THESIS

WATER UTILIZATION EFFICIENCY OF IRRIGATION PROJECT— A CASE STUDY OF DACCA-NARAYANGANJ-DEMRA PROJECT

Submitted by

Md. Ghulam Rabbani

In partial fulfilment of the requirements for the degree of Master of Science in Engineering (Water Resources)

Bangladesh University of Engineering & Technology, Dacca.

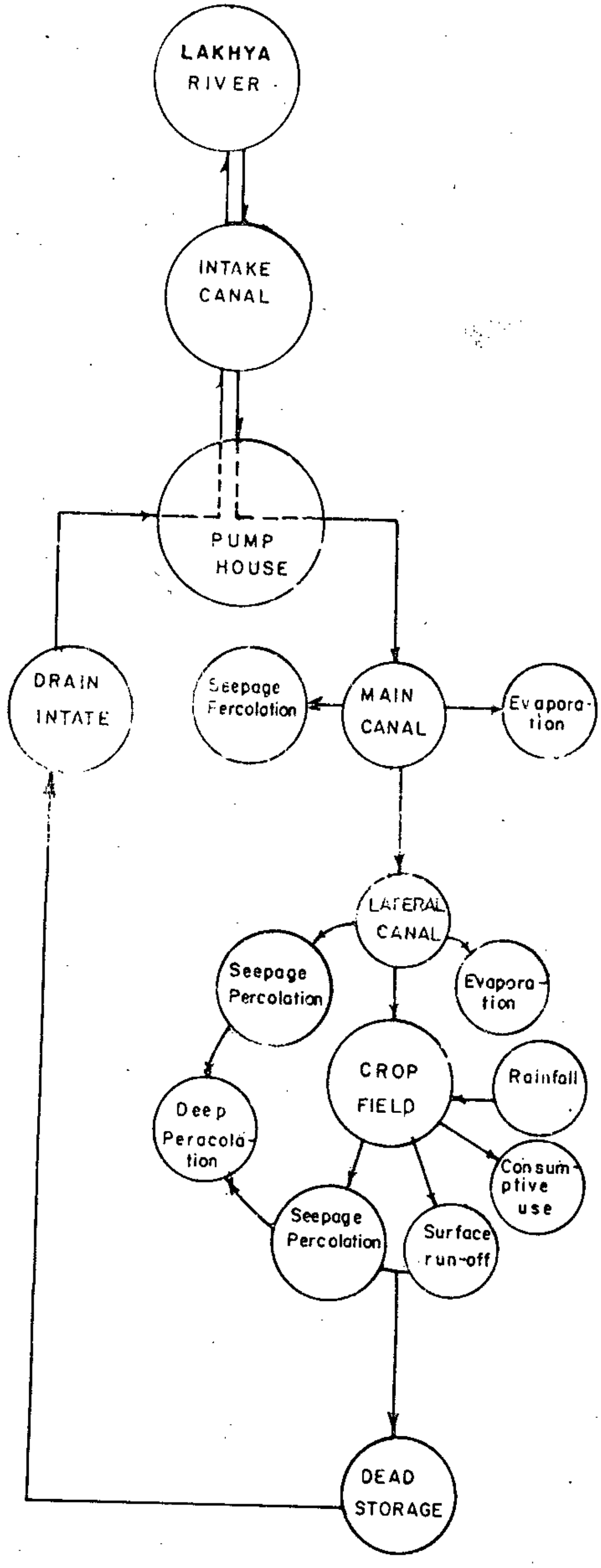
June 1981

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

June 1981

WE HEREBY RECOMMEND THAT THE THESIS PREPARED BY MD. GHULAM RABBANI ENTITLED WATER UTILIZATION EFFICIENCY OF IRRIGATION PROJECT - A CASE STUDY OF DACCA - NARAYANGANJ - DEMRA PROJECT BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENGINEERING (WATER RESOURCES)

Chairman of the Committee	(H. R. KHAN)
Member	(M. R. BISWAS)
Member	(M. A. MANNAN)
Member	(M. K. ALAM)
Member	(S. M. U. AHMED)
Head of the Department	(A. HANNAN)



REGIME OF WATER IN D-N-D PROJECT

ACKNOWLEDGEMENTS

I express my sincere appreciation and profound gratitude to my Adviser and Chairman of the thesis committee, Dr. Hamidur Rahman Khan, Professor, Department of Water Resources Engineering, BUET, for his sincere help, encouragement, guidance and cooperation in making this thesis possible. His active interest in this topic and valuable directions and advice were the source of inspiration.

Greatful acknowledgement is wholeheartedly extended to Dr. Abdul Hannan, Professor and Head, Department of Water Resources Engineering, BUET, for his helpful suggestions, comments and connections for the thesis.

I am deeply indebted to Dr. M.R. Biswas, Professor, Department of Irrigation and Water Management, BAU, and Dr. M.A. Mannan, Member-Director (Soil & Irrigation), BARC, for review the manuscript and helpful comments and connections.

Deepest gratitude and indebtedness are due to Dr. M.K. Alam, Assistant Professor, Department of Water Resources Engineering, BUET, for his help and suggestions at different stage of problems, which enabled me to complete the thesis.

Special appreciation is due to Dr. S.M.U. Ahmed, Assistant Professor, Department of Water Resources Engineering, BUET, for review the manuscript, helpful comments and corrections.

I owe special thanks to Mr. M.M. Ali for his help in typing the thesis.

M.G.R.

LIST OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Contd.)

LIST OF FIGURES

LIST OF FIGURES (Contd.)

LIST OF SYMBOLS

aft	= acre-ft
BAU	= Bangladesh Agricultural University
BPDB	= Bangladesh Power Development Board
BWDB	= Bangladesh Water Development Board
cc	= Cubic Centrimeter
cfs	= cubic feet per second
CU	= Consumptive Use
DL	= Dacca Left
D-N-D	= Darra-Narayanganj-Demra
DR	= Dacca Right
DTO	= Direct Turnout
Eqn	= Equation
FAO	= Food and Agricultural Organization
ft	= foot/feet
Fig	= Figure
gm	= gram
gm/cc	= gram per cubic centimeter
i.e.	= that is
in	= inch/inches
no	= number
NR	= Narayanganj-Right
RL	= Reduced Level
SL	= Serial
WHC	= Water Holding Capacity
WL	= Water Level
WR	= Water Requirement
%	= percent
'	= foot/feet
"	= inch/inches

CHAPTER - I

INTRODUCTION

The pressure for development and the need for additional food supply are causing the rapid expansion of irrigation throughout the whole world. This is particularly true for the countries like Bangladesh which is passing through the acute shortage of food. She has embarked on a real tough line for producing more and more food from her limited and dwindling agricultural lands adopting all possible means of increased production.

The agricultural scientists and irrigation engineers have shown that one of the quickest and surest means of increased production in Bangladesh is the use of irrigation water in crop fields. The farmers although in the earlier days were reluctant to use irrigation water, but now-a-days they are very much inclined to use that in their fields. This trend of the farmers gained a great momentum with the introduction of HYV rice particularly in the country.

However, to grow more cereal crops to meet the food crisis and nutrition gap, very large sums of money have been invested in irrigation projects in Bangladesh during the last few years. It is, however, being realized that the country is not obtaining the full benefits which these projects were expected to yield. A hard headed look at the performance of our irrigation projects lead to the inescapable conclusion that the main reason why additional production has not been achieved to the expected extent is the poor knowledge about efficiencies at various levels of irrigation projects (Khan, 1976). Unfortunately,no such research has already been made to assess the efficiency level of irrigation projects.

Poor planning and design practices at farm level cause a considerable loss of our basic resources at both land and water. The absence of drainage coupled with heavy seepage losses from unlined distribution system and excess application of irrigation water can result in serious damage to the land by water logging and salinization. At the same time, the absence of proper delivery systems and the failure to level and shape the farm lands in a proper manner results in wastage of great deal of water which has been impounded at a great cost to the community (Khan, 1976). Improper irrigation and excess water supply may waste large amounts of water leaching soil nutrients thereby impairing the productivity of the soils. Water for irrigation and other uses is becoming more and more valuable due to the increasing cost of irrigation project and a limited supply of good quality water. Efficient use of irrigation water is an obligation of each user. No man has the right to waste water which another man needs. Therefore, it is a must to learn the degree of water utilization in irrigation projects.

With this view a case study has been taken up to assess the water utilization level (water utilization efficiency) of the Dacca-Narayanganj-Demra Project with the following objectives:

(i) To determine the conveyance efficiency of irrigation,

(ii) To determine the application efficiency of irrigation,

(iii) To determine the consumptive use efficiency of irrigation,

(iv) To determine the overall (project) efficiency of irrigation, and

(v) To determine the distribution efficiency of irrigation.

CHAPTER - II

REVIEW OF STUDY

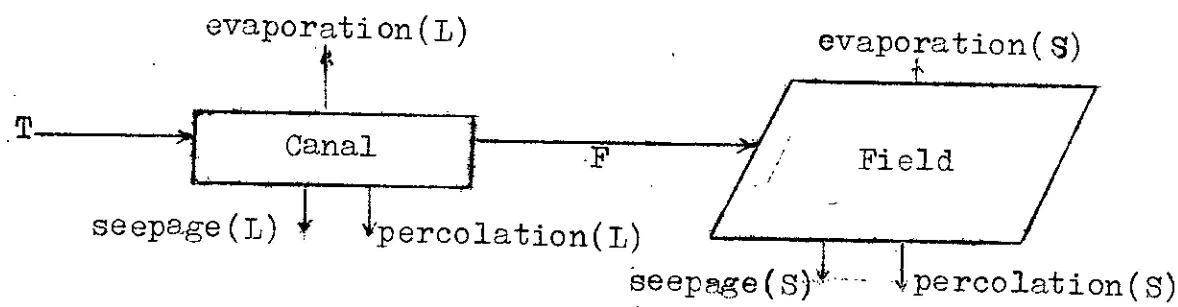
Irrigation is an age-old art, but its systematic studies are not of so long past. Now-a-days water is a precious resource, even though irrigation accounts for more than 85 percent of the total consumption of water controlled by men. The studies on its use and utilization are most vital and modern all over the world. So far, extensive studies in these fields have been made to assess the water utilization level in different irrigation projects and to determine when, how and how-much water would be used for optimal utilization to sustain its benefits. However, a comprehensive survey carried out by FAO (1971) shows that in many irrigation projects only 40 percent of water diverted at source fanally reaches the field. The application efficiency of the irrigation is generally around 60 percent. This is further reduced due to water conveyance and distribution losses (FAO, 1971). Overall project efficiency as low as 20-30 percent are common in the less developed countries, when management of water is virtually neglected.

It was presented at the Water Use Seminar, Damascus, sponsored by FAO (1972) that the magnitude of water loss ranges from 20-80 percent of water which is delivered by different irrigation system. An attempt was also made to demonstrate the magnitude of water losses, shown in the Table below, for four typical alternatives of systems and different rating of system and field water management.

Table for losses of irrigation water and project efficiency

System of irrigation	Rating of management	Conveyance losses L in% of T	Application losses S		Total Losses L+S	Project efficiency %
			In% of F	In% of T		
Canal not work with surface irrigation	best	10	20	18	28	72
	good	–	–	–	–	–
	fair	20	40	32	52	48
	poor	50	60	30	80	20
Canal net work with sprinkler irrigation	best	10	15	11	24	76
	good	15	25	21	36	64
	fair	20	35	28	48	52
	poor	–	–	–	–	–
Pipe net work with surface irrigation	best	5	20	19	24	76
	good	10	30	27	37	63
	fair	15	40	34	49	51
	poor	–	–	–	–	–
Pipe net work with sprinkler irrigation	best	5	15	14	19	81
	good	10	25	23	33	67
	fair	15	35	30	45	55
	poor	–	–	–	–	–

Where L is conveyance losses and S is application losses.



Where L = Evaporation(L) + Seepage(L) + Percolation(L)

and S = Evaporation(S) + Seepage(S) + Percolation(S)

In spite of these, to review the studies on water utilization efficiency of irrigation project in Bangladesh, it goes without saying that no studies of such kind have previously been made before this study taken up in the Dacca-Narayanganj-Demra Project in 1977. However, another consistent study on "Water Use and Adequacy" of the project was conducted by Mr. C.M.A.Khan (1978), during the period of rice culture in boro-season of 1978. In that study Mr. Khan determined only the overall water use efficiency of some sample areas within the project and not all the component irrigation efficiencies at different stages of water regulation. Here it is important to note that the terminology of water use efficiency of the project in that study was defined as the ratio of water used by the project as seepage-percolation plus evapotranspiration to the amount of water diverted for the project plus rainfall within the area. Whereas in the present study, the termionology of water utilization efficiency of the project has been defined as the ratio of water effectively used as evapotranspiration by the project to the amount of water diverted for the project plus rainfall within the area.

However according to Mr. C.M.A. Khan (1978), the water use efficiency varies from 56 to 100 percent with a seasonal value of 73 percent in case of lateral canal DL-1. Similarly, for lateral canals DL-3 and NR-1, it ranges from 43 to 93 percent with a seasonal value of 66 percent and 30 to 97 percent with a seasonal value of 62 percent respectively. In addition, it has also been reported that water use efficiency at project level ranges from 62 to 90 percent with a seasonal value of 76 percent.

CHAPTER - III

BASIC CONSIDERATIONS

WATER UTILIZATION EFFICIENCIES

Generally speaking water utilization efficiency of an irrigation project is the ratio of the quantity of water effectively used (i.e. consumptive use of water) by crop fields to the quantity of water diverted from the source for crop production plus rainfall in crop fields of the project.

The project efficiency may be split up into several component efficiencies at different stages of water regulation.

The efficiency in the first stage is the conveyance efficiency, which is the ratio between the quantity of water delivered into the farm and the quantity of water diverted from the source. It can be expressed as ––

$$Ea = \frac{Wf}{Wr} \times 100 \qquad \ldots \qquad \ldots \qquad (3.1)$$

Where Ea is the conveyance efficiency, Wf is the quantity of water delivered into the farm and Wr is the quantity of water diverted from the source.

The efficiency in the second stage is the application efficiency, which is the ratio between the quantity of water applied in the cropped area and the quantity delivered into the farm and can be expressed as —

$$Eb = \frac{Wa}{Wf} \times 100 \quad \ldots \quad \ldots \quad (3.2)$$

Where Eb is the application efficiency, Wa is the quantity of water applied in the cropped area and Wf is the quantity of water delivered into the farm.

The efficiency in the third stage is the consumptive use efficiency which may be defined as the ratio between the consumptive use of water by cropped area and the water applied in the cropped area, and can be expressed as—

$$Ec = \frac{Wc}{Wa} \times 100 \quad \ldots \quad \ldots \quad (3.3)$$

Where Ec is the consumptive use efficiency. Wc is the consumptive use of water by cropped area and Wa is the quantity of water applied in the cropped area.

Now the water utilization efficiency of the project (i.e. overall efficiency) is the multiplication of all these three component efficiencies and can be expressed as—

$$Ep = (Ea.Eb.Ec)\ 100 \quad \ldots \quad \ldots \quad (3.4)$$

Thus the ratio of the consumptive use of the project to the total supply for the project is the overall efficiency, and can be expressed as—

$$Ep = \frac{Cu}{I} \times \quad \ldots \quad (3.5)$$

Where, Cu = consumptive use of water of the project, and

I = total supply of water for the project.

Now the efficiency in the irrigation project which is very important from the angle of project water management, is the water distribution efficiency that represents the extent to which water is uniformly distributed all over the project. The mathematical expression for water distribution efficiency is

$$Ed = \left(1 - \frac{y}{d}\right) 100 \quad \ldots \quad \ldots \quad (3.6)$$

Where Ed is the water distribution efficiency, y is the mean deviation of depth of water stored from the average depth during irrigation of crop fields and d is the average depth of water stored during irrigation.

