumps which have to do the job of one-cusec pumps. Or, alternatively Pakistan can purchase 24,000 one-cusec pumps and irrigate 50 per cent additional area.

Small Private Low-Lift Pumps

According to a survey by the EP-WAPDA, quoted by the ADC, there are about five million acres of land situated on both sides of perennial streams which can be irrigated by low-lift pumps [6, Appendix XIII].

The 24,000 one-cusec pumps proposed for the ADC in this paper for the Third-Plan period plus a carryover of pumps from the Second-Plan period can irrigate about 1.5 million acres of land situated in blocks of 50 acres or more. The remaining area of 3.5 million acres will probably consist of smaller blocks where pumps of less than one-cusec capacity would be more economical. These can best be operated by farmers themselves.

The Agricultural Development Bank of Pakistan (ADBP) is importing 400 small pumps of 0.5 cusec capacity and 400 pumps of 0.25 cusec capacity at a cost of Rs. 4,60,000 in foreign exchange. The C & F cost of these pumps would be less than Rs. 600 each. However the import duty, sales tax, defence surcharge and profit allowed to the importers would raise the sale price of these pumps in East Pakistan to about Rs. 1,100 per pump. These pumps are being imported for the first time in East Pakistan but are in general use on a large scale in the rice growing areas of South East Asia, particularly in Thailand [13]. Ultimately, most farmers having larger holdings would like to have their own pumps.

There are about 6,50,000 farmers operating 7.2 million acres (38 per cent of the total cultivated area of the province) who have more than 7.5 acres each (Appendix Table A-6). Out of these, about 5,00,000 farmers are located in the districts of Sylhet, Mymensingh, Dacca, Comilla, Rajshahi, Faridpur, Pabna, Rangpur, Jessore, Chittagong, Khulna and Noakhali where water form perennial streams is available for pumping by low-lift pumps. Assuming that 10 to 20 per cent of these larger farmers purchase their own pumps in the near future, about 50,000 to 1,00,000 pumps can be sold in the next two to three years.

To facilitate the purchase of these pumps by the farmers, it is suggested that the government should either abolish the import duty and sales tax on low-lift pumps or allow a subsidy equal to the import duty and sales tax. This would permit the sales of these pumps at *C & F* cost plus a profit margin for the dealers, that is, at about Rs. 700 per pump. The once-and-for-all subsidy of Rs. 400, on the sale of these pumps would actually be much less than the continuous subsidy now being borne by the government on the working of the ADC pumps.

Only two types of pumps (one type of 0.25 cusec and one type of 0.5 cusec) are being imported by the ADBP. It is suggested that importers of all makes of pumps who are prepared to import and sell their pumps to the farmers should be allowed to import and sell all pumps that they can possibly sell. It is further suggested that small pumps should be placed on the free import list as has been done for tractors. The ADBP should finance the purchase of these pumps by the farmers under the International Development loan (IDA)

With the possibilities of making very high profits by growing IRRI rice with optimum use of fertilizer, which is possible only with irrigation water during the *boro* and *aus* seasons, the sale of these pumps may be even higher than that assumed in this paper. As the ADBP will recover the full foreign exchange cost from the IDA, repeat licences should be issued for any importer who has sold 50 per cent of his imported pumps and asks for a repeat licence .

Summary: Low-Lift Pumps

During the Second-Plan period, the low-lift pumps of the ADC provided irrigation facilities to a larger area (1,50,000 acres) than all the irrigation schemes of the WAPDA.

Two types of pumps have mainly been used by the ADC, one-cusec pumps and two-cusec pumps. The capital cost of a one-cusec pump is about Rs. 5,770 and it covered an average of 59 acres a year. The capital cost of a two-cusec pump is about Rs. 8,650 and it covered an average of 62 acres. The capital cost is thus Rs. 98 per acre for one-cusec pumps and Rs. 144 per acre for two-cusec pumps.

The annual operating cost of a one-cusec pump is Rs. 50 per acre irrigated whereas that of a two-cusec pump is Rs. 60 per acre irrigated.

The net benefit per acre was about Rs. 200 per acre in both cases. The benefit-cost ratio was thus 4.0 for a one-cusec pump and 3.3 for a two-cusec pump.

The ADC has now agreed to charge an annual hire charge of Rs. 1,100 plus cost of fuel for a two-cusec pump. It is estimated that the total area irrigated will increase from 62 acres under the old system to about 90 acres under the new system for two-cusec pump. It is further estimated that total annual operating charges will come to about Rs. 3,486 (Rs. 39 per acre), out of which Rs. 1080 will be spent directly by the farmers on the fuel and Rs. 1,100 will be paid by the farmers to the ADC as hire charges. The balance of Rs. 1,300 (37 per cent of the cost) will be borne by the government as a subsidy on the ADC operations compared to the existing subsidy of about 75 per cent.

In the past, two-cusec pumps covered only as much area as the one-cusec pumps because large blocks of land where two-cusec pumps could be used were not available in most parts of East Pakistan. As the number of pumps greatly expands during the Third-Plan period, area of blocks available at each site will become smaller and smaller. It would, therefore, be desirable to purchase 24,000 one-cusec pumps rather than 16,000 two-cusec pumps during the Third-Plan period. They will cost the same amount but will irrigate an area 50 per cent larger. It should be possible to reach an irrigation of about 1.5 million acres against 750 thousand acres proposed by the ADC.

III. GROUNDWATER DEVELOPMENT

Two projects on groundwater development now under execution in East Pakistan will be discussed in this section. One of these relates to large electric-driven tubewells installed by the WAPDA in the north-west portion of the province near Thakurgaon in the Dinajpur district. The second relates to small diesel-driven tubewells installed by the Pakistan Academy for Rural Development (PARD), Comilla. Finally, possibilities of installation of private tubewells in various parts of the province will be discussed at the end of this section.

1. GROUNDWATER DEVELOPMENT AND PUMP IRRIGATION IN THE NORTHERN DISTRICTS OF EAST PAKISTAN

Under this project, 380 large capacity electric tubewells, 60 electric-driven low-lift pumps and 800 diesel-driven low-lift pumps have been installed to irrigate 1,86,800 acres of land in the Dinajpur, Rangpur, Bogra and Rajshahi districts. A power-house with seven 1500-KW diesel-driven generating units has been set up at Thakurgaon to supply electricity to the 380 tubewells and 60 low-lift pumps.

Capital Cost

The capital cost of the tubewells, the electric-driven and the diesel-driven low-lift pumps is given in Table VII. The capital cost of one WAPDA tubewell comes to Rs. 1,20,000 without electric facilities and Rs. 2,30,000 per tubewell inclusive of electric generation, transmission and distribution facilities.

On the basis of 240 acres proposed to be irrigated by each tubewell, the capital cost is equal to Rs. 500 per acre without electric facilities and Rs. 960 per acre inclusive of electric facilities.

Annual Cost

In October 1963, the East Pakistan WAPDA estimated the annual operation cost of 380 tubewells and 60 electric-driven low-lift pumps at Rs. 12.2 million upto 1971/72 (Column (2) of Table VIII). The 380 tubewells are expected to irrigate 91 thousand acres and the 60 electric-driven low-lift pumps are expected to irrigate 19 thousand acres or a total of 110 thousand acres. The annual cost would, thus, be Rs. 110 per irrigated acre upto 1971/72 (Row (12) of Table VIII).

TABLE VII

CAPITAL COST OF WAPDA TUBEWELLS, ELECTRIC-DRIVEN LOW-LIFT PUMPS AND DIESEL-DRIVEN LOW-LIFT PUMPS

Item (1)	Total capital cost (2)	Number (3)	Cost of one tubewell/ electric low-lift pump/diesel low-lift pump (4)
	(million rupees)	*(number)*	*(rupees)*
Tubewells	45.63	380	120,000
Electric-driven low-lift pumps	6.25	60	104,000
Transmission lines	31.72	440[a]	72,000
Power-house	18.08	440[a]	41,000
Subtotal	101.68	440[a]	231,000
Diesel-driven low-lift pumps	32.95	800	4,000
Total	134.64		

a) 380 tubewells and 60 electric low-lift pumps. *Source*: [11, p. 11].

In the estimates prepared by the EP-WAPDA, a 5 per cent rate of interest was assumed for local currency and 4 per cent for the foreign exchange component. As previously noted, we have used a rate of interest of 8 per cent for all project discussed in this paper. The annual cost on the basis of an 8 per cent rate of interest comes to Rs. 15.3 million (Column (4) of Table VIII) against Rs. 12.2 million estimated by the EP-WAPDA on the basis of 4 and 5 per cent rate of interest. The annual cost is equal to Rs. 138 per acre against Rs. 110 per acre estimated by the EP-WAPDA.

After 1971/72 the Thakurgaon power-house is proposed to be integrated into the provincial grid. The cost of electricity is then assumed to be reduced from Rs. 0.13 per kwh for electricity supplied from the Thakurgaon power-house to Rs. 0.05 per kwh charged for agriculture on the provincial grid throughout East Pakistan. The annual operation cost for tubewells and electric low-lift pumps is then supposed to be reduced from Rs. 12.2 million in 1971/72, to Rs. 8.9 million in 1972/73. Therefore, the per acre cost would be reduced from Rs. 110 to Rs. 81 a year (Col. (3) of Table VIII).