FACTORS AFFECTING EFFICIENCIES

The water utilization efficiencies of irrigation projects are dependent on the standard of degree of water management within the project which controls the losses of water as evaporation, seepage, percolation and surface run-off from the project area. However all these parameters are controlled by the development features and physical conditions of the project which can be summarised as follows:

Distribution System:

Water distribution system is a main factor in evaluating the water losses and regulation of the project. Thus when the water supply is regulated and distributed with various method of irrigation such as flooding irrigation, continuous or rotational irrigation through lined or unlined canals, sprinkling irrigation etc., the losses of irrigation water will vary from method to method within a considerable range. In case of unlined canals, a valuable percentage of total supply seeps and percolates through the canal soil surface. As such when the canal is constructed by ground excavation method, it seeps and percolates relatively less water than that in the case of embankment-constructed canal. But the water lost as seepage from the latter case may partially goes to the cropped field on both sides of the canal rather than direct going to deep ground. On the other hand, in the former case, there remain a part of water in the canal as dead storage.

Soils:

Soils are solely responsible for storing water and making it available to plants. If the soils are sandy, the major part of irrigation water will be lost as seepage and percolation during the period of conveyance as well as from crop fields after storage for plant consumption. On the contrary, in case of fine textured soils, less water is lost and higher storage is possible in every stage of water regulation. Thus for a particular method, especially for check-basin-flooding method, soils nature and properties can give the index of irrigation efficiency to a great extent.

Topography:

Due to variation in ground levels throughout the project and higher elevation of ground surface from the ground water table, water regulation in the project becomes tedious and hampers the uniformity of the distribution. Thus when the depth to ground water table from the ground surface is more, more water is lost to fill up the porosity of soil and more water seeps from the project area. In addition, when contour levels vary from points to points, water supplied into the fields seeps from the higher plots to the lower plots where it accumulates and creates an acute problem in proper utilization and drainage of water. Under such condition, the lands at higher levels suffer from under moisture and the lower lands from inundation.

Drainage System:

When there is a drainage system of higher density, a higher percent of irrigation water drains out from the irrigation fields and low irrigation efficiency results.

Cultural Practices:

Water utilization efficiency, to some extent, is controlled by cultural practices. Thus if the lands are ploughed repeatedly throughout the year at sufficiently low moisture, the infiltration rate of soils becomes high. But when the lands are ploughed with a thin layer of water on the ground surface, due to stirring action of soils, silt and clay particles gradually settled below the root-zone and forms a hard impermeable plough pan which impeds the percolation of water from ground surface. Again when the lands are ploughed deeply and plough pan is crushed, water percolates very rapidly and a huge quantum of water wastes.

Operation and Maintenance:

Water utilization of a project is greatly influenced by operation and maintenance of various water regulating systems (irrigation and drainage) and hydraulic structures. Thus when the proper maintenance of distribution canals and bunds of crop fields are not maintained duly, a bulk share of water is lost in various ways such as seepage-percolation, free evaporation, run-off etc. Similarly when water controlling structures are not properly maintained and operated, a sufficient quantum of water may be lost.

Hydrometeorological Condition:

The consumptive use of water highly depends on hydrometeorological condition of growing season such as temperature, relative humidity, wind velocity, duration and intensity of sunshine etc.

Project Administration and Management:

The regularity and uniformity of allocation and distribution of water throughout the project mainly depend on administration policy and individual responsibility. Thus if the management is done through cooperative system and the interest is shared equally by all the members, then the question of responsibility falls on everybody in every corner. Which ultimately may becomes responsibility of none, especially for the countries like ours. Again in our country when water is withdrawn by farmers within a big irrigation project, the upstream's reparians take more facilities over the lower reparians and waste a huge amount of irrigation water which is virtually due to others. However, in case of state personnel, the maintenance and repairing of all water management system may not be taken up in time as desired by farmers.

Moreover, the system of water charges may handle the water management to some extent. Thus, if it is tax free, irrigation water may be wasted by farmers due to their negligence. Again if the charges are fixed on area-basis and volume-basis, in the former case each consumer may use water lavishly and in the latter case the higher land owners lose more financially than the owners of lower lands due to their disadvantageous position and ultimately the benefit from drainage will be discouraging.

Crop Character:

If the crops are deep rooted, more water is stored in the root-zone and more water is utilized than that by shallow rooted crop. Again in case of plants in saturated or water logged soils and in unsaturated or dry soils, the former uses more water than the latter case. However, amount of water transpired depends on density of crop, stage of growth, type and arrangement of foliage, nature of leaves, photosynthesis and so many factors.

Proximity of Sources:

The project's water utilization is, to some extent, affected by proximity of the sources of irrigation water. Thus if the project is far away from the source, a considerable quantity of water is lost while conveying to the farm from the source especially when the canals are earthen made or excavated. This factor is highly effective in case of conveyance efficiency.

CHAPTER - IV

DACCA-NARAYANGANJ-DEMRA PROJECT

LOCATION AND AREA

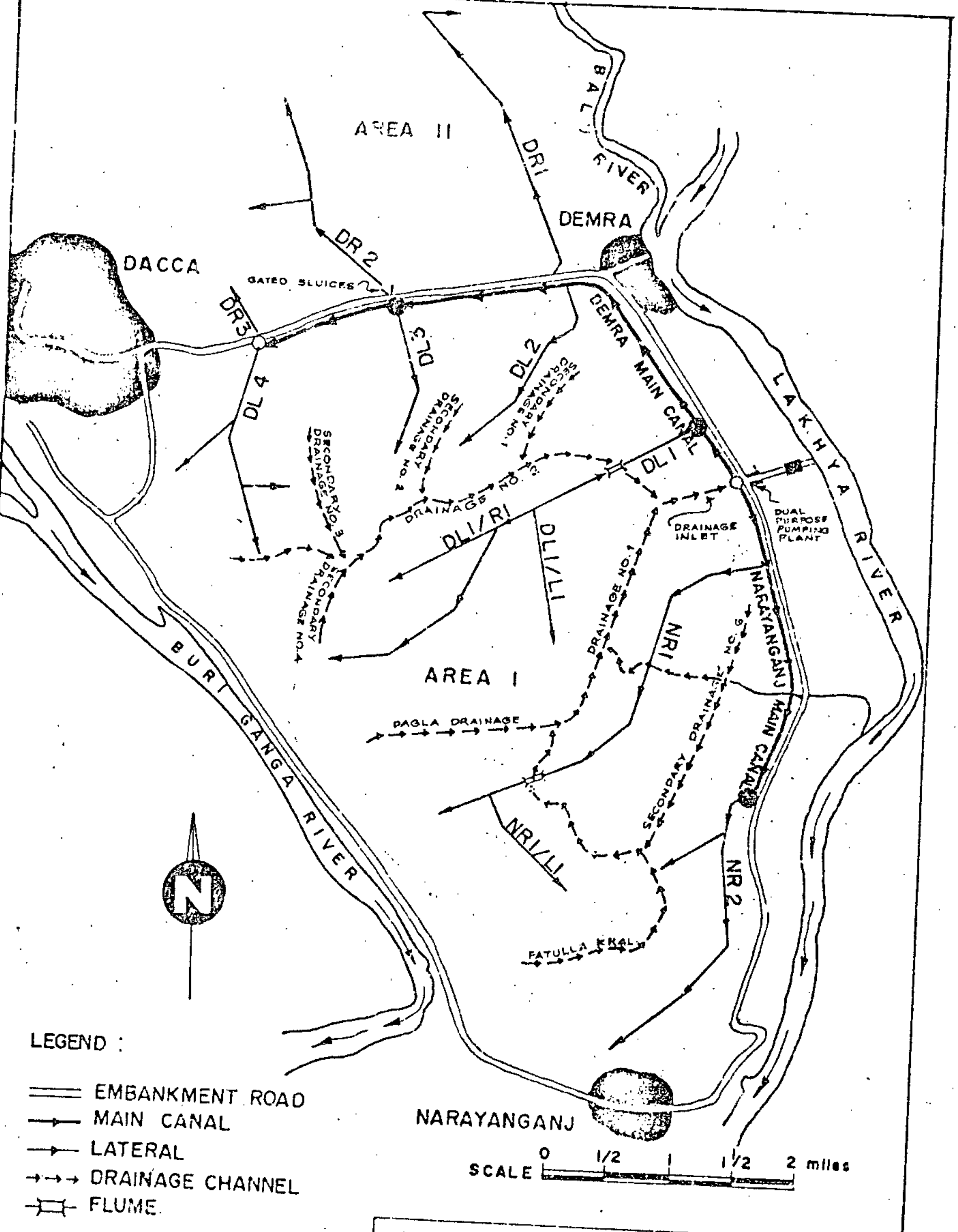
The project is located in the south-east suburb of Dacca city, and is surrounded by four rivers —— the Lakhya, the Buriganga, the Balu and the Dholai Khal. The whole project is divided into two parts — Area I and Area II. Area I (shown in Fig. 1) is a triangle enclosed by road and railroad embankments and countains 14500 acres of land, of which about 9884 acres are currently irrigable (BWDB, 1977). The rest of the project, Area II, is at the outside of the embankment. It contains about 6361 acres of land, of which 5240 acres are currently irrigable (BWDB, 1977).

PURPOSE

The Dacca-Narayanganj-Demra Project is a multipurpose development project. During the pre-project period the area was inundated by flood spills from the Lakhya and Buriganga Rivers to a depth of five to fifteen feet in monsoon and suffered from drought in dry season every year causing serious damage or very poor yield to crops. As a matter of consequence, the project was designed mainly for the facilities ——

(i) To provide its service area with water for irrigation,

(ii) To protect the project, especially Area I, from flooding of Lakhya and Buriganga Rivers, and



The Project Area

DACCA – NARAYANGANJ – DEMRA IRRIGATION PROJECT

Fig. 1

(iii) To provide drainage facilities by disposing irrigation waste water and excess rainfall during monsoon, for successful crop production especially HYV rice cultivation throughout the year.

WATER DISTRIBUTION SYSTEM

Irrigation water for the Dacca-Narayanganj-Demra Project comes from the Lakhya River at pump house through the intake canal in which water remains almost at the same level of Lakhya river. Both of the areas (Area I & II) are served with irrigation water supplied by pumping plant. First the irrigation water is withdrawn and stored in the main canal (Fig.1) from where water is supplied by gravity flow into the Area I & II through laterals and direct turnouts which have taken off from the main canal. The main canal is actually a huge reservoir rather than to be a canal. Irrigation water is always stored within the canal for readily supply and it remains almost calm and quiet. The full supply level and bed level of the canal are at 15.50 ft (PWD) and -5.00 ft.(PWD) respectively. The width of the canal is 125 ft and it can store about 100 acre-ft of water for each foot depth at the full supply width. However, after taking off from the main canal, the laterals and turnouts run through the crop-fields. They are usually constructed by embankments on both sides to maintain the water at a higher level above the ground so that irrigation water can be supplied through field outlets by gravity flow into the field ditches as well as crop fields. The embankments on both side of canals contain so many minute cracks and leaks through which water seeps from the canals into the crop fields. As a result in case of long lateral canals, the lands at far distances from the off-take of canals suffer occasionally from inadequacy of water. The supply is very continuous throughout the growing season except the days of repairing and maintenance of canals. The whole length of each canal is divided into several reaches for distribution facilities.

The farmditch outlets are generally at the level of the adjacent plots or field ditches which are earth-cut minor canals supplying water either by wild flooding from plot to plot or by scooping or Don.

SOIL-WATER CONDITION

Soils of Dacca-Narayanganj-Demra Project usually ranges from silty clay to clay (as shown in Fig. 2) with the permeability range of moderately slow to very slow. Several figures (Fig.3-5) have been presented showing different soil-water relationships of soils of the Dacca-Narayanganj-Demra Project. And the details of soil texture has been shown in Table 27. From soil texture view point and experiment the water holding capacity of soils has been obtained to be high. So, the applied water easily be retained by soils for readily consumption by crops. Soils having been puddled year after year clay particles have settled down to establish an impermeable layer termed as plough pan and resists water from seepage and deep percolation favouring for maximum water retention and thereby use of water.

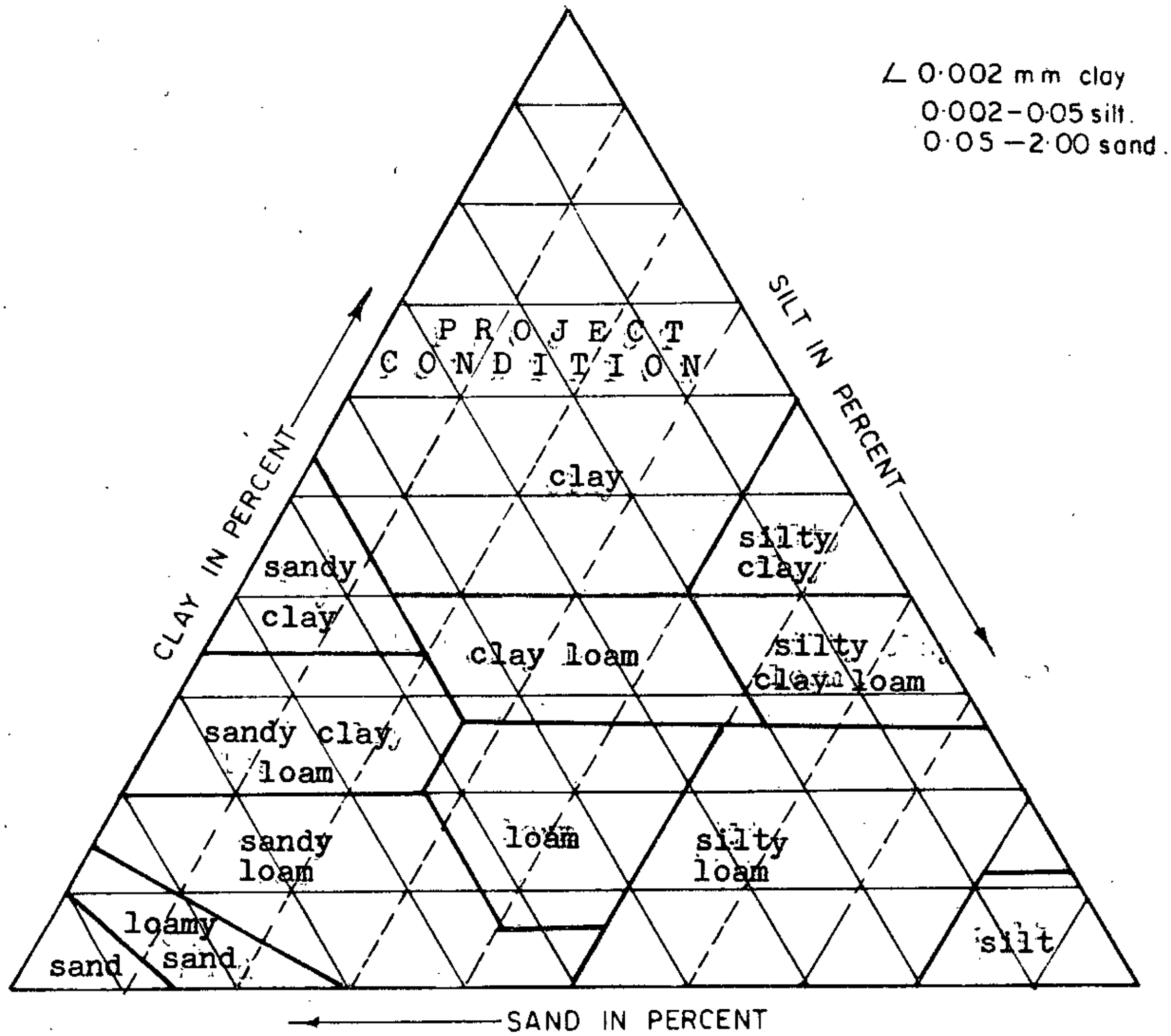


Fig. 2 – Soil textural classification chart.