TABLE VIII

ANNUAL OPERATION COST OF WAPDA TUBEWELLS, ELECTRIC-DRIVEN LOW-LIFT PUMPS, AND DIESEL-DRIVEN LOW-LIFT PUMPS

Item	Estimates by WAPDA at 4 and 5 per cent rate of interest		Estimate by the author on the basis of 8 per cent rate of interest
	Cost up to 1971/72	Cost after 1972/73	
(1)	(2)	(3)	(4)
A. *Tubewells and Electric Low-Lift Pumps* (*in thousand rupees*)			
1) Tubewells	4,267	4,267	5,609
2) Electric low-lift pumps	536	536	709
3) Transmission lines	1,789	1,789	2,804
4) Power-house	1,292	...	1,857
5) Fuel for power-house	4,630	...	4,630
6) Power from the provincial grid	..	2,074	.
7) Collecting fee	226	226	226
8) **Sub-total**	12,740	8,892	15,835
9) *Minus* sale of surplus power	578	.	578
10) **Total annual cost**	**12,162**	**8,892**	**15,257**
11) Area irrigated (*in thousand acres*)	110	110	110
12) **Cost per acre** (*in rupees*)	**110**	**81**	**138**
B. *Diesel Low-Lift Pumps* (*in thousand rupees*)			
13) Annual cost	3,911	3,911	4,821
14) Fuel for diesel pumps	1,230	1,230	1,230
15) Collecting fee	156	156	156
16) **Total annual cost**	**5,297**	**5,297**	**6,207**
17) Area irrigated (*in thousand acres*)	76	76	76
18) **Cost per acre** (*in rupees*)	**69**	**69**	**81**
C. *Tubewells, Electric Pumps and Diese Pumps* (*A - B*)			
19) Total annual cost (*in thousand rupees*) (row (10) + row (16))	**17,458**	**14,188**	**21,463**
20) Total area irrigated (*in thousand acres*) (row (11) + row (17))	187	187	187
21) Cost per acre (*in rupees*) (row (19) ÷ row (20))	93	76	115

Source: Columns (2) and (3) calculated from [11, p. 27].
Column (4) calculated using 8 per cent rate of interest.

As has been pointed out by the author in the section dealing with the Ganges Kobadak Project, the sale of electricity at Rs. 0.05 per kwh for agricultural use can be justified in the initial stage of development and subsidized by the government. However, in the benefit-cost analysis the full cost of electricity must be taken into consideration. The cost of pumping water from the WAPDA tubewells would, therefore, remain Rs. 138 per acre even after 1971/72.

If the diesel-driven pumps are also included, the per acre cost of the scheme is reduced to Rs. 115 per acre (*see*, row (21) of Table VIII).

In December 1964, the IECO estimated the annual operating cost for the entire scheme at Rs. 11.5 million [25, p. 204] against Rs. 17.5 and 14.2 million estimated by the WAPDA in October 1963. The per acre cost was shown to be Rs. 62 by the IECO against Rs. 94 and Rs. 76 estimated by the WAPDA. Apprently, the IECO failed to take into account the estimates prepared by the WAPDA in 1963.

In April 1965, Mr. B.M. Abbas, the then Commissioner for Water Development, EP-WAPDA, stated that the annual operating cost of tubewells would be as high as Rs. 135 per acre if electric power for pump operation, facilities for operators, construction of distributory channels, and other necessary facilities were taken into account [1, p. 3].

It may be pointed out that Mr. B.M. Abbas' estimate of Rs. 135 per acre is quite close to the estimate or Rs. 138 per acre when interest is calculated at 8 per cent and the full cost of electricity produced at the Thakurgaon power-house is taken into consideration.

Benefit-Cost Estimates

The gross benefit for the project is estimated by the WAPDA at Rs. 127.9 million for the whole project of Rs. 685 per acre [11, p. 25]. The net benefits are estimated to be 50 per cent of the gross benefits or about Rs. 343 per acre.

The annual operation cost for the tubewells is estimated at Rs. 138 per acre. The benefit-cost ratio comes to 2.5.

The IECO Master Plan estimates the gross benefits on full development at Rs. 102.2 million and net benefit at Rs. 51.1 million [25, p. 204]. The net benefits are equal to Rs. 274 per acre. The IECO estimated the annual cost to be at Rs. 62 per acre and the benefit-cost ratio at 4.4. However, taking the rate of interest at 8 per cent and the full cost of electricity, the annual operating cost comes to Rs. 138 per acre and the benefit-cost ratio falls to 2.0.

Utilization of Tubewell Water: Some Recommendations

The power-house and most of the tubewells were installed during 1962/63 and 1963/64. Actual irrigation started in May 1965 and about 4,000 acres were irrigated from 116 tubewells during summer 1965 and about 400 acres during winter 1965/66. The average commanded area per tubewell is 240 acres. But the irrigated area averaged only 35 acres per tubewell during summer 1965 and 3 acres per tubewell during winter 1965/66, even though no water charges were collected from the farmers. An examination of working records of tubewells indicates that basic causes for this failure to utilize tubewell water are the following:

i) Electricity connections have not so far been given to 50 tubewells.

ii) The main channels have not been constructed by the WAPDA on 180 tubewells.

iii) The main channels have been constructed only in part of the area served by the remaining 184 tubewells.

iv) The power-house runs for only 6 hours a day; 5 days a week. Electricity is supplied to some tubewells 3 days a week and to others 2 days a week.

v) During the period when electricity is supplied, the pump operator may be absent or on leave. If the pump operator is present, the agricultural overseer, responsible for giving names of farmers who need water, may be absent or on leave. In either case the pump remains unutilized.

If the WAPDA wishes the farmers to use water it is essential to create confidence among the farmers regarding the regular availability of water. For this purpose it is suggested that:

i) Electricity connections should be given to the 50 tubewells where these have not yet been given.

ii) The main channels should be constructed on all the 180 tubewells where these do not exist at present. These channels should cover the entire length and breadth of the commanded area.

iii) The main channels should also be completed in the entire length and breadth of commanded area on the 184 tubewells where these have so far been constructed in only a part of the commanded area.

iv) At Comilla, the tubewells run from 10 to 19 hours a day, with an average of about 12 hours a day. It is suggested that as a start the Thakurgaon power-house should run 12 hours a day, 7 days a week. All tubewells should get electricity for 7 days of the week and for 12 hours a day.

v) There is no need for the pump driver to obtain the list of farmers from the agricultural overseer. He should run the tubewells every day. Pumping should stop only on days when rainfall exceeds one-half inch or on days when farmers specifically request that the tubewell be stopped.

The author considers that the income from the tubewells can be greatly increased by the introduction of the high-yielding IRRI rice varieties, potatoe and tobacco. The IRRI rice varieties would give high yields only with irrigation water and optimum use of fertilizer. These are likely to increase the crop production on the lands served by tubewells so that the farmers would construct the field channels and utilise the tubewell water within a period of a few years. It is, therefore, suggested that fertilizer demonstration trial on IRRI rice be laid out during the *aman* 1966 season on each of the 116 tubewells which are now in working condition. The remaining tubewells should also be brought into use and fertilizer demonstration trials on IRRI rice laid on them. The whole of the area, which can be irrigated by the beginning of 1967, should be planted with *irrigated transplanted aus* in February 1967. It is this crop, which is likely to make the greatest increase in yield compared to the *unirrigated broadcast aus,* and which, therefore, will make it attractive for farmers to construct the field channels and utilize the tubewell water.

Summary : WAPDA Tubewell's

In the northern most part of East Pakistan, 380 tubewells have been installed to irrigate an area of about 91 thousand acres near Thakurgaon in the Dinajpur district. Each tubewell has an average discharge of about 3.0 cusecs and is expected to irrigate about 240 acres. The capital cost of the tubewells is Rs. 1,20,000 without electricity facilities and Rs. 2,30,000 with electricity generation, transmission and distribution facilities. The capital cost, thus, comes to Rs. 500 per acre for tubewell alone and Rs. 960 per acre for tubewell and electric facilities.

The annual operating cost of the tubewells comes to Rs. 138 per acre when the entire area is irrigated. The gross annual benefits are estimated at Rs. 547 to Rs. 685 per acre and the net annual benefits at Rs. 274 to Rs. 343 per acre by the IECO and the WAPDA. The benefit-cost ratio on full development will be between 2.0 and 2.5 when the whole area is irrigated.

Some of the tubewells were installed 4 years ago. More than 2 years have passed since all the tubewells were installed but only 4,000 acres have so far been irrigated. The major cause appears to be that the main channels have not been constructed on more than half of the tubewells and that the power-house is run for only few hours a day. Where main channels have been constructed, electricity is supplied for only 2 or 3 days a week and 6 hours a day. The farmers have not, therefore, constructed field channels and have not used the irrigation water. Construction of main channels on all tubewells and regular operation of tubewells is likely to create confidence among the farmers regarding the availability of water. Introduction of high-yielding IRRI rice varieties may provide a strong incentive for the farmers to construct the field channels for utilizing the irrigation water which is required to get high yields from the IRRI varieties.

2. THE COMILLA TUBEWELLS

This project is located in an area a major part of which is normally flooded every year. The project is under execution by the Pakistan Academy for Rural Development (PARD), Comilla. The PARD has demonstrated its capability in organizing rural cooperatives and in installing tubewells in the Comilla Kotwali Thana during 1963/64 and 1964/65 and in 7 other thanas of the Comilla district during 1965/66. By June 1966, 40 tubewells had been installed in 8 thanas of the Comilla district at an average cost of about Rs. 20,000 each [2;35].

The progress of tubewell irrigation in the Comilla Kotwali Thana is shown in Appendix Table B-1. In 1964/65, 34 tubewells irrigated a total of 1006 acres for an average of about 30 acres each. In 1965/66, some of the tubewells, where the farmers had not paid their dues, were closed and the remaining 25 tubewells irrigated a total of 1142 acres, or 46 acres each (Table IX).

This increase in area irrigated in 1965/66 took place primarily as a result of change in the collection of hire charges from a basis of Rs. 45 per acre in 1963/64 and 1964/65 to a fixed annual charge of Rs. 1,000 per tubewell plus cost of fuel and oil in 1965/66. Under this system most of the farmers increased the efficiency of water use and reduced the cost of pumping as is shown in Table IX which gives the results of all tubewells which worked in 1963/64, 1964/65 and 1965/66[11].

TABLE IX

RESULTS OF THE OPERATION OF THE COMILLA TUBEWELLS 1963/64 to 1965/66

Year	Per tubewell				Per acre		
	Hours worked	Water pumped	Cost of fuel consumed	Area irrigated	Hours run	Water used	Fuel consumed
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(number)	*(acre-feet)*	*(rupees)*	*(acres)*	*(number)*	*(acre-inches)*	*(rupees)*
1963/64	794	73	653	36	22	24	18
1964/65	1,158	106	1,158	27	43	47	44
1965/66	640	59	638	46	14	15	14

Source: Compiled from records of the PARD (Comilla) by Mr. A. Q. Ziauddin, a Staff Economist at the Institute.

[11] It might be argued that cost of the nine tubewells which were closed in 1965/66 should be charged, to the twenty-five tubewells which actually worked. However, the closure was a temporary disciplinary measure and all of the defaulting cooperatives have agreed to pay their arrears and work the tubewells in 1966/67.

A comparison of the working results of 1964/65 and 1965/66 clearly shows that:

i) The farmers reduced the number of hours of tubewell operation from 1,158 in 1964/65 to 640 in 1965/66, because they had to pay for the quantity of water used whereas in the previous years they paid the charges on a per acre basis and, therefore, did not economize in the use of water.

ii) Inspite of a reduction in the number of hours of tubewell operation, there was an increase in the irrigated area of more than 50 per cent, from 27 acres[12] per tubewell in 1964/65 to 46 acres per tubewell in the *boro* season 1965/66.

iii) The number of hours for each acre of irrigated crop was reduced from 43 in 1964/65 to 14 in 1965/66.

iv) Water was used more sparingly in 1965/66 and the farmers applied only 15 acre-inches of water to raise a *shaita*[13] and *boro* crop as compared to 47 acre-inches in 1964/65.

v) The net result was that farmers spent only Rs. 14.00 per acre on fuel in 1965/66 as compared to Rs. 44.00 per acre in 1964/65.

If the results of operation in 1963/64 are compared with those of 1965/66, it is seen that the farmers worked the tubewell for 22 hours and used 24 acre-inches of water to raise one acre of irrigated crop in 1963/64 compared to 15 acre-inches in 1965/66. Waste of water to this extent may be expected on operations where farmers do not pay for the cost of fuel. But in 1964/65, the waste of water appears to have been excessive.

The reason why farmers were able to raise a successful *boro* and *shaita* crop with 15 acre-inches of water is as follows. At the end of the monsoon season, the watertable comes quite close to the ground surface and the soil profile is completely saturated with moisture [27, p. B VII - 32]. There is some reduction of moisture in the soil in November and December but considerable moisture is still present in the soil profile below the ground surface. A relatively small quantity of irrigation provided to the crop, thus, enables the root system to make use of part of the water already stored in the soil.

The results of an experiment conducted on the yield of *boro* paddy at Hathazari Government Agriculture Farm, Chitttagong, with different depths and intervals of irrigation are presented in Appendix Table B-2. These result show

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[12] There is a slight difference in the number of acres irrigated per tubewell given in Appendix Table B-I (30 acre) and in Table IX (27 acre). Figures in Appendix Table B-I refer to *all* tubewells used in 1964/65, whereas those in Table IX refer only to the 25 tubewells used both in 1964/65 and 1965/66.

[13] *Shaita* is a short-growing season variety of *boro* rice. Literally *shaita* means sixty indicating that this rice will mature in sixty days. Actually, it takes about eighty days to mature.

that with the interval of irrigation at ten to fifteen days and a total depth of irrigation of forty-one acre-inches, the average yield of *boro* paddy from four replicated plots was thirty-eight maunds per acre. With the interval of irrigation at thirty to forty days and total depth of irrigation of thirteen acre-inches, the average yield of *boro* paddy was thirty-four maunds per acre [Appendix Table B-2]. There was, thus, a reduction of about four maunds per acre in the yield of *boro* when irrigation water was reduced from forty-one acre-inches to thirteen acre-inches. With a given quantity of water the farmers would, however, be better off by growing three acres of *boro* rice with thirteen acre-inches irrigation than by growing one acre of rice with forty-one acre-inches. This is what the farmers of the Comilla villages who had access to tubewell water appear to have done when they had to pay for the quantity of water used in 1965/66 rather than pay a flat per acre rate as in 1963/64 and 1964/65.

It should be pointed out, however, that when high-yielding IRRI varieties of rice are introduced in 1966/67 and adequate fertilizer is applied, much larger quantities of irrigation water will have to be made available to get the higher yields possible with the new varieties.

Annual Operating Cost of Tubewells

In August 1964, the annual operating cost of a diesel-driven tubewell was estimated by the PARD at Rs. 4,290 (Table X) [35, p. 57]. In this calculation, the period of amortization was assumed to be 50 years (to bring it in line with the IECO-WAPDA practice). The life of diesel engine was assumed to be 15 years and that of the tubewell 30 years. The rate of interest was assumed to be 5 per cent.

The PARD itself charges a 15 per cent rate of interest from the cooperative societies which run the tubewells. While a rate of interest of 15 per cent probably represents the scarcity value of capital for the farmers correctly, it probably overstates the overall scarcity of capital in Pakistan. As previously explained, we have used an 8 per cent rate of interest for all projects considered in this paper.

With regard to the life of tubewells, experience in West Pakistan indicates that their life is likely to be closer to 10 years than 30 years. On the basis of a 10-year life for tubewell, 15 years for diesel engines, an 8 per cent rate of interest and other expenses as actually incurred by the PARD in 1965/66, the annual operating cost of a tubewell comes to Rs. 6,085 (Column (3) of Table X) against Rs. 4,290 estimated by the PARD. For an average of 60 acres irrigated per tubewell the cost would be equal to Rs. 101 per acre.

Annual Income and Benefit-Cost Estimates for a Tubewell Commanding 60 Acres

The gross annual income is estimated by the PARD at Rs. 59,500 per tubewell with a cultivated area of 60 acres. The present value of crop production

TABLE X

ANNUAL OPERATING COST OF A DIESEL-DRIVEN TUBEWELL IN COMILLA

Item	As estimated by PARD for 60 acres	As estimated by the author for 60 acres and hire charges on a flat per acre basis	Estimates by the author for 80 acres with hire charges of 1,000 rupees a year plus cost of fuel	Estimates by the author for tubewell costing Rs. 13,000
(1)	(2)	(3)	(4)	(5)
1) Interest and amortization	1,174[a]			
2) *a*) Replacement reserve for engine and pump	370[b]	2,685[f]	2,685[f]	1,728[j]
b) Replacement reserve for tubewell	203[c]			
3) Operation and maintenance				
a) Diesel fuel	2,115[d]	2,640[g]	2,400[i]	2,400[i]
b) Maintenance	428[e]	760[h]	760[h]	760[h]
Total:	**4,290**	**6,085**	**5,845**	**4,888**
Water pumped (acre-feet)	*150*	*150*	*200*	*200*
Cost per acre-foot of water pumped (*rupees*)	29	35	29	24
Area irrigated (land-acres)	*60*	*60*	*80*	*80*
Cost per land-acre irrigated (*rupees*)	72	101	73	61
Crops irrigated (crop-acres)	*135*	*135*	*180*	*180*
Cost per crop-acre irrigated (*rupees*)	32	45	32	27

Source: Column (2) from [35, p. 57].
Columns (3) to (5): Estimates by the author. *See* text.