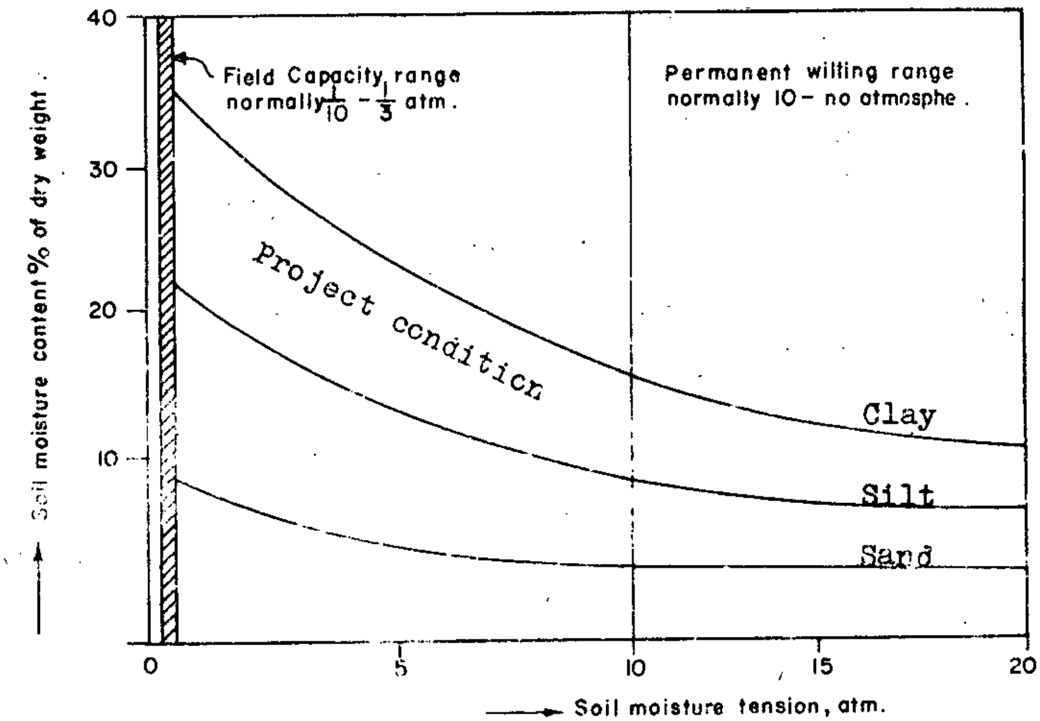


Fig. 3 -Typical curves of soil-moisture relationships showing soil-moisture variation with tension.

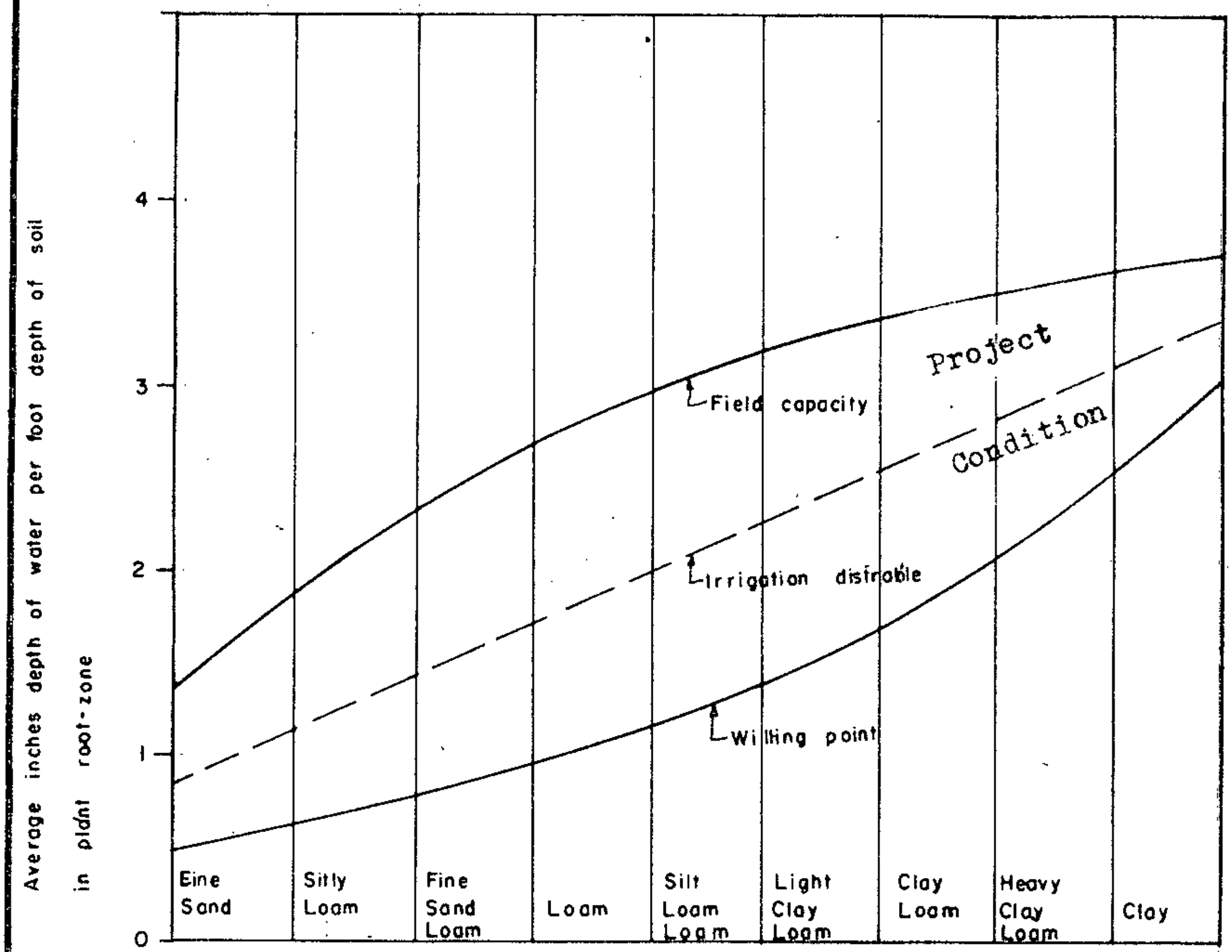


Fig. 4 --Simplefied comparision of water holding chariacteristics of different textured soils (U.S. Department of Agriculture, 1955)

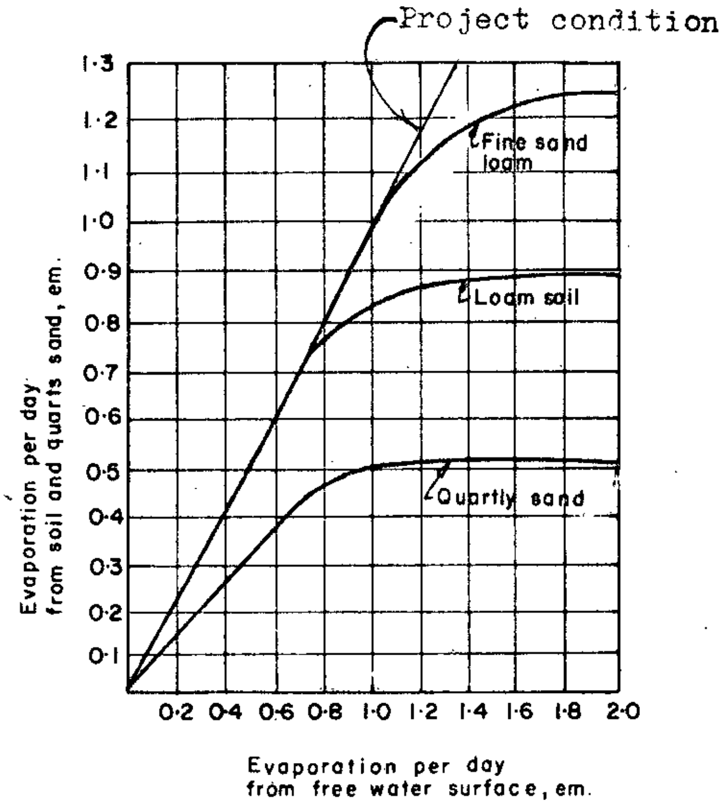


Fig. 5'- Rate of evaporation of water from columns of Soils and quarty sand with free-water at a depth of 60 cm versur rate of evaporation from free water surface (Gardner & Fireman, 1958)

There are three categories of land namely high, medium and low in the project area. The soil-water condition of irrigated plots fluctuates from flooding condition to some point at moisture level between field capacity and wilting point. At first water is applied in crop fields (especially high and medium) when its moisture level just remains below the field capacity and after application of water soils become saturated, and water surface comes above the soil surface. The water above the soil surface and within the root-zone is gradually used by crop fields and lost as seepage, percolation and surface run-off, and ultimately attains the previous moisture level within the range of readily available soil-moisture.

The saturated zone of soils usually exists at a depth of 8.28 inches on average (Table 6) from soil surface, just before watering which can easily maintain a thin film of water on the soil surface by capillay action. As a result constant rate of evaporation as from free water surface is possible under such a soil water condition (Fig. 5).

TOPOGRAPHY

The whole project area is not at the same level, rather its different areas lie at different levels forming an uneven topography throughout the project. A realistic picture of the project topographical condition has been presented in the Table 25 . And the Fig. 20 also shows the area-elevation and volume-elevation curves of the project. Under such an undulated topographical condition it is very tedious to regulate water uniformly in different plots at different levels as water always moves from the higher plots to the lower plots. Here virtually the major part of water lost from the higher plots is ultimately used by and accumulates in the lower plots.

DRAINAGE SYSTEM

The main drainage system has been presented in the Fig.1. The irrigation and drainage systems of this project are absolutely separate from each other. Initially ground water table in the project remain at hydrostatic condition with the river water level. Then irrigation starts and the regulator at pump house is closed for soil water conservation. The waste part of irrigation water gradually accumulates in drainage channels as well as in underground saturated zone, and the ground water table within the project gradually moves upward and ultimately inundates the low lying areas. Thus when inundating water level reaches a certain level (6.5.ft), the gates of the regulator are opened to expell the accumulated excess water from the project into the intake canal by gravity flow, the ground water table again moves downward to attain its hydrostatic condition with river. And again to retain soil moisture, the regulator at the pump house is closed to repeat the cycle. However, the drainage by gravity is only applicable during the dry period when the river water level remains low and permits gravity drainage. And during the wet period when the river water level remains higher than that within the basin, the excess drainage load from rainfall run-off is disposed by pumps from the basin area into the river Lakhya.

WATER BALANCE IN IRRIGATION FIELD

In case of low land rice culture, the maximum yield is obtained when an optimal layer of water on soil surface is maintained in the rice field.

Accordingly, in the project area, a specific feature of irrigated rice culture has become to maintain a layer of water on the field almost throughout the growing season. Under such a condition rice grows like an aquatic plant. To keep an uniform layer of water on each plot, each plot is levelled and water is supplied sufficiently so that after saturating the soil profiles water surface comes above the soils surface. In rice fields which are puddled for years, a more or less impermeable layer is established at a shallow depth to prevent excessive water losses to sub-soils. The amount that is used by crop field is the consumptive use of water and the losses are seepage, percolation and surface run-off. It is to be mentioned that the water lost as percolation, seepage and surface run-off from some plots may be necessary supply for others.

The hydrological balance of a rice field in Dacca-Narayanganj-Demra Project can be formulated as follows:

$$Qsi + P + Qlsi = S + ET + Qdo + Qls + Qso \quad \ldots \qquad (4.1)$$

Where, Qsi = surface inflow,

P = rainfall,

Qlsi = sub-surface inflow,

S = storage of water in and on the soil, The hydrological balance of a rice field can be formulated as follows.

$$Qsi + P + Qlsi = S + E + Qdo + Qts + Qso$$

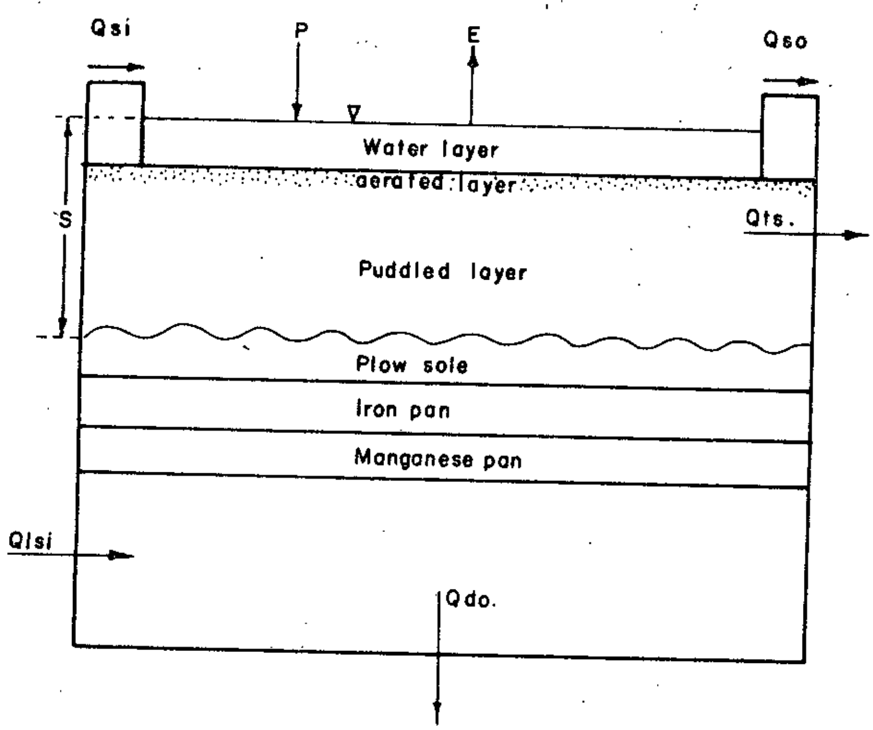


Fig.6 : Hydrological balance components of a rice field.

Where:-

Qsi = Surface inflow

P = Rainfall

Qlsi = Sub-Surface inflow

S = Storage of water in and on the soil

ET = evapotranspiration,

Qdo= percolation below the top soil,

Qls= seepage through the top soil bunds, and

Qso= surface outflow.

All these details of hydrological balance and water regime in rice field has been presented in the (Fig.6).

Though it is the general trend to maintain a flooding layer of water on the soil surface, but due to high deviation in ground levels from plot to plot, it is very difficult to fulfil the purpose. As a result, the relatively high plots suffer from inadequacy of water for optimal crop production and the lower ones suffer from excessive inundation. Due to which in both cases the yields and benefits are far away from target.

OPERATION, MAINTENANCE AND ADMINISTRATION

At present the operation and maintenance of the project is divided between several sub-divisions of the BWDB. The pumping plant's O&M is the responsibility of the Mechanical Equipment Organization (MEO) which is under the Director of General Services. The agricultural development work (including supervisor of farmers in O&M of field ditches) is the responsibility of the Directorate of Land and Water Use. The O&M of all civil works (flood embankments, irrigation system and drainage system) is the responsibility of the BWDB's Chief Engineer. And power for the project is generated and distributed by the BPDB.

Obviously the present organizational set-up for project's O&M has some direct adverse effect on the water use in the project. As long as responsibility and authority is fragmented in this manner, optimum efficiency is impossible. O&M of a multi-purpose project like Dacca-Narayanganj-Demra should be the direct responsibility of a single manager working within clearly defined policies established by his administrative supervisors.

In addition to the staff of BWDB, local farmers' associations have been organized with local leaders who work as liaison personnel with the BWDB's staff. Occasionally, local farmers arrange themselves for maintaining and repairing of irrigation canals. From the very beginning of the project upto 1977, the farmers were free from any obligation of taxes for water use in their crop fields. Presently BWDB is going to fix up the water charges for irrigation, but the basis of charges has not yet been decle-red.

HYDROMETEOROLOGY

Rainfall:

Total average annual rainfall is about 75 inches. About 75% of the annual rainfall falls during the rainy season from May through September. During this period the relative humidity remains much higher than in the rest part of the year.

Evaporation:

Higher evaporation takes place durig non-rainy summer days. During monsoon the rate of evaporation decreases due to cloudy sky and higher relative humidity. Total annual evaporation is about 40 inches.