Notes: *a*) At 5 per cent interest, repayment in 50 years.

b) Replacement in 15 years at 5 per cent interest.

c) Replacement in 30 years at 5 per cent interest.

d) For 1410 hours at Rs. 1.50 per hour.

e) At 2 per cent of the total capital cost.

f) At 8 per cent interest and repayment in 10 years for tubewell and 15 years for diesel engine on total capital cost Rs. 20,200 of which half is for tubewell and half for engine.

g) For 60 acres at Rs. 44 per acre.

h) Actual expenses during 1965/66 consisting of cost of spares (Rs. 64), repairs (Rs. 136), pay of driver (Rs. 360) and cost of supervision (Rs. 200).

i) For 2400 hours at one rupees per hour.

j) At 8 per cent interest and repayment in 10 years for tubewell and 15 years for diesel engine on a total capital cost of Rs. 13,000.

is estimated at Rs. 27,700 (Rs. 462 per acre). The increase in the gross value of crop production is, therefore, Rs. 31,900 for each tubewell covering 60 acres [35, p. 50][14].

Assuming the cost of production at 50 per cent of the gross value, the net increase in the value of crop production due to irrigation comes to Rs. 15,950 for 60 acres or Rs. 266 per acre[15].

The annual operating cost is about Rs. 101 per acre. The benefit-cost ratio is, therefore, 2.6.

Area Commanded by a Tubewell

For the WAPDA tubewells near Thakurgaon, it was assumed that each tubewell, with a discharge of about 3 cusecs, will cover about 240 acres. This is about 80 acres per cusec.

It now appears that the Comilla tubewells will also be able to command an area of about 80 acres per well instead of the 60 acres originally proposed by the PARD. An average area of about 46 acres per tubewell has already been irrigated during the *boro* season 1965/66. The *boro* area is expected to increase by about 10 acres on each tubewell during the next few years and reach about 56 acres per well.

With the introduction of high-yielding IRRI rice varieties, an area of about 40 acres (50 per cent of the cultivated area) may be expected to be irrigated during the *aus* season against the present *aus* acreage of about 42 per cent.

Aman rice is now grown on about 80 per cent of the cultivated area. This may be expected to remain at the present level. With the change in the system of hire charges, *aman* rice will, however, get irrigation water at the critical maturing stage as the farmers have to pay for fuel only for this supplementary irrigation. The farmers regard the rental charges of Rs. 1,000 a year mainly for the *boro* paddy which can not be grown without irrigation.

Total area under rice will probably reach 160 acres or about 200 per cent of the cultivated area (*boro* 56 acres, *aus* 40 acres and *aman* 64 acres). The present rice area is about 100 acres (125 per cent of the cultivated area) on each tubewell commanding 80 acres. Thus, there will be an increase of 60 acres in the rice area and improvement of yield on about 100 acres.

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[14] The PARD have given the present gross income, projected gross income and increase in gross income due to irrigation for 18,960 acres to be irrigated by tubewells, low-lift pumps and by surface canal irrigation. Proportionate figures for 60 acres for one tubewell have been assumed in this paper.

[15] The PARD has given the cost of production for each crop and the net increase in income is estimated by them at 49.3 per cent of the gross increase in income. In this paper, however, the net increase is assumed at 50 per cent of the gross increase as has been done for all other projects discussed in the paper.

Area under other irrigated crops may reach about 20 acres (25 per cent of the cultivated area) as estimated by the PARD [35, p. 46].

Benefit-Cost Estimates for a Tubewell Commanding 80 Acres

Irrigation water requirements of crops were estimated at 30 acre-inches per acre or 1800 acre-inches per tubewell (60 acres) by the PARD [35, p. 55]. Water requirements for individual crops were assumed to be as follows: *boro* 27 acre-inches: *aman,* 10 acre-inches: *aus* 8 acre-inches: other crops 10 to 15 acre-inches. Experience during the 1965/66 *boro* season indicates that with the present varieties of rice, the farmers will use much less water. However, with the introduction of high-yielding IRRI rice varieties, water use may reach the level estimated by the PARD. About 200 acre-feet of water for each 80 acres would then be required.

The discharge of tubewells was assumed at 1.5 cusecs by the PARD. It is now estimated as 1.1 cusecs [31]. Tubewells will, therefore, have to run for about 2,400 hours to deliver 200 acre-feet of water to the fields.

The annual operation cost of tubewell working for 2,400 hours and irrigating 80 acres is shown in Column (4) of Table X. The total annual cost comes to Rs. 5,845 or Rs. 73 per acre. The net annual income will be about Rs. 21,280 = (266 × 80) per tubewell. The benefit-cost ratio would be 266/73 = 3.6 ignoring any increase in the value of crop production due to high-yielding IRRI rice varieties.

If the farmers install their own tubewells, their net annual income after deducting the annual operating cost would be Rs. 15,435 (Rs. 21,280 minus Rs. 5,845). The farmers would, thus, recover the capital cost of Rs. 20,000 in less than 2 years.

Benefit-Cost Estimates for A Low-Cost Tubewell

It will be shown in a later section of this paper that the capital cost of a tubewell can be reduced from Rs. 20,000 to about Rs. 13,000 with the use of locally manufactured diesel engine, ADBP-imported lining pipe and use of coir string strainer. The annual operating cost will then come to Rs. 4,888 (Column (5) of Table X) or Rs. 61 per acre.

The benefit-cost ratio will become 266/61 = 4.4.

Benefit-Cost Estimates with IRRI Rice Varieties

Five acres of IRRI rice were grown at Comilla during the *aus* season 1966. These gave an average yield of 50 maunds per acre. This is exactly what had been forecast by Chandler who estimated the yield of IRRI rice varieties at 50 maunds per acre during the *aus* and *aman* season and 75 maunds per acre during the *boro* season [4, p. 21].

Under large-scale operations by farmers yields are likely to be lower. Assuming an average yield under farmers condition of 35 maunds per acre for *irrigated aus* and *irrigated aman* and 45 maunds per acre for *irrigated boro* and the income from other crops as estimated by the PARD, the total income from 80 acres on one tubewell comes to Rs. 93,000 as shown in Table XI.

TABLE XI

ESTIMATED INCOME FROM CROP PRODUCTION ON TUBEWELL WITH IRRI RICE

Crop (1)	Area (2)	Yield per acres (3)	Total production (4)	Rate per maund (5)	Total value (6)
	(acres)	*(maunds)*	*(maunds)*	*(rupees)*	*(rupees)*
Aus	40	35	1,400	13	18,200
Aman	64	35	2,240	14	31,360
Boro	56	45	2,520	14	35,280
Other crops	20				8,000
Total	**180**				**92,840**

Source: See Text.

From the gross value we should deduct the present value of crop production of Rs. 36,960 (Rs. 462×80). The increase in gross value comes to Rs. 55,880. If half of this is taken as the cost of production, the net increase in income due to tubewell and IRRI varieties comes to Rs. 27,440. This is equal to Rs. 349 per acre. The benefit-cost ratio, thus, comes to 4.8 or 5.7, depending upon whether the annual operating cost of Rs. 73 or Rs. 61 per acre is used.

Farmers installing their own tubewells and growing IRRI rice will have a net income of Rs. 21,595 after deducting the annual operating cost (Rs. 27,440 *minus* Rs. 5,845). They will, thus, recover the capital cost of Rs. 20,000 or Rs. 13,000 in one year.

Subsidy on Comilla Tubewell Operations

Although the annual operating cost of a tubewell comes to Rs. 5,845 for 80 acres, the PARD is charging only Rs. 1,000 as rental charges plus cost of fuel which comes to about Rs. 2,400 for 80 acres of cultivated land growing 135 acres of irrigated crops.

Total charges to be paid by the farmers come to Rs. 3,400. The balance of Rs. 2,445 is borne as a subsidy and is met out of Rural Works Programme funds. The subsidy is 42 per cent of the annual operating cost.

The tubewell programme has just started in East Pakistan. It is one of the key elements in increasing agricultural production in areas where low-lift pumps can not be used due to lack of surface water. It is, therefore, desirable to continue this subsidy till tubewells have covered a major part of the area suitable for tube-well installation.

Summary: Comilla Tubewells

Forty tubewells have been installed by the PARD, during the last three years, in the cooperative villages of the Academy near Comilla. The average capital cost of these is about Rs. 20,000 . These tubewells have an average discharge of about 1.1 cusecs and are expected to cover an area of about 80 acres each. The capital cost, thus, comes to Rs. 250 per acre.

The working of these tubewells was under the complete control of the PARD in 1964/65 and the farmers were charged Rs. 45 per acre irrigated. The total annual cost was estimated at Rs. 101 per acre out of which about Rs. 44 was spent on fuel.

During 1965/66, the farmers were required to pay Rs. 1,000 per tubewell as rental charges plus cost of fuel. With this change, the cost of fuel was reduced from Rs. 44 to Rs. 14 per acre and the total annual cost is estimated to have decreased to about Rs. 73 per acre. The farmers are expected to pay a total of Rs. 3,400 (Rs. 1,000 rental charge plus Rs. 2,400 on fuel) or Rs. 42.5 per acre. This would imply a subsidy of about 42 per cent.

The net benefits on full development of 80 acres are estimated at Rs. 21,280 per tubewell or Rs. 266 per acre, giving a benefit-cost ratio of 3.6. The farmers installing their own tubewell are expected to recover the capital cost in less than 2 years.

It is possible to reduce the capital cost of installation of a tubewell from Rs. 20,000 to about Rs. 13,000 by the use of locally manufactured diesel engine and coir string strainers. This will reduce the annual operating cost to about Rs. 61 per acre and raise the benefit-cost ratio to about 4.4. The subsidy to be borne by the government will then be reduced to about 30 per cent.

Introduction of high-yielding IRRI rice varieties is expected to increase significantly the net income accruing from the installation of tubewells and is expected to cause a rapid demand for tubewell installations.

3. PRIVATE TUBEWELL DEVELOPMENT IN EAST PAKISTAN

One of the major causes of increase in agricultural production in West Pakistan during the Second-Plan period has been the private investment in tubewell installation. It is estimated that about 27,000 private tubewells were installed during the last five years, raising the total number from about 4,600 at the end of 1959/60 to about 31,600 at the end of 1964/65[16]. Early in 1964, the author proposed a similar installation of private tubewells in East Pakistan for the Third-Plan period [15, p. 250]. Serious doubts have, however, been expressed about the availability of groundwater for pumping and the extent to which it could be annually recharged without mining, by the publication of the reports by Professor Thijsse [47 and 48]. Evidence available on the subject indicates that these doubts are perhaps not fully justified.

Groundwater

A considerable body of information is available on the existence and recharge of groundwater in East Pakistan as well as in other alluvial deltic areas of the world. One of the best studies which compiles most of the information available on the subject in East Pakistan is that by Mr. H. V. Peterson, Ground Water Hydrologist, of International Engineering Company. This report on *Groundwater in East Pakistan* describes the aquifer material of tubewells in different parts of East Pakistan [41]. From a study of these logs he concludes that over much of the area of East Pakistan silt and clay predominate in the top 50 to 80 feet, with sands forming the major part of the deposits from 80 to 300 feet and below.

Peterson concludes that where a well penetrates 150 or more of clean medium to coarse sand, a good yield is assured; for fine and very fine sands a greater thickness is required. He further considers that these minimum thicknesses of sand should be present within 300 feet of drilling depth [41, p. 6].

Somewhat similar conclusions can be drawn from a study of the wells in the Dacca municipal area carried out by Mr. Welsh of Parsons Corporation. This report on *Dacca Ground Water Supply* states that in a depth of 180 to 400 feet the average well encounters 120 to 200 feet of aquifer material generally labelled as fine to medium sand [50, p. 9]. It is capable of giving a discharge of 2.8 cusecs with a thickness of 115 feet of fine to medium sand and an 8-inch diameter tubewell [50, p. 11].

A number of good results have been obtained in other parts of East Pakistan. Successful tubewells have been installed at Thakurgaon (Dinajpur district), Comilla, Gauripur (Mymensingh district), Gaibanda (Rangpur district), Nator

[16] For tubewells installed up to 1963/64, *see* [16, p. 7]. Number of tubwells installed during 1964/65 is taken from unpublished results of a survey by the author in collaboration with Directors of Agriculture, Lahore, Peshawar, and Hyderabad.

(Rajshahi district) and a number of other places. The depth of these tubewells ranges from 125 to 300 feet and they give a discharge of 1.0 to 4.0 cusec each [11; 35; 41; 42; 43; 44].

Recharge

Professor Thijsse is particularly doubtful regarding the recharge of groundwater. Here again his doubts do not seem to be fully justified. Although no specific studies have been carried out on the extent of recharge, the fact that watertable rises every year by 5 to 10 feet during the monsoon season over major part of East Pakistan indicates that there is a large recharge of groundwater in East Pakistan. An order of magnitude of how much water can actually be pumped from tubewells without unduly mining the aquifer can be had from the working of municipal tubewells in the Dacca area. There are 24 tubewells located in an area of 1,900 acres in Old Dacca City [50]. These tubewells pump about 8.6 million gallons a day or about 8,900 acre-feet of water in a year. This is equal to 4.7 acre-feet per acre for the Old Dacca City area, and is considered to be in excess of the annual recharge. The watertable is, therefore, going down in the Old Dacca City area. In the remaining municipal area of Dacca, 9.4 million gallons of water a day, or 9,700 acre-feet a year, is being pumped from 8,100 acres. This means an annual extraction of 1.2 acre-feet per acre. Parsons Company consider that more water can be pumped in this area [50]. They consider that the total yield of water in the entire Dacca Municipal area can be increased from 18 million gallons a day at present to about 33 million gallons a day during the next 10 years. This would mean a total pumping of about 34,000 acre-feet from 10,000 acres, giving an extraction rate of about 3.4 acre-feet per acre. Although it is not explicitly stated, some of these tubewells would probably be located outside the present municipal area of 10,000 acres. The extraction rate would probably be somewhat less than 3.4 acre-feet per acre.

The Parsons Corporation recommend installation of large tubewells of 60,000 gallons per hour (2.8 cusecs) capacity but suggest that these wells should not be located at less than 2,000 feet apart to prevent excessive mutual interference [50, p. 14]. In other words, a tubewell of 2.8 cusecs capacity should not have an area of less than 92 acres. Here again the Parsons Corporation does not refer to the lowering of watertable which was specifically pointed out for the Old Dacca City area. The Parsons Corporation appear to imply that there would be no undue mining of water if tubewells of less than 2.8 cusecs capacity are located to serve areas of more than 92 acres each.

Tubewells installed in West Pakistan, and those proposed for East Pakistan in this paper, would have less than half the capacity of tubewells in the Dacca

Municipal area, that is about 1.0 to 1.4 cusecs each, and would serve 100 to 200 acres each. These are, therefore, not likely to cause any mining of groundwater.

Both Professor Thijsse [47, p. 20] and Mr. Peterson [41, p. 21] stressed the undesirable effects of pumping water from tubewells on the reduction of discharge in the rivers during the dry season when the rivers have low discharges. In stressing these undesirable effect, it appears that the assumption has been made that all pumping from tubewells will take place during the winter season. This is not necessarily correct. The major part of pumping on the 116 tubewells which worked in the 1965/66 season in the Thakurgaon area took place in the summer season when 4,000 acres were irrigated. Only a small part of the pumping took place during the winter season when less than 400 acres were irrigated. The same is true of the Ganges-Kobadak Project area where 75 per cent of the water pumped during the year was used in the summer season (May to October) and only about 25 per cent of the pumped water was used in the winter season [19].

It was only in Comilla that tubewells were used mostly during the winter season during the last two years. With the change in the system of realization of charges for irrigation, tubewells are now also being used in the summer season at Comilla.

It should, however, be pointed out that in the Thakurgaon area as well as in the Ganges-Kobadak Project area, more and more pumped water will be used during the winter season when irrigation develops. Considerable part of the pumping will, however, continue to be done during the summer season and this should have no undesirable effects on the depletion of groundwater.

Professor Thijsse seems to have used a very high figure for water requirement of crops and hence for pumping of water during the *rabi* season. He uses a figure of 5.3 acre-feet per acre for a *boro* crop grown from December to April [47, p. 38, Tables I, II and III]. Farmers in the Comilla area applied only 1.3 acre-feet per acre to the *boro* crop in 1965/66. For the whole area of the village where the tubewells were located (200 acres) the pumping was about 0.3 acre-feet per acre. This is insignificant compared to the likely recharge from the monsoon rainfall and other sources. It is true that water requirements of crops will increase as *shaita* rice is replaced by *boro* and the *boro* is replaced by high-yielding IRRI rice varieties. But even then much less water will be used by the farmers than that assumed by Professor Thijsse, and less pumping of water will therefore take place. It appears from the above analysis that there is no need to be concerned in the immediate future with a likely permanent lowering of the ground watertable until the number of tubewells has increased very considerably.

Size of Holdings and Tubewells in East Pakistan

It is argued by the East Pakistan government officials that private tubewells can be installed in West Pakistan but not in East Pakistan because of very small size of holdings in the latter province. To test the validity of this hypothesis, we have collected data on the size of holdings of 33,000 farmers who have installed 20,100 tubewells in four major districts of West Pakistan. The results of this survey are summarized in Appendix Table C-1. At the end of 1965, there were 14,200 farmers who had installed their own individual tubewells; 18,800 additional farmers had jointly installed 5,900 more tubewells. About 6,500 farmers (or 20 per cent of all farmers installing tubewells) had less than 12.5 acres each. In most cases they combined to install jointly owned tubewells.

We have applied that results of the survey on the West Pakistan size of holding to East Pakistan and calculated the number of tubewells that could be installed in East Pakistan, singly and jointly owned if size of holdings was the sole criterion. The results of this exercise are given in Appendix Table C-2. There should be about 11,000 single tubewells and about 15,000 joint tubewells or a total of 26,000 tubewells in East Pakistan under this assumption. There are, however, other points to be considered. Of the total cultivated area of 21.6 million acres, low-lift pumps can be used in 5 million acres. Tubewells can be used in a greater part of the remaining 16.6 million acres. However, in some areas out of these 16.6 million acres, the aquifer material is not so suitable for tubewells. These areas will have to be left out. There are still some other areas in the south near the seas where tubewells cannot be installed on account of saline groundwater. If all these areas are excluded, it may be possible to install tubewells over 5 to 10 million acres.