Temperature:

The climate of this area is essentially the same of Dacca and Narayanganj. The cooler weather begins in November and continues till the end of February. During this period the temperature may vary from a maximum of $100^{o}F$ to a minimum of $42^{o}F$. On set of March the warm weather begins and continues till mid-June. This is the hottest period of the year with temperature varying from $50^{o}F$ to $108^{o}F$. From mid-June through mid-October is the monsoon season with temperature varying from $62^{o}F$ to $102^{o}F$.

CROPPING PATTERN

Multiple cropping pattern is followed in the project and the intensity is more than two. Lowland rice culture is practised all through the seasons of year. Besides rice, sometimes jute, oilseeds, pulses, vegetables are grown as minor crops on very high lands. Transplantation of HYV rice, especially IR-8, begins in Boro-season usually from the last week of December and ends in the middle of January. Here the area under the lateral canal DL-3 was transplanted during the first fortnight of January, 1977, in the Boro-season.

CHAPTER - V

PROCEDURES

To determine the water utilization efficiency of the project, parameters in water management have been collected, observed and computed depending on water management condition during the Boro-Season of rice cultivation in 1977. These could be sumarised as follows:

SITE SELECTION

In case of overall (project) efficiency, the Area I of the project has been taken into consideration. And from the water balance of the project, the overall efficiency has been determined.

In case of component efficiencies, due to hugeness of the project, an experimental area (Fig. 1) was taken at the middle of northern part of Area I which is served by the lateral canal DL-3.

SAMPLING TECHNIQUE

The total command area under the lateral canal DL-3 is 75[illegible] acres of which 612 acres were irrigated in the Boro-season of 1977. And out of 1300 plots, 59 plots were taken to determine the water application efficiency, the consumptive use efficiency and water distribution efficiency. The numbers of high, medium and low plots were 220,926 and 154, of which 10,92 and 7 nos. were selected respectively for each type of land.

AGRONOMICAL OBSERVATION

The transplantation of IR-8 rice in the area was started on January 1 and continued upto mid of January, 1977. After transplantation irrigation was continued upto April 5, till the begining of heavy shower. During this period of 94 days (1.1.77 to 5.4.77) of irrigation soil water conservation was the main target of water management.

However after beginning of rainfall (5.4.77) drainage was the acute problem rather than irrigation, to raise crop successfully. Accordingly, upto the completion of harvesting (31.5.77), excess water has been expelled from the crop field. The last fortnight of the month of May (1977) was the harvesting period. The total growing period from 1.1.77 to 31.5.77 was 151 days of, which the effective days for consumptive use of water for the crop field was 136 days (as shown below).

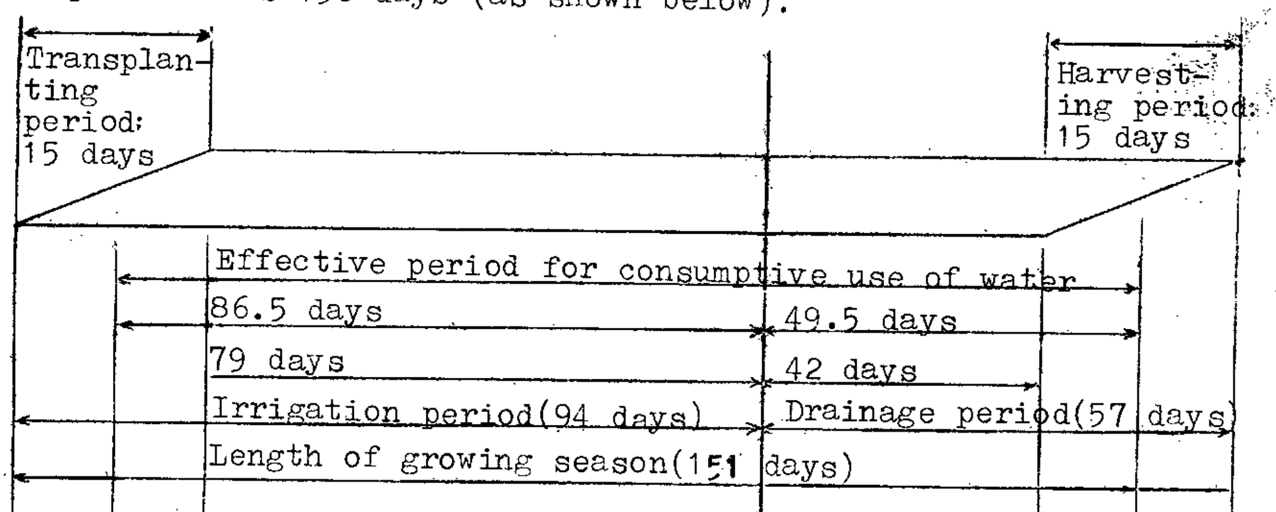


Fig. 7 Periods under different phases of growing season

The effective days for consumptive use of water during irrigation period was about 87 days and that during drainage period was about 50 days.

HYDROLOGICAL OBSERVATION

Rainfall:

The rainfall in the project area was measured by 5" - dia bucket graduated in inches and centimeters. For daily rainfall, gauge reading was taken at 9 A.M. The daily rainfall record during the crop growing season from Jan. 1 to May 31, 1977 has been shown in the Table 1.

Evaporation:

The daily evaporation record during the growing season was collected and has been shown in the Table 1.

DETERMINATION OF WATER SUPPLIED FOR THE PROJECT

The required amount of water for irrigation of the project was withdrawn by pumps from the Lakhya river into the main canal at the pump house. Water levels at both the delivery and suction sides were recorded at each one hour time interval. Thus the total pumping head for each of the pumping unit was determined by water level difference. Then with the help of performance curve of each pumping unit, the discharge was computed for each corresponding head. All these discharge data on daily basis have been shown in the Table 2. The total amount of water thus withdrawn is 28051 acre-ft (Table 2).

DISCHARGE MEASUREMENT OF LATERAL CANALS

To measure the discharge of lateral canals, suitable sections through which flow was unidirectional, were selected at the uppermost end of each of the lateral canals, especially for DR-1, Dr-2, DR-3, DL-3, DTO-8 and DTO-9.

The discharges of the canals were computed with the equation—

$$Q = \frac{Vr}{\sqrt{d_r}} \cdot C = K.C. \quad \ldots \quad \ldots \quad (5.1)$$

Where, Q = discharge of canal in cfs.

Vr = average velocity in ft/sec. along the depth d_r

d_r = depth in ft, and

C = channel factor

The Fig. 8 shows a section of a channel. For a channel flowing steadily, the relation between the velocities and the

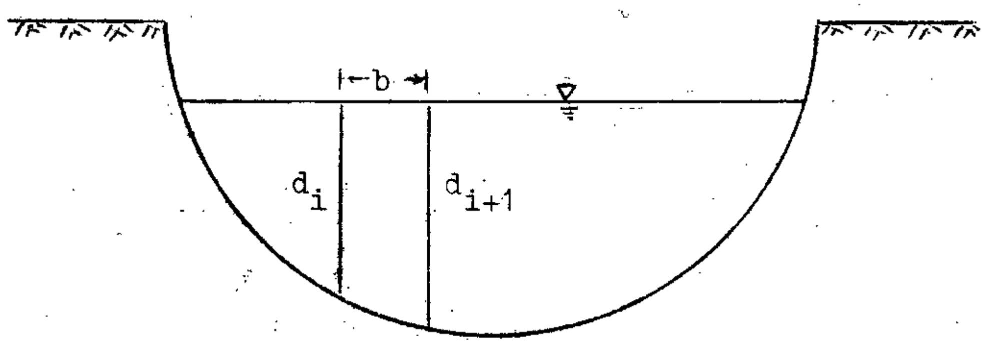


Fig. 8 Cross-Section of a typical canal

corresponding depths across a channel remains more or less same as —

$$\frac{V_r}{\sqrt{d_r}} = K$$ Where, V_r and d_r are velocity and depth at any particular point across a channel

i.e. for the Fig. 8

$$\frac{V_i}{\sqrt{d_i}} = \frac{V_{i+1}}{\sqrt{d_{i+1}}} = K$$

Where, V_i = average velocity along the depth d_i and

V_{i+1} = average velocity along the depth d_{i+1}

Now, the area of and the velocity through the shaded area (Fig. 8) are —

$$\text{Area} = \frac{d_i + d_{i+1}}{2} \cdot b$$

$$\text{and Velocity} = \frac{V_i + V_{i+1}}{2} = \frac{K\sqrt{d_i} + K\sqrt{d_{i+1}}}{2}$$

Therefore, discharge through the shaded area is —

$$\Delta Q = \frac{d_i + d_{i+1}}{2} \cdot b \cdot \frac{K\sqrt{d_i} + K\sqrt{d_{i+1}}}{2}$$

$$= K \cdot \frac{b}{4} (d_i + d_{i+1}) (\sqrt{d_i} + \sqrt{d_{i+1}})$$

Thus the discharge through the whole section be —

$$Q = \sum \Delta Q = K \sum \frac{b_i}{4} (d_i + d_{i+1}) (\sqrt{d_i} + \sqrt{d_{i+1}})$$

$$= K.C. \qquad \ldots \qquad \ldots \qquad (5.2)$$

Where, $C = \sum \frac{b_i}{4} (d_i + d_{i+1}) (\sqrt{d_i} + \sqrt{d_{i+1}})$

= Channel factor for the given section upto the water level.

Here it should be noted that the channel factor changes with the change of water level. Thus at different levels of a particular channel section there are different corresponding channel factors which can be presented by a curve shown in Fig. 9. Now for a particular water level having a particular energy gradient, knowing the value of $V_r/\sqrt{d_r}$ at any point along the channel section, the discharge passing through the section can be obtained (BWDB). Accordingly, the discharges of DR-1, DR-2 and DL-3 have been computed and shown in Table 3. But the canal DR-3 and DTOs 8 & 9 being smaller in size, their discharges have been

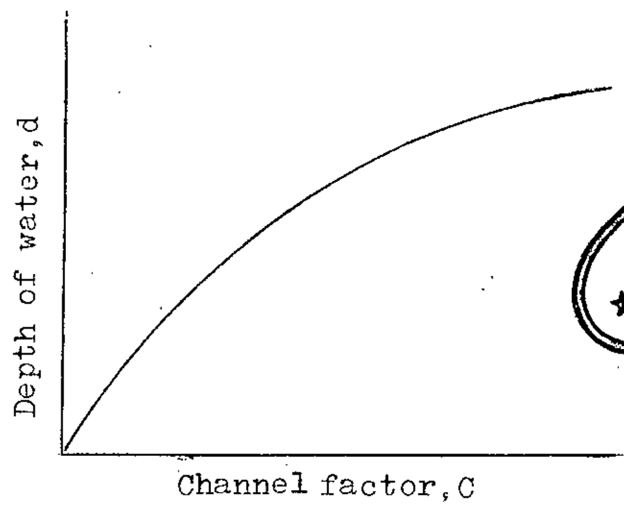


Fig. 9 Curve showing the relationship between channel factor and water level

directly computed by multiplying the cross-sections of flow with the velocities measured with current meter and shown in Table 4. However, the velocity and channel factor required for discharge computation were determined as follows:

Velocity Computation:

The average velocity of flow along the depth at a point of the cross-section has been measured by a current meter. Where the depth of flow d is less than 1.50 ft the reading for average velocity was taken at the depth of 0.6d from the water surface. And where the depth of flow d is more than 1.50 ft, the average velocity was determined by the mean of the velocities at the depths of 0.2d and 0.8d from the water surface. Actually the initial reading of current meter was obtained in nos. of revolutions, which has been converted into velocity from the calibration curve of velocity vs. revolutions for the current meter. The curve has been shown in the Fig. 13.

Channel Factor Computation:

To compute the channel factor required for discharge measurement of the canals DR-1, DR-2, DR-3 and DL-3, the cross-sections of these canals were surveyed and drawn as shown in Fig. 14. The channel factors of these channels for different depths of flow, as per equation ___

$$C = \sum \frac{b_i}{4} (d_i + d_{i+1}) (\sqrt{d_i} + \sqrt{d_{i+1}}),$$ were

computed, which have been shown in the Table 5. Fig. 15 also shows the channel factor vs. depth curve for the channels DR-1, DR-2 DR-3 and DL-3.

DETERMINATION OF WATER APPLIED IN CROPPED AREA OF DL-3

Irrigation water is usually applied in each individual plot by rotational method. Just before irrigation each time into the crop-field, the representative soil columns extending from the soil surface to the saturated zone were collected by thin walled cylinder of required length. Precaution was taken against the moisture loss as evaporation from the soil by covering with polythein bags. Then the soil samples were weighed in laboratory. After making saturated, the samples were again weighed and the additional water required to saturate the soil at field condition was determined. The volume of water required to saturate a soil column of particular dimension was converted into depth of water for the length of the soil column. Then the amount of water on the soil surface was determined by measuring the water depth in each plot with scales graduated in inches which were put parpendicularly in each of the observation plots. The reading of observation was taken once a day at 9 A.M. and at the time of watering. Thus the amount of water supplied within the soil and on the soil surface was determined and expressed in depth of inches of water, which has been summarised and presented in the Table 6. However, the average depth of water applied in the field during irrigation period has been obtained to be 35.43 inches (Table 6).

DETERMINATION OF CONSUMPTIVE USE OF WATER(FOR AREA OF DL-3)

Consumptive use of water of an irrigation project can be determined with water balance method under some condition by substracting the total losses of the project from the total supply for the project. However, due to lack of confinement and isolation of the area served by the canal DL-3 from rest of the project area, the method of water balance was not applicable in this case. So, to determine the consumptive use of water for this area, two other attempts have been made, one, by reviewing the research data of consumptive use of water for IRRI rice during boro season under the same field condition and the other by applying imperical formulae based on hydrometeorological conditions of the area and crop character. These approaches can be described below:

Consumptive Use from Research Data:

The research data of consumptive use of water of rice field so far available and studied in Bangladesh in different growing season have been collected and compiled in the Table 7. The table shows that the consumptive use of water of rice field during boro-season ranges from 19 inches to 57 inches with the average value of 41.79 inches. However, due to high diversiveness of values, this might be avoided for ideal application.

Consumptive Use from Imperical Formulae:

There are so many imperical formulae of which Blaney Criddle method, Penman method, Modified Penman method, Solar Radiation (Jensen and Haise) method may be mentioned as widely known, to predict the evapotranspiration of crop fields by using hydrometeorological data and suitable crop factor. However, the consumptive use of water may be tried to be found out by Blaney Criddle method and Modified Penman method which are extensively used all over the world.

(i) Modified Penman method: According to Japan International Cooperation Agency (1978), the Modified Penman method can be adopted as given below for calculating evapotranspiration index in the project area.

$$ETo^{*} = W.Rn + (1 - W) \cdot f(u) \cdot (Ca - ed) \quad \ldots \quad (5.2)$$

$$ETo^{*} = C.ETo$$

Where, ETo^{*} = reference Evapotranspiration Index, mm/day (not adjusted)

ETo = adjusted Evapotranspiration Index, mm/day

W = temperature related weighting factor,

Rn = net radiation in equivalent evaporation, mm/day,

f(u) = difference between the saturated vapour pressure at mean air temperature and the mean actual vapour pressure of the air both in mbar, and

C = adjusting coefficient.

Evapotranspiration index, as shown in Table 8, have been calculated by adopting the Modified Penman method in reference to the last 10-year meteorological data (1967-1976) obtained at Dacca Station (Japan International Corporation Agency, 1978).

Consumptive use of crop field has been calculated by the following formula:

$$ET\ (crop) = ETo.\ Crop\ Factor \quad \ldots \quad \ldots \quad (5.3)$$

Where, ET (crop) = Evapotranspiration (consumptive use), and

ETo = Evapotranspiration Index.

Crop factors used for this procedure follow the figures indicated in the report "Bangladesh Land and Water Resources Sector Study", IBRD, 1972, Vol.7 , and are shown in the Table 9(Japan International Cooperation Agency, 1978).