Organization For Tubewell Installation

In West Pakistan, the Department of Agriculture has so far been responsible for installation of tubewells for the farmers. The Department of Agriculture undertakes the drilling of holes and installation of pipes and strainers. The remaining work, *i.e.*, supply and installation of pump and engine and construction of pump-house is done by the farmers themselves. Pipes and strainers can be purchased from the Department of Agriculture or from the local market. Private drillers have also been drilling wells for the farmers for the last twenty years or so but have entered this field in a big way only during the last seven years [16, pp. 2-3].

For the purposes of tubewell installation, West Pakistan is divided into three regions. The Central Region is the most important and has over 90 per cent of all tubewells. East Pakistan corresponds in area and possibilities of tubewell installation to the Central Region of West Pakistan.

The tubewell organization in the Central Region of West Pakistan consists of a Director of Agricultural Engineering, 2 Agricultural Engineers, 21 Assistant Agricultural Engineers[17], 18 Drilling Supervisors and about 190 Drillers, one for each hand-operated drilling rig. It is suggested that the Government of East Pakistan should set up a similar tubewell drilling organization in the Department of Agriculture or in the Agricultural Development Corporation.

It is further suggested that Government of East Pakistan should place immediate orders for the import of 200 hand-operated drilling rigs of the type used in West Pakistan and at Comilla. These would cost about Rs. 4 million [32, p. 45]. Out of these about 100 should reach Dacca within the next 6 months and the remaining in 12 months.

Assuming that each rig installs 8 to 9 tubewells in a year[18], these rigs would install about 5,000 tubewells in the last three years of the Third-Plan period. For the installation of the remaining 5,000 tubewells, it is suggested that some of the private tubewell drillers from West Pakistan should be invited to start their drilling operations in East Pakistan.

Cost of a Six-inch Tubewell

In West Pakistan, the average cost of a 6-inch diesel-driven tubewell comes to about Rs. 10,000 [16, p. 51]. The average cost of a 6-inch diesel-operated tubewell at the PARD, at Gauripur-Mymensingh and at Gaibända (Rangpur) comes to about Rs. 20,000 each. The major items where cost can be reduced in East Pakistan are in the cost of *i*) the diesel engine, *ii*) the lining pipe, and *iii*) the strainer.

i) *Diesel Engine*

West Pakistan farmers are using locally manufactured low-speed diesel engines of 18 to 22 HP costing about Rs. 4,500 to Rs. 5,000 each. Inclusive of the pump, the cost comes to about Rs. 6,000. Against this, the PARD is using imported German-made high-speed diesel engines costing about Rs. 10,000 each. The German-made high-speed diesel engines are more efficient in the utilization of fuel oil but these are highly sophisticated and difficult to maintain under Pakistani conditions. Even under the excellent supervision and repair services provided by the PARD, most of the German-made engines had to be overhauled within a period of three years [31]. On the other hand, the West Pakistan's locally manufactured low-speed diesel engines are somewhat less efficient in the consumption of diesel

[17] These include Assistant Engineers incharge of mechanized cultivation (bulldozers) and drilling operations as well as workshop superintendents and training and research engineers.

For tubewell operations alone, Mr. Majid Hasan Khan, Director of Agricultural Engineering, considers that one Assistant Engineer should be adequate for 25 hand-operated drilling plants [33].

[18] In West Pakistan one drilling rig installs one tubewell in one month. In East Pakistan it is assumed to take a longer time.

oil[19], but they are very sturdy and extremely durable. The West Pakistan manufactures guarantee to replace *free* any part which goes out of order during a period of three years. Even after three years there is no difficulty on spares and repairs as all parts are locally manufactured. This would reduce cost of Comilla tubewells by Rs. 4,000.

ii) Lining Pipe

Lining pipe of 6-inch diameter costs about Rs. 20 per foot at Comilla whereas the West Pakistan Directorate of Agricultural Engineering has been selling the same at Rs. 10 per foot. The Agricultural Development Bank is importing lining pipe worth two million rupees in foreign exchange for installation of tubewell under the IDA Loan in West Pakistan. This pipe is expected to sell at about Rs. 7 per foot at the village level. It is suggested that the ADBP should be requested to import lining pipe worth about one million rupees in foreign exchange for sale of the same to the farmers in East Pakistan as well as to the PARD. This would reduce the cost of Comilla tubewells by about Rs. 1,000.

iii) Strainer

West Pakistan farmers use coir string strainer manufactured from iron strips and coconut fibre rope imported from East Pakistan. This sells for about Rs. 6 to 7 per foot in the rural area. The PARD (Comilla) uses brass strainer which costs about Rs. 30 to 40 per foot.

The coir string strainers are quite durable. According to a survey conducted by the author in November-December 1965, more than 99 per cent of the private tubewells installed by the farmers in Multan, Montgomary, Gujranwala and Lahore districts were in satisfactory working condition at the time of the survey. These tubewells had mostly been installed within the last 10 years but 692 tubewells or 3.4 per cent of the total were older and were still in satisfactory working condition. There is no reason to believe that coir string strainers will not do as well in East Pakistan as they are doing in West Pakistan. In order to reduce the initial capital cost, coir string strainers should be used in East Pakistan just as they are being used in West Pakistan. This would reduce the cost of Comilla tubewells by another Rs. 3,000.

It is possible to reduce the cost of a 6-inch tubewell from Rs. 20,000 at Comilla to about Rs. 12,000 with the use of locally manufactured low-speed diesel engines, coir string strainers, and the ADBP-imported lining pipes. The depth of tubewells will, however, be somewhat more in East Pakistan than in West Pakistan. About 50 feet extra lining pipe and 50 feet extra coir string strainer would cost Rs. 700.

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[19] The 15 HP German-made high-speed diesel engines consumed 253 gallons of diesel oil in 640 hours at Comilla in 1965/66, giving a rate of consumption of 0.4 gallon per hour. In a comparable area in the Gujranwala-Sialkot districts in West Pakistan, locally manufactured low-speed diesel engines of 18 HP consumed an average of 32 drums (1440 gallons) in 2430 hours [16, p. 52]. This gives a rate of consumption of 0.6 gallon per hour.

It would also cost about Rs. 500 extra in drilling charges. Total cost of the tubewell should, therefore, be about Rs. 13,000 in East Pakistan against Rs. 10,000 in West Pakistan.

Summary: Private Tubewells

A large programme of private investment in tubewell installation on the lines now under way in West Pakistan is considered feasible for a major part of those areas of East Pakistan where low-lift pumps cannot be used.

There is reason to believe that groundwater is available in pumpable quantties in various parts of East Pakistan as shown by irrigation tubewells installed at Thakorgaon (Dinajpur), Rangpur, Comilla, Gauripur (Mymensingh), Gaibanda (Rangpur), Natore (Rajshahi) and other places. There is also reason to believe that the recharge in East Pakistan is large, as shown by the rise of watertable by 5 to 10 feet every year after the monsoon over major parts of East Pakistan.

Evidence collected on the size of holdings of tubewell farmers in West Pakistan indicates that about 11,000 single tubewells and 15,000 joint tubewells or a total of 26,000 private tubewells could have been installed by the farmers of East Pakistan if size of holding was the sole criterion. These tubewells can be installed now by providing an aggressive drilling organization and strong incentives for the farmers to install private tubewells. A Tubewell Drilling Directorate in the EP-ADC on the lines of the Directorate of Agricultural Engineering in West Pakistan and some incentives to the private drillers in West Pakistan to start their drilling operations in East Pakistan can do the job.

The cost of a private tubewell of about one-cusec capacity with the locally manufactured diesel engine and coir string strainer is estimated at about Rs. 13,000 in East Pakistan compared to about Rs. 10,000 in West Pakistan. With the introduction of high-yielding IRRI rice varieties which can be grown during the *boro* and *aus* season only with irrigation, the farmers will recover the capital cost in less than 2 years.

IV. COMPARISON OF DIFFERENT IRRIGATION PROJECTS STUDIED

Table XII summarizes the capital cost, the annual operating cost, the annual benefit and benefit-cost ratio for the four different projects discussed in this paper.