As per detailed calculation shown in Table 10, the consumptive use for the growing season has been obtained as 26 inches. And according to the Fig. 17 the consumptive use from January 1 to April 4, 1977, has been obtained as 13 inches. This value also seems too low.

(ii) Blaney Criddle method: To calculate the evapotranspiration (consumptive use) the Blaney Criddle method can be used as follows:

$$U = \frac{K.tp}{100} = Kf \quad \ldots \quad \ldots \quad (5.4)$$

Where, U = monthly evapotranspiration, inches,

K = crop factor (crop coefficient),

t = mean monthly temperature, ^{o}F,

P = monthly percent of day time hours of year, and

f = $\frac{(tp)}{100}$ = monthly evapotranspiration factor.

Monthly percent of day time hours of year and mean monthly temperature of the project have been collected from Land and Water Use Directorate of BWDB and shown in Table 11. The detailed computation has also been shown in the same table. And the consumptive use for the growing season has been obtained as 38 inches. Now the consumptive use upto April 4, 1977, might be taken as 22 inches as shown in Fig. 17 , which is 58 percent of the total value (38 inches). These values seem quite natural in comparison with the average value of research data. However, here it should be noted that the BWDB practises this method for calculating the consumptive use of water for irrigation projects of Bangladesh.

DETERMINATION OF EVAPORATION LOSSES

The total quantum of evaporation losses from the free water surface area of irrigation and drainage channels was computed for different phases of water management during growing season.

Accordingly, the area covered by irrigation and drainage channels have been surveyed. The area of evaporating surface and the evaporation from the surfaces of irrigation and drainage channels have also been computed in the Table 12 & 13. The amount has been computed by multiplying the channel water surface area with the depth of evaporation loss and obtained as 112.89 acre-ft and 51.53 acre-ft during irrigation period, and 97.92 acre-ft and 44.33 acre-ft during drainage period from irrigation canals and drainage channels respectively. And that for the whole growing season are 210.81 acre-ft and 95.86 acre-ft respectively.

SEEPAGE-PERCOLATION LOSSES FROM MAIN CANAL

Usually the seepage-percolation loss of a flowing channel within a reach is determined by the difference of discharges through the sections at the two ends of the reach. But in case of the main canal, water usually almost remains still and calm. And the canal serves like a storage reservoir for readily supply of irrigation water into the project. Under such circumstances, the current meter could not be used to measure the flow. However, two other approaches have been applied to determine the losses of water from the canal a day - one, from the view point of hydrological balance of the canal and the other from the view point of theory of seepage from canal, each of which can be described below:

Hydrological Balance Method:

Hydrological balance of a canal can be formulated as —

$$WLf + E + SP - R = WLi$$

$$SP = WLi - WLf - E + R \quad \ldots \quad (5.5)$$

Where, SP = seepage-percolation losses from the canal,

WLi = initial water level within the canal,

WLf = final water level within the canal,

E = evaporation from the canal and

R = rainfall within the canal.

Now, after having the values of WLi, WLf, E and R, the value of SP could be determined. Accordingly, all inflows into and outflows from the main canal were stopped on April 7, 1977 at 9 A.M. and the initial water level was recorded. Then on 8,9 and 10 of April, 1977, the water level, evaporation and rainfall were recorded at the same time (9 A.M.), which have been shown in the Table 14. These data were put in the above equation and the values of seepage have been obtained to be 0.27 inch on average a day. The detailed computations for seepage loss have been shown in the Table 14.

Seepage Theory Method:

As much more direct method of solution for the seepage from canals was given by Vedernikov (Harr, 1962). Accordingly, the quantity of seepage from a trapezoidal shaped canal is given by

$$q = K\ (B + AH) \quad \ldots \quad \ldots \quad (5.6)$$

Where q is the quantity of seepage, K is the co-efficient of permeability, B is the top width of the canal, H is the depth of water in the canal, and A is a function of B, H and Z (Fig. 10) and its relationship has been shown in the Fig. 18

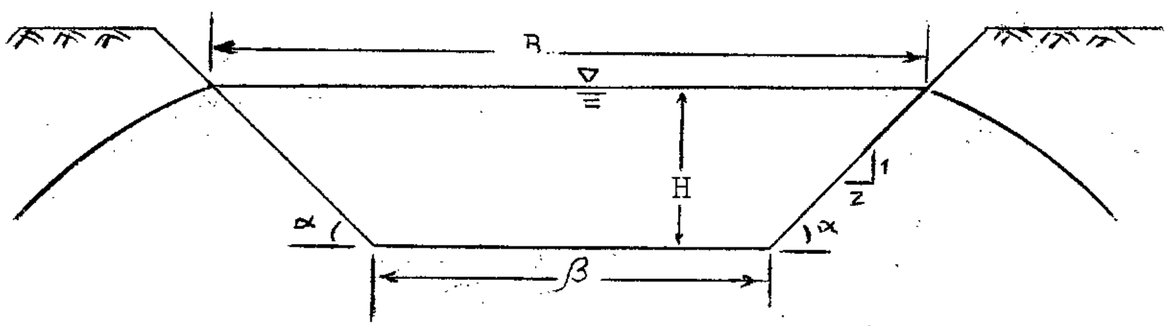


Fig. 10 Typical section of a trapezoidal canal

Similarly in case of trangular shaped canal (Fig. 11) the quantity of seepage can be determined by——

$$q = K\ (B + AH) \quad \ldots \qquad \ldots \qquad (5.7)$$

Where q is the quantity of seepage, K is the co-efficient of permeability, B is the top width of canal, and A is a function of B, H and α presented in the Fig. 11 and Fig. 19.

Since in our problem the canal bed lies below the ground water table, seepage loss takes place only through the banks instead of through both the banks and bed. So, here the loss from trapezoidal section will be equal to that from triangular section for the same values of α and H in both cases. And the seepage loss from the main canal follows the equation valid for triangular canal.

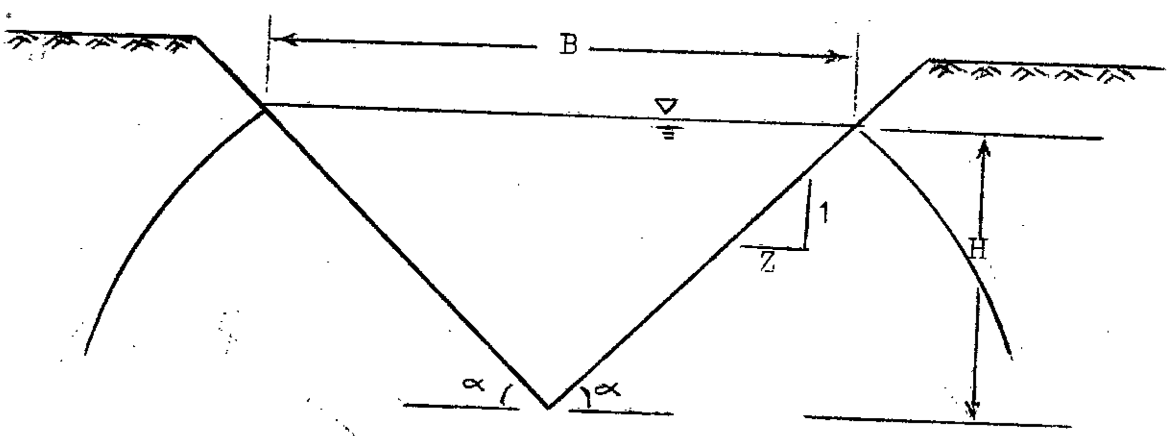


Fig. 11 Typical section of a triangular canal

Thus to compute the seepage losses from the main canal, the values of α and H have been surveyed and shown in the Fig. 12. The physical properties of soils along with coefficient of permeability of different reaches along the whole length have been compiled and shown in the Table 13. The value of A has been obtained from the Fig. 15 for the value of $\alpha = 33.69^{o}$. Now taking the values of K, B, A and H, the quantity of seepage from the main canal has been obtained to be 187.05 acre-ft and detailed in the Table 16.

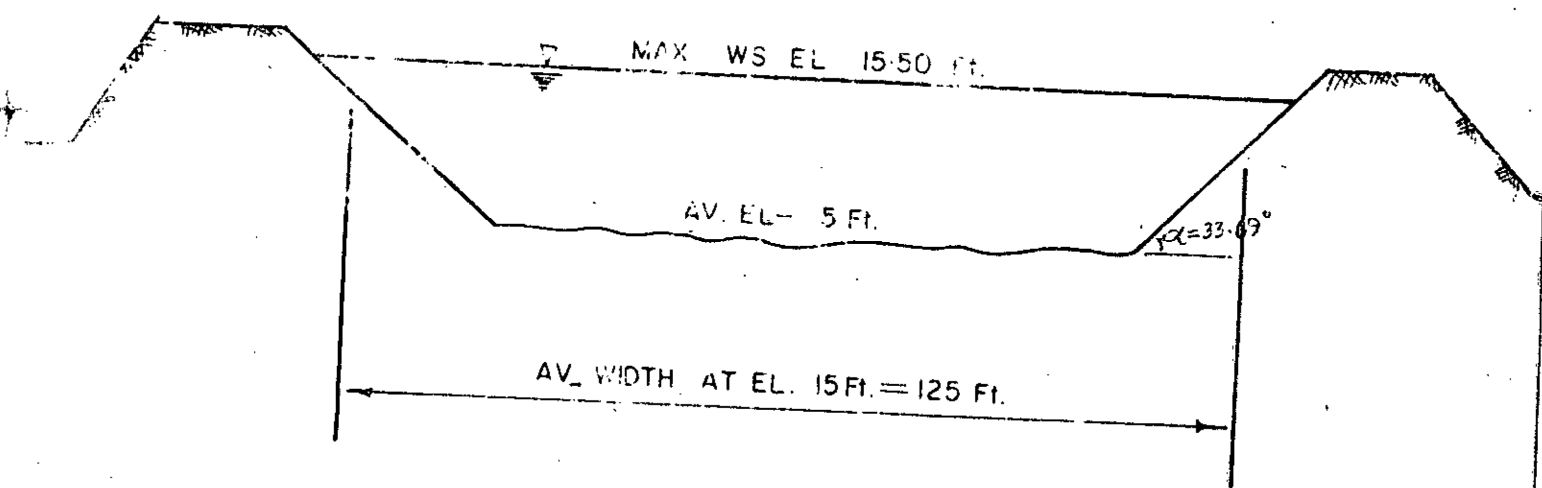


Fig. 12 DND Project main canal typical cross section.

DETERMINATION OF DRAINAGE DISPOSAL

During dry period the drainage load from the project disposed by gravity under the hydraulic condition of submerged orifice flow through the regulator vents at the pump house. To compute the discharge through regulator vents, the head water and tail water levels were recorded at each one-hour time interval. The numbers and size of vents in operation were also recorded.

The co-efficient of discharge for the square lip entrance for the length of 20 ft and hydraulic radius of 1.0 was taken 0.82. Then the discharge was computed by the equation $Q = CA\sqrt{2gh}$, where Q is the discharge in cfs, C is the co-efficient of discharge, g is the acceleration due to gravity in ft/sec^2 and h is the head difference in ft between head water and tail water levels. The computed amounts of drainage disposal on daily basis have been shown in the Table 21 and the total quantum is 3649.22 acre-ft.

However, during the wet period when the river water levels were higher than that in the basin, the drainage load from the project area was disposed by pumping at the pump house.

The amount of drainage load disposed by pumps was determined by the performance curves of the pumping units showing the relationship between the pumping head and the corresponding discharge. The amounts of water thus disposed from the basin have been shown in the Table 22 and the total amount obtained to be 17163.60 acre-ft (Table 22).

ASSESSMENT OF DEAD STORAGE

The amount of dead storage within the basin area of the project on January 1, April 5, and May 31 of 1977 have been computed to equate the hydrological balance of the project during different phases of water management to assess the amount lost from or gained in the previous amount of dead storage. Accordingly, the amounts of dead storage within the basin area on the dates mentioned have been computed by storage read out from the volume elevation curve of the project area (Area I) plus the storage within channels (shown in Table 23) for the respective levels of the basin. The daily basin water levels and the volume-elevation curve of the project area (Area I) have been shown in the Table 17 and Fig. 20 respectively. However, the dead storage for the dates April 5 and May 31 were 1227.6 and 1357 acre-ft respectively.

SEEPAGE-PERCOLATION LOSSES FROM THE AREA OF DL-3

The amount of water applied in the cropped area under the command of DL-3 has been recorded and shown in Table 6. This amount on the average is equal to 45.33 inches. The amount of water diverted from the main canal for application is 49.01 inches, which has been shown in page 65. The consumptive use of water for the area during irrigation period has already been found to be 22 inches as mentioned in page 40. The seepage-percolation losses from the cropped area are, therefore, about 23.33 inches and along with the losses from the canals within the study area the total losses amount to be 27.01 inches.

SEEPAGE-PERCOLATION LOSSES FROM THE PROJECT AREA-I

Continuous flooding irrigation throughout the year has created the problems of water logging in the study zone and has raised the groundwater table. This probably encourages water losses in the form of seepage and percolation from the project area especially during dry season. The losses however could be quantified from the concept of flownet. But non-availability of detailed informations about the underground soil properties, groundwater table etc. became main obstacle in the analysis.

To findout the losses from the whole project area the concept of evapotranspiration of the cropped area has, therefore, been adopted which is described below.

WATER CONSUMED BY CROPPED AREA OF THE PROJECT AREA-I

As discussed in page 23 the whole area is divided into three categories of land namely high, medium and low. From the area-elevation curve, the water logged area at the central portion of the project is about 2000 acres(23 percent of net area) and other areas where soil-water condition varies from saturated condition to within readily available moisture range(20-30 percent of soil moisture content of dry weight) is about 6700 acres. Further for the project area the following soil-water conditions prevail—

(i) Water logging problem and poor drainage system are two general phenomena of the project area.

(ii) The soils of the project area varies mainly from silty clay to clay which retain maximum amount of water for crop consumption.

(iii) The soils of the project area can retain an amount of 3.50 inches of water per feet depth of soil (Figs. 3 & 4), of which about 0.50 inch is readily available.

(iv) Study of the project area under DL-3 shows that the soil-moisture was depleted by 1.75×10^{-2} inch on the average and 3.9×10^{-2} inch maximum in between two irrigations. Thus it is clear that the cropped area never suffers from water stress and gets the required moisture within the readily available range.

(v) From the Table - 6 the average and recorded maximum depths to the water table below the soil surface are 8.28 inches and 21.20 inches respectively. Fig. 5 also explains that the rate of evaporation from the soil surface is equal to that from the free water surface even upto a depth of 24 inches below the soil surface. Thus the rate of evaporation from the project area may be taken as that from the water logged areas.

Under the above conditions, the consumptive use of water for irrigating area of the project will be equal to the potential evapotranspiration which has been computed by Blaney Criddle Method as described earlier to be 38 inches for the whole growing season. And that during irrigation and drainage periods to be 22 inches and 16 inches respectively.

DETERMINATION OF CONVEYANCE EFFICIENCY

The conveyance efficiencies of the main canal and the lateral canal DL-3 have been computed by different methods as mentioned below:

Efficiency of Main Canal:

The efficiency of conveyance of the main canal has been determined by the ratio of the water, the canal could successfully supplied into the project, to the amount supplied in the canal. However, the amount of water, the canal could successfully supply, was determined by substracting the amount of losses from the total supply. Here it should be mentioned that these losses from the main canal have been determined by two different approaches — one by hydrological balance and another by seepage theory. The amounts of losses in the first and second cases have been determined to be 311.72 acre-ft and 274.58 acre-ft respectively. And the total amount supplied in the canal was 28051 acre-ft. So, the efficiencies have been determined to be 98.88 percent and 99.02 percent respectively. The details of calculation have been shown in Appendix - A (A.1.01).

Efficiency of Canal DL-3:

To compute the conveyance efficiency of the canal DL-3, the discharge at its uppermost up-stream and lowermost downstream sections were computed and obtained to be 10.61 cfs and 9.96 cfs (Table 26). Now, the conveyance efficiency has been determined by the ratio of the discharge at uppermost section to that at the lowermost section, and obtained to be 93.96 percent. The details of calculation have been shown in Appendix - A (A.1.02).

DETERMINATION OF APPLICATION EFFICIENCY

To compute the application efficiency the amount of water delivered into the farm (here the area under DL-3) was obtained from the total flow passed through the regulator at the off-take of the canal DL-3. Water flowed through the regulator under submerged orifice flow condition. During the period of watering the head water of the regulator was at a certain level (15.50 ft) and the gate was open full throughout the irrigation period without the days for maintenance and repairing. So, the flow through the gate was more or less constant throughout the operating period. Thus the total amount of water delivered into the farm (area under DL-3) was obtained by the multiplication of flow rate in unit time and the total time of operation. Then the water depth supplied for each plot has been determined by dividing the total volume with the area to be 39.11 inches (A.2 of Appendix-A) plus rainfall (9.92 in) and equals 49.01 inches.

The amount of water applied in each of the selected plots has been determined from the multiplication of the total number of watering and the average depth of watering in each plot. However, the weighted average, computed from all the average depths for the plots, has been determined to be 35.43 inches. Now adding the rainfall (9.92 inches) with the weighted average value (35.43 in), the total depth of application in cropped field has been obtained to be 45.35 inches. Thus the ratio of water (45.33 in) applied in the cropped area to the amount of water (49.01 in) diverted for the area gives the application efficiency of 92.49 percent. The details of calculation have been shown in Appendix-A (A.2).

DETERMINATION OF CONSUMPTIVE USE EFFICIENCY

To determine the consumptive use efficiency the average depth of water applied in the cropped area has already been computed to be 45.33 inches. And the amount of water utilized as consumptive use has been determined to be 22 inches (during irrigation period) by using the imperical formula of Blaney Criddle method (Fig. 17 and Table 11). Now the consumptive use efficiency has been determined by the ratio of the consumptive use of water to the amount stored in crop field (45.33 in) to be 48.53 percent. The detailed computation have been shown in Appendix-A (A.3).

DETERMINATION OF OVERALL EFFICIENCY (AREA OF DL-3)

The overall efficiency of the area under the lateral canal DL-3 has been computed by multiplying the component efficiencies i.e., the vonveyance efficiency (93,6 percent), the application efficiency (92.4 percent) and the consumptive use efficiency (48.5 percent) of the area and it has been obtained to be 41.97 percent according to the Eqn. 3.4 .The detailed calculation has been shown in Appendix -A (A.4).

DETERMINATION OF OVERALL (PROJECT) EFFICIENCY OF AREA-I

The overall efficiency of Area I of the project has been determined by the ratio between the amount of water, the project (Area I) effectively consumed and the total amount of water supplied for the project. However, the amount of water the project consumed has been determined for different phases of water management of the project. As such the water consumptions of the project (Area I) have been determined for the periods of irrigation and drainage as well as for the whole growing season to be 15985.09 acre-ft, 11625.52 acre-ft and 27610.61 acre-ft respectively. While the total water supply for the project area (Area I) during these periods were 28400.29 acre-ft, 28053.78 acfe-ft and 56454.07 acre-ft respectively. Thereby the overall efficiencies of the project (Area I) during the periods of irrigation and drainage have been computed to be 56 percent and 41 percent respectively, and that for the whole growing season has been 49 percent. The details of calculation have been shown in Appendix - A(A.5).

DETERMINATION OF DISTRIBUTION EFFICIENCY

Due to variation in topography from plot to plot water can not be distributed uniformly in all the plots. But in particular individual plot water is distributed uniformly for level ground surface. The average water depth in each plot has been shown in the Table 6. And then the weighted mean of all the average depths has been computed to be 3.92 inches. The mean deviation of which is 2.123 inches. With the help of mean deviation, the deviation from uniform distribution of water throughout the project has been determined. Thus the distribution efficiency of the study area has been determined according to the Eqn.3.7 and obtained to be 45.58 percent. The details of computation have been shown in Appendix - A (A.6).

CHAPTER - VI

RESULTS AND DISCUSSIONS

The following results have been obtained as output of the study and discussion on the results as a whole is made in this chater.

CONVEYANCE EFFICIENCY

The conveyance efficiencies of the main canal and the lateral canal DL-3 has been obtained as 98.88 and 93.76 percent respectively (A.1 of Appendix - A). The efficiencies are satisfactory and justified under the following considerations:

(i) The main canal is situated along the central part of the project as a result it needs not convey water over a long distance to supply water into the crop-field, that is, the proximity of source of water is very near for proper utilization.

(ii) The main canal always reserves water for irrigation and rice is cultivated throughout the year for years by check-basin-flooding method as a result ground water within the project have raised upward and the project's soil has become water logged. Accordingly, less water seeps from the canal.

(iii) The soil texture of the project usually ranges from silt clay to clay (Table 27) and the permeability is naturally less, which causes low seepage loss.

(iv) Finally, as the bed level of the main canal remains below the river water level, no percolation loss takes place.

From the view point of above discussion, the higher value of conveyance efficiency of main canal may be justified.

APPLICATION EFFICIENCY

The application efficiency of the area under the lateral canal DL-3 has been determined to be 92.49 percent (A.2 of Appendix - A) which is satisfacotry, behind this value of the result, there are some reasonings:

(i) The soil culture method of HYV rice cultivation in the project is traditional puddling, that is, ploughing with a layer of water on the soil surface. As a result, clay and silt migrate downward and form a more or less impermeable plough pan just below the root-zone, which impeds the percolation of water and enables the farmers to distribute the water from plot to plot without much loss.

(ii) Due to continuous water maintenance in the project through-out the year for years water logging in the project has become more natural, the condition which is favourable for high efficiency.

On these grounds the result of application efficiency may be justified.

CONSUMPTIVE USE EFFICIENCY

The value obtained for consumptive use efficiency in the area under the lateral canal DL-3 is 48.53 percent (A.3 of Appendix - A). For check basin flooding method of irrigation the efficiency might be optimal under the project condition. The only loss through the sub-soil is seepage-percolation and flows as sub-surface flow towards low potential areas and accumulates in the low pockets. Such losses might be encouraging to some extent for washing and leaching out all the noxious materials formed within the soil due to application of various chemical subtances such as fertilizers, pesticides, etc. and water logging.

OVERALL EFFICIENCY OF THE AREA (UNDER DL-3)

The overall efficiency of the area under DL-3 is 41.56 percent (A.4 of Appendix - A) which is the resultant of the multiplication of all the three component efficiencies namely conveyance, application and consumptive use efficiency. So, its justification might be dependent on the justification of the component efficiencies.

OVERALL EFFICIENCY OF THE PROJECT

Overall efficiency of the project can be split up into three different phases as follows:

During Irrigation Period:

The irrigation period in Boro-season (1977) from the first of January to April 5 and during the period the overall water utilization efficiency of Area I has been found to be 56 percent (A.5.01 of Appendix - A). In comparison with the overall efficiency of the area under the lateral canal DL-3, this efficiency is higher. This is reasonable due to several reasonings. One, the seepage and percolation loss from the area under the canal DL-3 might be actually more, because this area is at periphery of the Area I and relatively high. As a result water from this area seeps into low depressions at central part of the project as well as towards rivers, But from view point of the whole project this relative movement from one part to another has not been considered. Secondly amount of water supplied per acre in the area under DL-3 is much higher than that in the project as a whole. And the lengths in case of others except the canal DL-3 are so long that the lands far off from the off-take get relatively less water which is used with much care, and due to short time submergence on soil surface relatively less amount of water seeps through the bunds of irrigation plots than that from the irrigation plots of DL-3. On these grounds the higher value of efficiency for the whole project than that of the area under DL-3 may be justified.

Here it should be noted that as the distribution system of the project is poor and water distribution is made by check-basin-flooding method, the loss might be higher. Moreover, the soils are mainly of alluvial diposits and the project is bounded by rivers of sufficiently low levels, under such a condition seepage and percolation loss from the project area might be considerable ultimately causing a low efficiency of the project. Considering all these factors the project efficiency of 56 percent during the period might be satisfactory.

During Drainage (Wet) Period:

The water utilization efficiency during the wet period has been obtained as 41 percent (A.5 of Appendix - A). Materially, during this period the supply of water from rainfall was much higher than its maximum effective value. Here the period has been considered from 5.4.77 to 31.5.77, of which the last 15 days was harvesting period. Actually the requirement of water for crop after the flowering stage falls drastically and the total consumption during this later part of growing season is relatively low. And the effective growing period was 50-days (Fig.7), of which 20-days may be excluded as ripening period requiring no water. So, the actual need and consumption of water during this period was considerably low than the supply. As a result the efficiency of 41 percent might be sufficiently satisfactory in this case.

Throughout the Growing Season:

The project efficiency or water utilization efficiency of the project throughout the growing season has been computed to be 49 percent (A.5.03 of Appendix - A). This result might not exactly represent the actual efficiency of the project for the cropped area. Because the actual consumptive use of water of the project cropped area has not been determined by direct measurement from the field. Moreover the amount of seepage water which may enter into the project area from the peripherial rivers during wet season,when the river stage remain higher than the basin level,has been neglected. However, in spite of all these limitations, care has been taken to consider all possible factors to compute the real value and in case of a project of poor distribution system and with the distribution of check basin flooding method in alluvial deposits, the overall project efficiency of 48 percent might be satisfactory.

DISTRIBUTION EFFICIENCY

The distribution efficiency of the area under the lateral canal DL-3 has been considered to be 45.58 percent (A.6 of Appendix - A), which is a so poor figure. So to say, the project topography remains almost in original natural condition. Under such a condition the distribution of water by flooding method of irrigation must be uneven. Thus ultimately the relatively low areas suffer from a higher depth of submergence and the relatively high areas suffer from lower depth or scarcity of water. Where in both cases, from the view points of crop physiology and others cultural practices, due to low efficiency of distribution, a considerable percent of available water is lost which is liable for low irrigation efficiency and low yield results.

CHAPTER - VII

CONCLUSIONS

So far discussed about the water utilization efficiency of the Dacca-Narayanganj-Demra Project concludes the following points:

(i) The conveyance efficiency of distribution canals has been obtained 98.88 percent (Main) and 93.76 percent (DL-3) respectively.

(ii) The water application efficiency of the Area under DL-3 has been computed to be 92.49 percent.

(iii) The consumptive use efficiency of the area under DL-3 has been determined as 48.53 percent.

(iv) The overall efficiency of the area under DL-3 has been found to be 41.56 percent.

(v) The overall efficiency of the project (Area I) has been obtained as 56 percent during irrigation period.

(vi) The overall efficiency of the project (Area I) has been obtained as 41 percent during drainage period.

(vii) The overall efficiency of the project throughout the trowing season has been computed to be 49 percent.

(viii) The distribution efficiency of the area under DL-3 has been obtained as 45.58 percent.

BIBLIOGRAPHY

1. Black, C.A., 1968, "Soil-Plant Relationship", John Wiley and Sons, Inc., New York.

2. Biswas, M.R. and Ali, F.M., 1976, "Determination of Consumptive Use of Water for IR-8 Rice", Department of Irrigation and Water Management, BAU, Mymensingh.

3. Chow, V.T., 1964, "Handbook of Applied Hydrology", McGraw Hill Book Company, New York.

4. FAO, 1971, "Irrigated Farm Water Management" Irrigation and Drainage Paper - 10, Kuala Lampur, Malayasia.

5. FAO, 1972, "Water Use Seminar, Damescus", Irrigation and Drainage Paper - 13, Damescus, Syria.

6. Goor, V.D., 1973, "Drainage of Rice Fields", International Institute for Land Reclamation and Improvement, Wageningen.

7. Halim, M.A., January 1977, "Water Reouirements for BR-3 Variety of Rice", Bangladesh University of Engineering and Technology, Dacca.

8. Harr, M.E., 1962, "Groundwater and Seepage", McGraw-Hill Book Company, Inc., New York.

9. Huang, C.H., 1963, "Water Requirement of Rice by Tank Experiment, Findings and Recommendations", FAO of UN, Dacca.

10. Huizing, H.G.J., 1970, "Water Consumption Experiment on Modhupur Clay Soils", Directorate of Soil Survey, East Pakistan.

11. Hug, A.K.M.F., Khan, S.H. and Qasem, M.A., 1970, "Consumptive Use Coefficient Determination of T.Aus, Aman and Boro Rice for the Ganges-Kobadak Areas of East Pakistan", Pakistan Journal of Soil Science, Vol.VI, No.2.

12. Idris, M., 1977, "Consumptive Use of Water by Boro Rice", Department of Soil Science, Bangladesh Agricultural University, Mymensingh.

13. IECO, Inc., 1968, "Definite Report, Dacca-Narayanganj-Demra Project, EPWAPDA, Dacca.

14. Israelson. P.W. and Hansen V.E., 1962, "Irrigation Principles and Practices", John Wiley and Sons, Inc., New York.

15. Japan International Cooperation Agency, 1978, "Feasibility Report on Narayanganj-Narsingdi Irrigation Project", BWDB, Bangladesh.

16. Khan, C.M.A., October 1978, "Determination of Irrigation System Performance: Water Use Efficiency and Water Adequacy Studies in the Dacca-Narayanganj-Demra Irrigation Project in Bangladesh", — A Thesis of Master of Engineering, Asian Institute of Technology, Bangkok, Thailand.

17. Khan, H.R., December, 1976, "Water Utilization at Various Stages of Irrigation Projects", Presented at the Twenty First Annual Convention of the Institution of Engineers, Bangladesh.

18. Schwab, G.O., Frevest, R.K: Edminister, T.W., and K.K. Barnes, 1966, "Soil and Water Conservation Engineering", John Wiley and Sons, Inc., New York.

APPENDIX - A

(Calculations of Results)

APPENDIX - A

CALCULATIONS OF RESULTS

A.1 CONVEYANCE EFFICIENCY

A.1.01 Main Canal

(i) Hydrological view point:

Irrigation period from 1.1.77 to 4.4.77 = 94 days

Evaporation from 1.1.77 to 4.4.77 = 9.909 inches(Table 1)

Surface area of main canal = 106 acres (Table 12)

Hence the evaporation loss from main canal for the period = $\frac{9.909}{12}$ x 106 = 87.53 acre-ft.

Seepage loss per day = 0.27 in (Table 14)

Hence seepage loss from main canal = $\frac{0.27}{12}$ x 94 x 106

= 224.19 acre-ft.

Now the total loss from the main canal = 87.57 + 224.19

= 311.71 acre-ft

Therefore, the conveyance efficiency $= \frac{28051 - 311.72}{28051}$

$= \frac{27739.28}{28051}$

= 98.88 percent

(ii) Seepage theory view point:

Evaporation for the period = 87.53 acre-ft (as above)

Seepage loss for the period = 187.050 acre-ft (Table 16)

Now the total loss from the main canal = 274.58 acre-ft

Therefore the conveyance efficiency $= \frac{28051 - 274.58}{28051}$

$= \frac{27776.42}{28051}$

= 99.02 percent

A. 1.02 Lateral Canal DL-3:

The lateral canal DL-3 was open throughout the season for 87 days out of 94 irrigating days and the rest 7 days were spent mainly for repairing and maintenance. The gate was open full and worked against a particular head difference as the water level in the main canal was constant and the discharge through gate was 10.60 cfs.

The total length of the canal (DL-3) = 5600 ft(Table 24)
The discharge at upstream end = 10.61 cfs (Table 24).
The discharge at the downstream end = 9.96 cfs(Table 24).
Now the loss for the length = 10.60 - 9.96 = 0.64 cfs.
Hence the efficiency of the canals, Ea = $\frac{10.60-0.64}{9.96}$

= 93.96 percent

A.2 APPLICATION EFFICIENCY

The average depth of water applied in each cropped plot

= 35.43 in (Table 6)

The depth of water applied in each cropped plot as rain fall = 9.90 in (Table 6)
The total depth of water applied = 35.43 + 9.90

= 45.33 in

The cropped area under DL-3 = 612.00 acres (Table 26)
The total operating period of DL-3 = 87 days(Table 4)
The discharge of the canal DL-3 = 10.60 cfs (Table 4)
Hence in depth of water diverted from the main canal through DL-3 for each plot was (10.61 x 24 x 87) ÷ 612 = 39.11 in. and as rainfall = 9.90 in. Hence the total

depth of water was to be applied in each plot $= 39.11 + 9.90 = 49.01$ in. Hence the application efficiency $= \frac{45.33}{49.01} = 92.49$ percent.