The capital cost of the Ganges-Kobadak Project as well as the WAPDA tubewells is exceedingly high, about Rs. 900 per acre, whereas the capital cost of low-lift pumps is only about Rs. 100 per acre. The capital cost of Comilla tubewells is about Rs. 250 per acre but can be reduced to about Rs. 160 per acre. With the same amount of funds, it is possible to cover nine times the area with

TABLE XII

COMPARATIVE COSTS AND BENEFITS OF SOME IRRIGATION PROJECTS IN EAST PAKISTAN

Item	Surface water development					Groundwater development			
	Ganges-Kobadak Project	Low-lift pumps				WAPDA tubewells in North Bengal	Comilla tubewells		
		Worked by ADC		Worked by farmers			Worked by the Academy (60 acres)	Worked by the farmers (80 acres)	Assuming local diesel engine and coir string strainers (80 acres)
		Two-cusec pumps	One-cusec pumps	Two-cusec pumps	One-cusec pumps				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Capital cost	886[a]	144[b]	98[c]	98[d]	82[e]	500[f] 960[g]	333[h]	250[i]	163[j]
Annual operating cost	96	60	50	39	39	138	101	73	61
Annual benefits	215	200	200	200	200	274 to 343	266	266	266
Benefit-cost ratio	2.2	3.3	4.0	5.1	5.1	2.0 to 2.5	2.6	3.6	4.4

Notes: *a*) Rs. 292 million for 330 thousand acres of irrigated areas.
b) Rs. 8,650 for 62 acres actually irrigated.
c) Rs. 5,770 for 59 acres actually irrigated.
d) Rs. 8,650 for 90 acres likely to be irrigated.
e) Rs. 5,770 for 70 acres likely to be irrigated.
f) Rs. 45.8 million for 380 tubewells for 91 thousand acres of irrigated land excluding electrification facilities.
g) Inclusive of electric generation, transmission and distribution facilities.
h) Rs. 20,000 for 60 acres.
i) Rs. 20,000 for 80 acres.
j) Rs. 13,000 for 80 acres.

Source : See text.

low-lift pumps as compared with Ganges-Kobadak Project or the WAPDA tubewells. The tubewells of the type installed in Comilla would cover nearly four times the area with the same funds as the WAPDA tubewell or the Ganges-Kobadak Project.

The annual operating cost of the WAPDA tubewells is the highest of all (Rs. 138 per acre), whereas that of Ganges-Kobadak Project is slightly less than Rs. 100 per acre. The low-lift pumps have the lowest annual operating cost of about Rs. 50 to 60 per acre even when worked under the old ADC system. When the working of these pumps is organized in such a way that farmers have to pay for the amount of water used by paying for the fuel instead of paying a flat per acre rate, the cost is expected to be reduced to about Rs. 39 per acre.

The annual cost of Comilla tubewells is less than that of the WAPDA tubewells but is still quite high. It has been reduced from Rs. 100 per acre to Rs. 73 per acre by making the farmers pay for the quantity of water used. It can be further reduced to about Rs. 60 per acre if locally manufactured diesel engine, the ADBP-imported lining pipe and coir string strainers are used. These would reduce the capital cost to about Rs. 13,000 per well and the annual cost to about Rs. 60 per acre.

The benefit-cost ratio is the lowest in the case of Ganges-Kobadak Project (2.2) and about the same in the case of the WAPDA tubewells (2.0 to 2.5). It is the highest in the case of one-cusec low-lift pumps (4.0) with that of a two-cusec pump somewhat less (3.3). It is expected to become even higher (5.1) when the farmers have to pay for the volume of water used by purchasing their own fuel and when one-cusec pumps are used in most areas of East Pakistan and two-cusec pumps are limited to areas where larger blocks of land are available for irrigation.

The benefit-cost ratio of the Comilla tubewells (2.6 to 3.6) is midway between the Ganges-Kobadak Project and the WAPDA tubewells on the one hand and low-lift pumps on the other. It can, however, be increased to 4.4 by reducing the capital cost to about Rs. 13,000 per well by using locally manufactured diesel engines and coir string strainers.

V. CONCLUSIONS

Evidence presented in this paper leads to six important inferences which support the hypotheses enunciated in the beginning of this paper.

1) The capital cost of a low-lift pump is about Rs. 80 to 140 per acre, whereas that of a small 6-inch tubewell is about Rs. 160 to 330 per acre irrigated. Against this the capital cost of a gravity canal system fed by large pumps installed on large

rivers is about Rs. 900 per acre. The capital cost of large government tubewells is also high, about Rs. 500 per acre without electrification network and about Rs. 960 per acre inclusive of electricity generation, transmission and distribution facilities. A large programme to cover major part of East Pakistan by low-lift pumps and small tubewells in preference to that of large gravity canals fed by large pumping plants and government tubewells would, therefore, be more appropriate for East Pakistan.

The small low-lift pumps can be provided in an area of about 5 million acres out of the total cultivated area of 21.6 million acres. At Rs. 100 an acre, these would cost about Rs. 500 million.

The remaining area of 16.6 million acres cannot be served entirely by tubewells due to an unfavourable aquifer condition in some parts and salinity hazard in other parts. Excluding these unfavourable areas, it may be possible to develop about 5 million acres by tubewells during the Third-Plan period. These would require about 60,000 tubewells, each covering about 80 acres and costing about Rs. 13,000 each. The total cost of this programme for 5 million acres would be about Rs. 800 million. The total cost of the low-lift and the tubewells programme for 10 million acres would, thus, be about Rs. 1,300 million.

2) The annual operation cost of an ADC pump is estimated at Rs. 50 and Rs. 60 per acre for a one-cusec and a two-cusec pump respectively. When hire charges are fixed on annual rental basis plus cost of fuel, the per acre cost is likely to be reduced to about Rs. 39 for the *boro* crop. It is likely to be reduced still further when farmers begin to use the pumps for the *aus* and the *aman* crops. Similarly, the cost of fuel used on Comilla tubewells has been reduced from Rs. 44 to Rs. 14 an acre by shifting from a per acre hire charge to an annual rental charge plus cost of fuel. The total cost of working of Comilla tubewells now comes to about Rs. 73 per acre, but can be reduced to about Rs. 60 an acre by reducing the capital cost of installation from Rs. 20,000 to about Rs. 13,000 by the use of locally manufactured diesel engines, the ADBP-imported lining pipe and coir string strainers.

The annual operation cost of large gravity canals fed by large pumping plants comes to about Rs. 96 per acre. The cost of large government tubewells comes to Rs. 138 per acre irrigated.

The capital cost and annual operation cost of large gravity canal and large government tubewells are higher than those of small low-lift pumps and small tubewells. They also have much longer gestation period. On the other hand, small low-lift pumps and small tubewells begin to yield benefits from the first year. A much larger programme for small low-lift pumps and small tubewells and a much smaller programme for large gravity canals and large government tubewells is, therefore, desirable.

3) The small low-lift pumps as well as small tubewells have been used in areas which are normally inundated by floods to varying depths. No flood protection works have to be provided for these low-lift pumps and the tubewells. This means that costly flood protection works proposed by the IECO, the WAPDA and the Planning Commission can be postponed till a large part of East Pakistan is provided with irrigation facilities by means of low-lift pumps and tubewells.

It is important that there is no misunderstanding on this point. In the long run, flood protection works will be required; they are essential if the summer crop yields are to be materially improved. What is proposed here is that the area under crops can be increased by some ten million acres during the winter season. Furthermore, the yield of early summer crops (*aus* paddy, jute, sugarcane, *etc.*) can be materially increased in a large part of ten million acres and that of *aman* paddy on a large part of ten million acres with the low-lift pumps and the small tubewells. The additional production from additional ten million acres of winter crops and improved yield of *aus* and *aman* season crops will enable East Pakistan to launch a flood-protection programme to protect the sixteen million acres of monsoon season crops.

4) The irrigation water used by farmers for crop production on small tubewells and low-lift pumps is only 15 to 21 acre-inches for winter crops. Another 10 to 15 acre-inches would probably be required for the *aus* and the *aman* crops at the beginning of the *aus* season and end of the *aman* season. Thus, only 30 acre-inches of water (about 2.5 acre-feet) would be required during the year against 6.2 acre-feet proposed to be pumped by the WAPDA with a system of gravity canals which lose half of the water by seepage in the distribution system. Much less pumping of water would therefore be required.

5) The capital cost of a one-cusec pump per acre irrigated is much lower (Rs. 98) than the capital cost of a two-cusec pump (Rs. 144). The annual operating cost of a one-cusec pump (Rs. 50 per acre) is also lower than the annual operating cost of a two-cusec pump (Rs. 60 per acre). The benefit-cost ratio of a one-cusec pump (4.0) is, therefore, higher than that of a two-cusec pump (3.3). The one-cusec pumps have done better than two-cusec pumps because larger blocks of land where two-cusec pumps can be fully used are not available in most places in East Pakistan. As the number of pumps greatly expands during the Third-Plan period, area available at each site will become smaller and smaller. It would, therefore, be desirable to purchase 24,000 one-cusec pumps instead of 16,000 two-cusec

pumps proposed by the ADC. They will cost the same but irrigate 50 per cent additional area.

6) Low-lift pumps and small tubewells are highly productive and would repay their cost in a period of about 2 years. These would, therefore, be taken up by the farmers and a large part of the Rs. 1,300 million required for 10 million acres would be provided by the farmers if a system of incentives for private investment in tubewells and low-lift pumps is provided. A programme for the sale of low-lift pumps at a subsidized price and of private investment in tubewell installation with a small subsidy should, therefore, be prepared. The government may not have to spend more than Rs. 500 million out of the total capital cost of Rs. 1,300 million required for irrigation facilities for 10 million acres if appropriate incentives are provided to the farmers.