A.3 CONSUMPTIVE USE EFFICIENCY

As shown previously the average depth of water successfully applied in each plot was 45.33 in. According to Fig. 7 the effective days for consumptive use of water by cropped field was 87 days out of 94 days, for the period consumptive use of water was 22.00 in. (Fig. 17). Hence the required efficiency, $Ec = \frac{22.00}{45.33} = 48.53$ percent.

A.4 OVERALL EFFICIENCY OF THE AREA (UNDER DL-3)

The overall project efficiency = Ea.Eb.Ec x 100

$= 0.936 \times 0.924 \times 0.4853 \times 100$

$= 41.97$ percent

Considering the efficiency of main canal, the required project efficiency $= 0.9902 \times 41.97 = 41.56$ percent

A.5 OVERALL EFFICIENCY OF THE PROJECT

A.5.01 During Irrigation (Dry) Period:

Withdrawal of water at pumping plant = 28051.00 acre-ft (Table 2). Water diverted into Area II = 8459.48 acre-ft. Table 4). Evaporation loss from main canal = 87.53 acre-ft (Table 12). Seepage loss from main canal $= \frac{0.27}{12} \times 94 \times 106$ acre-ft.

Total loss from main canal = 87.53 + 224.19 = 311.72 acre-ft. Therefore water diverted into the Area I

= 28051-(8459.48 + 311.72)

= 19279.80 acre-ft.

Water received from rainfall = $\frac{9.90}{12}$ x 12040.25

= 9120.49 acre-ft

Total inflow into Area I, I = 1927.80 + 120.49

= 28400.29 acre-ft.

Irrigating area of Area I = 8719.14 acres (Table 26)

Consumptive use of water during irrigation(dry) period = 22.00 inches (Fig. 17).

Total amount of water consumed, CU = $\frac{22}{12}$ x 8719.14

= 15985.09 acre-ft.

Project Efficiency = $\frac{CU}{I} = \frac{15985.09}{28400.29}$ = 56.28 percent.

A.5.02 During Drainage (Wet) period:

Water received from rainfall = 12040.25 x 2.33

= 28053.78 acre-ft.

Water received from pumping plant = 0 acre-ft.

Total inflow into the project, I = 28053.78 + 0

= 28053.78 acre-ft.

Irrigating area = 8719.14 acres.

Consumptive use of water = 38-22 = 16 inches.

Total amount of water consumed, CU = $\frac{16}{12}$ x 8719.14

= 11625.52 acre-ft.

Project Efficiency = $\frac{11625.52}{28053.78}$ = 41.44 percent.

A.5.03 Throughout the Growing period:

As shown above,

Consumption of water during irrigation period

= 15985.09 acre-ft.

Consumption of water during drainage period

= 11625.52 acre-ft

Total consumption = 15985.09 + 11625.52 = 27610.61 acre-ft

Water inflow into the project during irrigation period

= 28400.29 acre-ft.

Water inflow into the project during drainage period

= 28053.78 acre-ft

Total inflow = 28400.29 + 28053.78 = 56454.07 acre-ft

The effective project efficiency = $\frac{27610.61}{56454.07}$

= 48.90 percent

A.6 DISTRIBUTION EFFICIENCY

Water distribution efficiency of the area under canal DL-3 can be calculated from the relation,

$$Ed = 100\ (1 - \frac{y}{d})$$

From Table 6,

The mean deviation of depths = 2.123 in. and the mean depth = 3.92 in.

Hence, $Ed = 100 \times (1 - \frac{2.123}{3.920}) = 45.58$ percent.

APPENDIX - B

(Tables and Data Analysis)

Table 1 Hydrological condition of the project

Date	January Evaporation (in)	January Rainfall (in)	February Evaporation (in)	February Rainfall (in)	March Evaporation (in)	March Rainfall (in)	April Evaporation (in)	April Rainfall (in)	May Evaporation (in)	May Rainfall (in)
1	0.081	0.00	0.098	0.00	0.126	0.000	0.126	0.140	0.252	1.040
2	0.084	0.00	0.084	0.00	0.126	0.000	0.168	0.220	0.540	0.240
3	0.070	0.00	0.098	0.00	0.126	0.000	0.54	0.040	0.112	0.000
4	0.084	0.00	0.084	0.00	0.112	0.000	0.140	0.500	0.154	0.000
5	0.098	0.00	0.098	0.00	0.140	0.000	0.056	0.900	0.168	0.000
6	0.098	0.00	0.112	0.00	0.126	0.000	0.133	2.350	0.147	0.470
7	0.084	0.00	0.112	0.00	0.112	0.000	0.163	0.000	0.112	0.000
8	0.098	0.00	0.126	0.00	0.112	0.000	0.112	0.040	0.126	0.000
9	0.098	0.00	0.126	0.00	0.126	0.000	0.133	0.350	0.154	0.000
10	0.084	0.00	0.140	0.00	0.126	1.330	0.000	1.780	0.140	0.000
11	0.084	0.00	0.126	0.00	0.091	0.750	0.182	1.280	0.154	0.000
12	0.098	0.00	0.126	0.00	0.091	0.000	0.140	0.140	0.135	0.450
13	0.098	0.00	0.112	0.00	0.140	0.000	0.126	0.600	0.364	5.180
14	0.084	0.00	0.126	0.00	0.126	0.000	0.124	0.360	0.119	0.190
15	0.070	0.00	0.126	0.00	0.126	0.000	0.182	1.900	0.112	0.000
16	0.084	0.00	0.112	0.00	0.140	0.000	0.000	0.900	0.154	0.000
17	0.070	0.00	0.112	0.00	0.168	0.000	0.112	0.000	0.161	0.310
18	0.070	0.000	0.126	0.00	0.168	0.000	0.126	0.000	0.154	0.000
19	0.084	0.00	0.126	0.00	0.154	0.000	0.140	0.000	0.210	0.700
20	0.042	0.00	0.126	0.00	0.140	0.000	0.154	0.000	0.154	0.000
21	0.070	0.00	0.140	0.00	0.126	0.000	0.154	0.000	0.322	3.500
22	0.070	0.00	0.140	0.00	0.140	0.000	0.161	0.250	0.126	0.000
23	0.084	0.00	0.077	0.130	0.140	0.000	0.168	0.300	0.112	0.000
24	0.089	0.00	0.070	0.120	0.168	0.000	0.119	0.150	0.042	0.220

Contd.

Date	January Evaporation (in)	January Rainfall (in)	February Evaporation (in)	February Rainfall (in)	March Evaporation (in)	March Rainfall (in)	April Evaporation (in)	April Rainfall (in)	May Evaporation (in)	May Rainfall (in)
25	0.098	0.00	0.000	2.700	0.140	0.000	0.154	0.000	0.168	0.000
26	0.084	0.00	0.084	0.000	0.154	0.000	0.091	0.950	0.140	0.000
27	0.098	0.00	0.098	0.000	0.154	0.000	0.126	0.000	0.105	0.050
28	0.084	0.180	0.112	0.000	0.168	0.000	0.112	0.000	0.119	0.550
29	0.098	0.00	-	0.000	0.105	2.070	0.168	0.000	0.168	0.420
30	0.98	0.00	-	0.000	0.112	0.000	0.154	0.000	0.050	2.100
31	0.084	0.00	-	0.000	0.126	0.000	-	0.200	0.140	0.000
	2.545	0.180	2.765	2.960	3.955	4.150	3.899	14.35	5.252	15.420

Rainfall from 1.1.77 to 4.4.77 (94 days) = 9.92 inches
Evaporation from 1.1.77 to 4.4.77 (94 days) = 9.90 inches
Rainfall for the rest of the growing season (from 5.4.77 to 31.5.77) = 27.97 inches
Evaporation for the rest of the growing season = 8.04 inches
Total rainfall for the growing season = 37.06 inches
Total evaporation during the growing season = 18.60 inches.

Table 2 Amount of Water withdrawal from Lakhya river for irrigation

Date	Amount (acre-ft)	Date	Amount (acre-ft)
1.1.77	97.83	30.1.77	441.18
2.1.77	154.28	31.1.77	444.48
3.1.77	116.93	1.2.77	462.24
4.1.77	155.44	2.2.77	319.11
5.1.77	324.26	3.2.77	314.82
6.1.77	356.30	4.2.77	334.56
7.1.77	390.26	5.2.77	325.38
8.1.77	335.94	6.2.77	148.65
9.1.77	339.24	7.2.77	349.65
10.1.77	395.92	8.2.77	376.20
11.1.77	399.36	9.2.77	395.96
12.1.77	352.80	10.2.77	305.04
13.1.77	403.20	11.2.77	344.05
14.1.77	324.48	12.2.77	380.40
15.1.77	319.92	13.2.77	330.82
16.1.77	274.04	14.2.77	371.32
17.1.77	499.20	15.2.77	204.12
18.1.77	441.76	16.2.77	254.54
19.1.77	357.12	17.2.77	365.20
20.1.77	219.34	18.2.77	369.20
21.1.77	312.48	19.2.77	329.67
22.1.77	415.38	20.2.77	322.56
23.1.77	274.12	21.2.77	263.12
24.1.77	238.08	22.2.77	315.27
25.1.77	359.28	23.2.77	289.71
26.1.77	287.68	24.2.77	49.90
27.1.77	376.96	25.2.77	80.32
28.1.77	266.49	26.2.77	77.76
29.1.77	224.16	27.2.77	127.92

Contd.

Date	Amount (acre-ft)	Date	Amount (acre-ft)
28.2.77	222.41	20.3.77	395.46
-	-	21.3.77	387.60
1.3.77	135.24	22.3.77	392.16
2.3.77	203.91	23.3.77	388.74
3.3.77	202.86	24.3.77	493.43
4.3.77	195.00	25.3.77	430.00
5.3.77	189.05	26.3.77	480.00
6.3.77	313.10	27.3.77	477.00
7.3.77	242.60	28.3.77	287.97
8.3.77	328.96	29.3.77	289.71
9.3.77	310.50	30.3.77	150.15
10.3.77	339.90	31.3.77	239.72
11.3.77	183.30	-	-
12.3.77	282.24	1.4.77	134.16
13.3.77	200.60	2.4.77	139.10
14.3.77	206.00	3.4.77	119.90
15.3.77	299.86	4.4.77	66.60
16.3.77	416.84	5.4.77	34.71
17.3.77	344.76	Total:	28051.00
18.3.77	468.28		
19.3.77	445.72		

Table 3 Discharge of the lateral canals

SL. No.	Name of canal	Flow depth d (ft)	No.of revs./sec n	Velocity v (ft/sec)	Channel factor C	Discharge Q (cfs)
1	DL-3	4	0.80	0.70	30.29	10.61
2	DR-1	8.75	0.35	0.34	198.23	22.66
3	DR-2	6.00	0.43	0.43	77.30	13.43

Table 4 Water supply into the area II of the project

SL. No.	Name of canal	Discharge Q (cfs)	Days of operation	Total discharge (acre-ft)	Total discharge in area - II (acre-ft)
1	DL-3	10.61	87	1840.14	-
2	DR-1	22.66	85	9192.20	9192.20
3	DR-2	13.43	88	2715.68	2715.68
4	DR-3	5.30	86	911.60	911.60
5	DTO-8-9	3.60	89	640.00	640.00
Total					8459.48

Table 5 Channel factors at different levels of different channels

Canal : DR - 2

$$\Delta C = \frac{b}{4} (d_1 + d_2) (\sqrt{d_1} + \sqrt{d_2})$$

(a) Depth at middle = 6.00 ft

Vertical No.	Distance (ft)	Depth d (ft)	Section width b (ft)	$\sqrt{d}$	d_1+d_2	$\sqrt{d_1}+\sqrt{d_2}$	Channel factor C
1	0.00	0.00		0.00			
			2.50		4.70	2.17	6.37
2	2.50	4.70		2.17			
			2.75		10.70	4.62	33.99
3	5.25	6.00		2.45			
			2.75		10.20	4.50	31.56
4	8.00	4.20		2.05			
			2.50		4.20	2.05	5.38
5	10.50	0.00		0.00			
Total							77.30

(b) Depth at middle = 8.00 ft

Vertical No.	Distance (ft)	Depth d (ft)	Section width b (ft)	$\sqrt{d}$	d_1+d_2	$\sqrt{d_1}+\sqrt{d_2}$	Channel factor C
1	1.00	0.00		0.00			
			3.50		6.70	2.59	15.18
2	2.50	6.70					
			2.75		14.70	5.42	54.78
3	5.25	8.00		2.85			
			2.75		14.20	5.32	51.94
4	8.00	6.20		2.49			
			3.50		6.20	2.49	13.51
5	11.50	0.00		0.00			
Total							135.41

(c) Depth at middle = 4.00 ft

Vertical No.	Distance (ft)	Depth d (ft)	Section width b (ft)	$\sqrt{d}$	d_1+d_2	$\sqrt{d_1}+\sqrt{d_2}$	Channel factor C
1	1.00	0.00		0.00			
			1.50		2.70	1.64	1.66
2	2.50	2.70		1.64			
			2.75		6.70	3.64	16.77
3	5.25	4.00		2.00			
			2.75		6.20	3.48	14.83
4	8.00	2.20		1.48			
			1.50		2.20	1.48	1.22
5	9.50	0.00		0.00			
Total							34.48

Canal : DR-1

$$\Delta C = \frac{b}{4}(d_1+d_2)\ (\sqrt{d}_1+\sqrt{d}_2)$$

(a) Depth at the middle = 6.75 ft

Vertical No.	Distance (ft)	Depth d (ft)	Section width b (ft)	$\sqrt{d}$	d_1+d_2	$\sqrt{d}_1+\sqrt{d}_2$	Channel factor C
1	1.00	0.00		0.00			
2	4.00	4.00	3.00	2.00	4.00	2.00	6.00
3	8.00	6.75	4.00	2.60	10.75	4.60	49.45
4	12.00	4.75	4.00	2.18	11.50	4.78	54.97
5	15.00	0.00	3.00	0.00	4.75	2.18	7.77
Total							118.19

(b) Depth at the middle = 8.75 ft

Vertical No.	Distance (ft)	Depth d (ft)	Section width b (ft)	$\sqrt{d}$	d_1+d_2	$\sqrt{d}_1+\sqrt{d}_2$	Channel factor C
1	0.00	0.00		0.00			
2	4.00	6.00	4.00	2,45	6.00	2.45	14.70
3	12.00	6.75	4.00	2.96	14.75	5.41	79.80
4	12.00	6.75	4.00	2.60	15.50	5.56	86.18
5	16.00	0.00	4.00	0.00	6.75	2.60	17.55
Total							198.23

(c) Depth at the middle = 10.95 ft

Vertical No.	Distance (ft)	Depth d (ft)	Section width b (ft)	$\sqrt{d}$	d_1+d_2	$\sqrt{d}_1+\sqrt{d}_2$	Channel factor C
1							
			1		1.75	1.32	0.58
2	2	1.75		1.32			
			2		4.75	3.05	7.24
3	4	3.00		1.73			
			2		5.00	3.14	7.85
4	6	2.00		1.41			
			1		2.00	1.41	0.71
5	7	0		0			
Total							16.38

Canal : DL – 3

$$\Delta C = \frac{b}{4}(d_1+d_2)\ (\sqrt{d}_1+\sqrt{d}_2)$$

(a) Depth at the middle = 3 ft

Vertical No.	Distance (ft)	Depth d (ft)	Section width b (ft)	$\sqrt{d}$	d_1+d_2	$\sqrt{d}_1+\sqrt{d}_2$	Channel factor C
1	1	0		0			
			1		1.75	1.32	0.58
2	2	1.75		1.32			
			2		4.75	3.05	7.34
3	4	3.00		1.73			
			2		5.00	3.14	7.85
4	6	2.00		1.41			
			1		2.00	1.41	0.71
5	7	0		0			
Total							16.38