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Appendix A

TABLE A-I

CLASSIFICATION OF CULTIVATED AREA OF EAST PAKISTAN WITH RESPECT TO DEPTH OF FLOODING

Type of land	Area		Depth of flooding
	Per cent	Million acres	
(1)	(2)	(3)	(4)
High	7.8	1.69	Above flood level
Intermediate	44.8	9.70	Less than 2 feet
Low	27.3	5.91	3 to 10 feet
Very low	4.6	0.99	More than 10 feet
Saline-tidal	14.6	3.16	Subject to saline-tidal action
Hilly	0.9	0.20	
Total	100.0	21.64	

Source: [27, p. B-IV-9].

TABLE A-2

TOTAL CAPITAL COST OF THE GANGES-KOBADAK PROJECT, KUSHTIA UNIT, PHASES I AND II

Item	Capital cost
	(*million rupees*)
Powerhouse	13.7
Pumping stations	44.7
Irrigation canals	84.0
Intake channel	12.2
Drainage canals	21.8
Structures	68.8
Tools and plants	14.7
Establishment	9.6
Other items	64.4
Total	333.9

Source: Information supplied by Project Director, Ganges-Kobadak Project in May 1966.

TABLE A-3

LOW-LIFT POWER PUMPS USED AND AREA IRRIGATED DURING THE SECOND-PLAN PERIOD

Year (1)	Total number of pumps used (2)	Total cusec capacity utilized (3)	Total area irrigated (*in acres*) (4)
1960/61	1,367	1,743	62,100
1961/62	1,555	2,267	73,900
1962/63	2,024	3,461	133,000
1963/64	2,277	4,604	156,800
1964/65	2,239	4,381	131,400

Source: [10, p. 16].

TABLE A-4

LOW-LIFT PUMP PROGRAMME OF THE ADC FOR THE THIRD-PLAN PERIOD

Year (1)	Number of pumps to be procured (2)	Number of pumps proposed to be utilized (3)	Total cusec capacity to be utilized (4)	Area proposed to be irrigated (*in acres*) (5)
1965/66	1,000	3,600	7,840	235,000
1966/67	2,000	4,480	9,740	292,000
1967/68	3,000	6,400	12,830	385,000
1968/69	5,000	8,390	17,520	521,000
1969/70	5,000	12,400	25,460	764,000

Source: [10, p. 17].

TABLE A-5

NUMBER OF PUMPS, HOURS WORKED, AND AREA IRRIGATED BY LOW-LIFT PUMPS OF THE AGRICULTURAL DEVELOPMENT CORPORATION IN EAST PAKISTAN, 1962/63 TO 1965/66

Year	Number of pumps used			Hours worked by			Area irrigated by			Total fuel consumption by		
	All pumps	2-cusec pumps	1-cusec pumps	All pumps	2-cusec pumps	1-cusec pumps	All pumps	2-cusec pumps	1-cusec pumps	All pumps	2-cusec pumps	s1-cuec pumps
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	(........*number*...)			(...*thousand hours*...)			(...*thousand acres*...)			(...*thousand rupees*...)		
1962/63	2019	1096	643	1721	1018	442	133	69	44	1295	770	336
1963/64	2477	1649	343	1748	1166	343	157	105	28	1973	1322	287
1964/65	2239	1822	349	1532	1164	264	131	109	15	2156	1881	239

Source: Compiled from a statement supplied by the Agricultural Development Corporation with their letter No. ADC/ENG/DEN-B/IP-33/65 3225, dated December 7, 1965.

TABLE A-6

NUMBER OF LARGE OPERATIONAL HOLDINGS, TOTAL CULTIVATED AREA, WHICH CAN BE IRRIGATED BY LOW-LIFT PUMPS AND AREA WHICH CAN NOT BE SERVED BY LOW-LIFT PUMPS IN DIFFERENT DISTRICT OF EAST PAKISTAN

District	Number of farmers having operational holdings above				Area of the district		
	40 acres	25 acres	12.5 acres	7.5 acres	Total cultivated area	Area which can be served by low-lift pumps	Area which cannot be served by low-lift pumps
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(......*number in thousands*......)				(......*thousand acres*......)		
Mymensing	5	27	269	908	3069	1041	2028
Sylhet	4	28	208	529	1724	759	965
Dacca	2	10	91	318	1285	539	746
	11	**65**	**568**	**1755**	**6078**	**2339**	**3739**
Comilla	—	1	27	143	1337	425	912
Rajshahi	5	33	263	727	1714	309	1405
Faridpur	2	10	94	329	1382	369	1013
Pabna	2	14	103	297	984	276	708
Rangpur	5	26	187	594	1590	271	1319
Jessore	1	9	116	455	1220	271	949
Chittagong	2	7	49	144	714	69	645
Khulna	2	15	138	408	1070	50	1020
Noakhali	2	6	45	131	831	86	745
	21	**121**	**1022**	**3228**	**10842**	**2126**	**8716**
Barisal	8	33	209	584	1884	?	1884
Dinajpur	3	21	170	475	1151	122	1029
Bogra	1	7	59	211	831	106	725
Kushtia	2	10	94	253	669	52	617
Chittagong Hill Tract	—	2	16	52	187	264	(—)77
	14	**73**	**548**	**1580**	**4722**	**544**	**4178**
Total	**46**	**459**	**2138**	**6563**	**21642**	**5009**	**16633**

Source: Columns (1) to (5) from [37, pp. 29-34].
Column (6) from [27, p. B IV-9].
Column (7) from [6, Appendix XIII].
Column (8) is Column (6) *minus* Column (7)

Appendix B

TABLE B-1

PROGRESS OF IRRIGATION ON TUBEWELLS IN COMILLA, KOTWALI THANA

Year	Number of tubewells worked	Total area irrigated	Area irrigated per tubewell
		(.........*acres*.........)	
1962/63	2	36	18
1963/64	12	437	36
1964/65	34	1006	30
1965/66	25	1142	46

Source: Compiled from the records of the PARD, Comilla, by Mr. A. Q. Ziauddin, Staff Economist at the Institute.

TABLE B-2

YIELD OF BORO PADDY WITH DIFFERENT IRRIGATIONS HATHAZARI, CHITTAGONG, 1964/65

Interval of irrigation (1)	Total irrigation water applied during *boro* season (2)		Average yield of *boro* paddy (4 replications) (3)	
(*days*)	(*acre-inches*)		(*maunds per acre*)	
10	50.7	41.2	38.8	38.0
15	31.8		37.3	
20	21.6		36.3	
25	18.9		32.6	
30	14.0	13.4	33.3	33.7
35	14.7		32.9	
40	11.5		34.9	
Control	nil		12.8	

Source: Figures collected from the Agricultural Assistant, Hathazari, Government Agricultural Farm, Chittagong, on April 8, 1966.

Appendix C

TABLE C-1

SIZE OF HOLDING AND NUMBER OF SINGLE AND JOINT TUBEWELLS IN THE LAHORE, GUJRANWALA, MONTGOMERY AND MULTAN DISTRICTS AT THE END OF 1965

Size of holdings (*acres*)	Total number of farmers	Number of farmers who installed tubewells			Number of tube-wells installed jointly by farmer	Percentage of farmers who installed tubewells		
		Indivi-dually	Jointly	Total		Indivi-dually	Jointly	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0	—	119	200	319		—	—	
0.0—5.0	337,415	65	730	795		.019	.216	
5.0—7.5	94,669	141	1,599	1,740		.149	1.686	
7.5—12.5	138,356	535	3,398	3,933		.387	2.913	
12.5—25.0	131,865	1,592	5,670	7,162		1.192	4.300	
25.0—50.0	44,981	4,206	5,233	9,439		9.359	11.634	
50.0—150.0	9,196	6,117	1,887	8,004		66.518	20.520	
above 150.0	712	1,489	83	1,572		206.129	11.657	
	757,194	14,244	18,798	33,042	5,904	1.883	2.483	

Source: Survey by the PIDE.

TABLE C-2

POSSIBLE NUMBER OF TUBEWELLS IN EAST PAKISTAN ON THE BASIS OF SIZE OF HOLDING IN FOUR DISTRICTS OF WEST PAKISTAN

Size of holding (*acres*)	Total number of farmers	Percentage of farmers likely to install tubewells		Number of farmers likely to install tubewells			Number of tubewells likely to be installed		
		Indivi-dually	Jointly	Indivi-dually	Jointly	Total	Indivi-dually	Jointly	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0.0—5.0	4784,900	.019	.019	909	10,335	11,244			
5.0—7.5	698,450	.149	.149	1,040	11,775	12,815			
7.5-12.5	442,360	.387	.387	1,712	12,886	14,589			
12.5-25.0	187,790	1.192	1.192	2,238	8,075	10,313			
25.0-40.0	21,370	9.359	9.359	2,486	2,475	4,961			
above 40.0	4,610	66.518	20.520	3,066	946	4,012			
	6139,480			11,451	46,492	57,943	11,453	14,600	26,053

Source: Column (2) from [37, pp. 29-34]. Other columns calculated from Appendix Table C-1.