(b) Depth at the middle = 4 ft

Vertical No.	Distance (ft)	Depth d (ft)	Section width, b (ft)	$\sqrt{d}$	d_1+d_2	$\sqrt{d}_1+\sqrt{d}_2$	Channel factor C
1	0	0		0			
2	2	2.75	2	1.66	2.75	1.66	2.28
3	4	4.00	2	2.00	6.75	3.66	12.35
4	6	3.00	2	1.73	7.00	3.73	13.06
5	8	0	2	0.00	3.00	1.73	2.60
Total							30.29

(c) Depth at the middle = 5.00 ft

Vertical No.	Distance (ft)	Depth d (ft)	Section width b (ft)	$\sqrt{d}$	d_1+d_2	$\sqrt{d}_1+\sqrt{d}_2$	Channel factor C
1	1	0.00		0.00			
2	2	3.75	3	1.94	3.75	1.94	5.46
3	4	5.00	2	2.24	8.75	4.18	18.29
4	6	4.00	2	2.00	9.00	4.24	19.08
5	9	0.00	3	0.00	4.00	2.00	6.00
Total							48.83

Table 6 Soil water condition of the area under DL-3

SL. No.	Plot No.	Relative state of land	No.of watering	Vol.of soil sample (c.c.)	Wt.of sample before watering(gm)	Wt.of saturated sample (gm)	Total moisture depletion before watering (c.c.)
1	2	3	4	5	6	7	8
1	2080	Med.	14	389.900	676.000	679.10	3.10
2	2530	Med.	14	408.760	724.130	731.38	7.25
3	354	Med.	15	418.468	781.340	784.56	3.22
4	311	Low	0	417.764	780.430	783.65	7.96
5	330	Med.	15	425.619	757.540	765.50	7.96
6	336	Med.	15	416.878	697.780	700.65	3.87
7	341	Med.	13	407.856	730.900	733.83	2.92
8	593	Med.	13	413.247	685.570	795.35	9.78
9	613	Med.	13	410.560	761.550	767.07	5.52
10	619	High	25	417.856	730.370	746.50	16.13
11	661	Med.	14	411.002	720.910	730.44	9.52
12	890	High	24	408.757	712.230	726.52	14.29
13	921	Med.	15	389.900	678.410	782.21	3.80
14	938	Med.	14	408.760	712.680	717.73	5.05
15	959	Med.	13	418.468	775.350	781.50	6.15
16	1006	Med.	14	425.878	760.250	763.25	3.00
17	1031	Med.	15	407.856	700.590	703.79	3.20
18	1059	Med.	15	417.854	744.320	748.63	4.31
19	1082	Med.	14	410.560	750.140	756.51	6.30
20	1023	Med.	13	413.247	759.820	766.32	6.50
21	1155	Med,	13	411.002	688.540	695.43	6.89
22	1259	Med.	13	408.767	741.460	747.92	6.46
23	1217	Low	0	416.876	716.280	721.74	-
24	1184	Med.	14	389.900	736.890	740.47	3.58
25	1212	Med.	14	408.076	729.630	733.19	3.56
26	1250	Med.	15	418.468	773.460	776.80	3.34

Contd.

Sl. No.	Average moisture depletion (in) x 10^{-2}	Average depth to saturated zone (in)	Average depth of surface water layer (in)	Average amount of water added each time (in)	Depth of water supplied through-out the season (in)	Rainfall during irrigation period (in)
1	9	10	11	12	13	14
1	0.80	6.50	2.55	2.558	35.812	9.92
2	1.77	8.50	2.75	2.767	38.730	9.92
3	0.77	6.10	2.35	2.357	35.35	9.92
4	-	-	17.00	-	-	9.92
5	1.90	9.20	2.65	2.669	40.03	9.92
6	3.93	7.10	2.45	2.459	36.88	9.92
7	0.72	5.70	2.95	2.957	38.44	9.92
8	2.37	10.50	2.15	2.173	28.25	9.92
9	1.34	7.30	2.25	2.263	29.41	9.92
10	3.85	20.00	2.85	2.886	72.15	9.92
11	2.32	11.00	2.70	2.723	38.122	9.92
12	3.49	18.30	2.40	2.434	58.416	9.92
13	0.97	7.20	2.30	2.309	34.635	9.92
14	1.24	6.80	2.80	2.812	39.368	9.92
15	1.47	7.50	3.05	3.097	40.26	9.92
16	0.70	5.60	2.05	2.057	28.798	9.92
17	0.78	5.80	2.65	2.657	39.85	9.92
18	1.03	7.30	2.45	2.460	36.90	9.92
19	1.55	8.00	2.55	2.565	35.91	9.92
20	1.57	8.3	2.55	2.563	33.345	9.92
21	1.76	9.00	2.45	2.467	31.681	9.92
22	1.58	9.10	2.65	2.667	34.645	9.92
23	-	-	19	-	-	9.92
24	0.92	7.20	2.35	2.359	33.026	9.92
25	0.87	6.90	2.75	2.758	38.610	9.92
26	0.79	6.10	2.25	2.257	33.850	9.92

Contd.

1	2	3	4	5	6	7	8
27	1269	Med.	15	425.619	752.250	759.29	7.04
28	1288	Low	0	410.530	732.300	728.13	-
29	1296	Low	0	411.620	750.000	744.39	-
30	1438	Med.	13	418.330	743.430	737.56	5.87
31	3001	Med.	13	422.490	761.710	753.74	7.97
32	3051	Med.	14	417.160	725.300	715.95	9.35
33	3687	High	23	409.68	727.50	737.51	10.10
34	3706	Med.	15	412.350	730.31	734.03	3.72
35	3716	High	24	413.210	729.71	741.60	11.89
36	3766	High	23	416.320	632.73	744.30	11.77
37	3773	Med.	14	408.750	721.15	730.20	9.05
38	3800	High	25	409.660	745.48	759.32	13.84
39	3836	Med.	13	421.460	752.68	760.17	7.49
40	3845	Med.	15	415.610	713.59	723.03	9.44
41	3863	Med.	14	414.250	770.29	773.40	3.11
42	3892	Med.	15	416.84	775.45	781.20	5.75
43	3945	Low	0	408.90	-	756.62	-
44	3954	Med.	13	410.62	730.870	737.46	6.59
45	3992	High	24	410.57	728.25	744.25	16.00
46	4010	Med.	13	407.57	720.50	729.20	8.70
47	4168	Low	0	419.43	-	747.11	-
48	4204	Low	0	418.72	-	754.54	-
49	4222	Mcd.	12	427.28	762.27	769.60	7.33
50	4251	Med.	15	413.37	769.42	776.72	6.85
51	4280	Med.	13	415.19	718.34	726.10	7.76
52	4288	Med.	14	412.52	739.52	748.80	4.28
53	4323	Med.	14	408.21	727.22	730.57	3.35
54	4340	Med.	13	423.41	732.90	739.73	6.83
55	4351	Med.	15	410.27	746.78	751.90	5.12
56	4400	Med.	14	411.98	761.57	765.21	3.64
57	4415	High	23	416.56	729.05	745.73	15.68
58	4828	High	14	408.52	741.32	747.49	6.17
59	4838	High	13	416.38	730.11	733.50	3.39
		Total					
		Average					

Contd.

1	9	10	11	12	13	14
27	1.65	8.50	2.85	2.866	42.990	9.92
28	–	–	16.00	–	–	9.92
29	–	–	6.00	–	–	9.92
30	1.40	7.70	2.95	2.969	38.953	9.92
31	1.86	8.50	2.05	2.068	26.884	9.92
32	2.24	10.10	3.05	3.072	43.008	9.92
33	2.44	12.00	3.15	3.1524	72.496	9.92
34	0.93	6.10	1.35	1.359	20.385	9.92
35	2.88	16.30	2.75	2.778	66.670	9.92
36	2.83	20.20	2.20	2.228	51.244	9.92
37	2.21	10.00	2.90	2.990	41.86	9.92
38	3.38	17.30	2.30	2.330	58.25	9.92
39	1.78	9.20	2.80	2.817	36.62	9.92
40	2.27	11.00	2.40	2.422	36.33	9.92
41	0.75	6.10	2.70	2.707	37.89	9.92
42	1.38	7.60	2.50	2.513	37.72	9.92
43	–	–	9.00	–	–	9.92
44	1.60	8.40	2.60	2.616	39.24	9.92
45	3.90	18.20	2.60	2.639	63.33	9.92
46	2.13	9.20	2.5	2.521	32.77	9.92
47	–	–	13.0	–	–	9.92
48	–	–	18.0	–	–	9.92
49	1.73	8.60	2.70	2.717	38.03	9.92
50	1.66	8.00	2.40	2.416	36.24	9.92
51	1.87	9.40	2.80	2.818	36.63	9.92
52	1.04	7.30	2.35	2.360	33.04	9.92
53	0.82	6.60	2.90	2.908	40.71	9.92
54	1.61	8.40	2.20	2.216	28.80	9.92
55	1.25	7.50	2.95	2.960	44.40	9.92
56	0.83	6.20	2.15	2.158	30.21	9.92
57	3.76	21.20	3.10	3.104	42.15	9.92
58	1.51	7.80	2.10	2.107	29.61	9.92
59	0.81	6,50	3.20	3.260	41.704	9.92
Total	91.01	488.63	101.60		2090.63	584.10
Average	1.75	8.28	3.920		35.43	9.92

Table 7 Consumptive use of water by rice

SL. No.	Name of Researcher	Place	Period	Consumptive use of water by rice (inches)		
				Boro	Aus	Aman
1	FAO	Amla expt. station	1958-62	44.18	19.72	31.51
2	Huq	Amla expt. station	1965-67	38.05	34.80	35.54
3	Huizing	Modhupur	1970	19.00	-	-
4	Biswas & Ali	BAU	1974	-	43.70	-
5	Halim	BRRI	1976	56.94	-	-
6	Idris	BAU	1977	50.80	-	-
	Mean			41.79	32.74	33.53
7	Consumptive use obtained by Blaney Criddle method			37.97	-	-

Table 8 Evapotranspiration Index

Months		(Modified Penman Method) E To E.I./month, (inches)
January	... ...	2.10
February	... ...	2.80
March	... ...	4.70
April	... ...	5.80
May	... ...	5.90
June	... ...	4.40
July	... ...	4.30
August	... ...	4.50
September	... ...	3.70
October	... ...	3.50
November	... ...	2.50
December	... ...	2.00
	Total: ...	46.20

Table 9. Crop coefficients of different crops

Crop	Growing period (days)	Remarks	1		2		3		4		5		11		12	
			I	II	I	II	I	II	I	II	I	II	I	II	I	II
Boro	120	HYV	1.20	1.25	1.25	1.30	1.40	1.45	1.50	1.35						
	135	HYV	1.20	1.25	1.25	1.30	1.35	1.40	1.40	1.45	1.50	1.30				
T.Aus	105	HYV	1.20	1.25	1.30	1.40	1.45	1.50	1.35							
	120		1.20	1.25	1.25	1.30	1.40	1.45	1.50	1.35						
	135	Local	1.20	1.25	1.25	1.30	1.35	1.40	1.45	1.50	1.30					
T.Aman	105	HYV	1.20	1.25	1.30	1.40	1.45	1.50	1.35							
	150	Local	1.20	1.25	1.25	1.30	1.35	1.35	1.40	1.40	1.50	1.30				
Wheat	105		0.50	0.60	0.70	1.00	1.15	1.25	1.00							
Jute	120		0.50	0.65	0.95	1.15	1.50	1.40	1.40	1.40						
Pulses	90		0.50	0.70	0.95	1.10	1.10	1.10	0.95							
Oilseed	90		0.50	0.65	0.95	1.10	1.10	0.95								
Others	90	Winter Veg.	0.40	0.50	0.80	0.90	0.90	0.70								
Others	90	S.Veg.	0.40	0.65	0.80	0.90	0.95	0.85								
Sugarcane	12 months		0.60	0.80	0.90	1.00	1.20	1.30	1.30	1.30	1.30	1.30	1.30	1.25	1.20	0.95

Table 10 Calculation of consumptive use of water by Modified Penman method

Crop : Boro HYV IR - 8, BR - 3 of 135-day's growing period

Month	December		January		February		March		April		May		June		Remarks
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	
Pattern															
Crop factor		1.20/2	1.25	1.25	1.30	1.35	1.49	1.45	1.50	1.00	1.00				
Eto in			2.10		2.80		4.70		5.80		5.90		4.40		
ET(crop)		0.60	1.32	1.75	1.82	3.17	3.29	4.21	4.35	3.84	1.48				Consumptive use
Conulative consumptive use		0.63	1.95	3.70	3.52	8.69	11.98	10.98	20.54	24.38	25.56				
Total		0.63	1.32	1.75	1.82	3.17	3,29	4.21	4.35	3.54	1.48				25.86 in.

Table 11 Calculation of consumptive use of water by Blancy Criddle method

Month	January		February		March		April		May		June		Remark
	I	II	I	II	I	II	I	II	I	II	I	II	
Pattern													
Percent day time hours P	7.58		7.17		8.40		8.60		9.30		9.20		
Average temperature, ^oF t	67.30		71.60		79.05		83.65		84.55		83.45		
Consumptive use factor f	5.10/2		5.13		6.64		7.19		7.85		7.68		
Crop factor k	1.20/2	1.25	1.25	1.30	1.35	1.40	1.45	1.50	1.30	1.0/2			
Consumptive use u	1.53	3.19	3.21	3.33	4.48	4.65	5.12	5.39	5.10	1.96			
Cumulative consumptive use	1.53	4.72	7.93	11.26	15.74	20.39	25.51	30.90	35.00	37.96			
Total													37.96 in

Table 12 Evaporation loss from irrigation canals

Name of canal	Length (ft)	Average width of water surface (ft)	Area of evaporating surface (acres)	Depth of evaporation		Volume of water evaporated		
				For irrigation period (ft)	For growing season (ft)	During irrigation period (acre-ft)	Throughout the growing season (acre-ft)	During drainage period (acre-ft)
NR-1	24220	13.00	7.20	0.83	1.55	5.98	11.16	5.18
NR-2	19370	10.00	4.45	0.83	1.55	3.69	6.90	3.21
DL-1	27300	15.00	9.40	0.03	1.55	7.80	14.57	6.77
DL-2	12000	9.00	2.48	0.83	1.55	2.06	3.84	1.78
DL-3	56000	8.00	1.03	0.83	1.55	0.85	1.60	0.75
DL-4	12200	9.50	2.66	0.83	1.55	2.21	4.12	1.91
DTO	27000	4.50	2.79	0.83	1.55	2.32	4.32	2.00
Main	37000	125	106	0.83	1.55	87.98	164.30	76.32
Total						112.89	210.81	97.92

Table 13 Evaporation loss from drainage channels

Name of channel	Length (ft)	Average width of water surface (ft)	Area of evaporating surface (acre)	Depth of evaporation		Volume of water evaporated		
				During irrigation period (ft)	Throughout the growing season (ft)	During irrigation period (ft)	Throughout the growing season (ft)	During drainage period (acre-ft)
Primary-1	33400	29.25	22.62	0.83	1.55	18.77	35.06	16.29
Primary-2	24200	25.75	14.31	0.83	1.55	11.88	22.18	10.30
Fatullah	8350	17.50	3.35	0.83	1.55	2.78	5.19	2.41
Pagla	9190	20.00	4.22	0.83	1.55	3.50	6.54	3.04
Secondary-1	3340	13.75	1.05	0.83	1.55	0.87	1.63	0.76
Secondary-2	9185	16.50	3.48	0.83	1.55	2.89	5.39	2.50
Secondary-3	11690	16.00	4.29	0.83	1.55	3.56	6.65	3.09
Secondary-4	7520	15.75	2.37	0.83	1.55	1.97	3.67	1.70
Secondary-5	12530	17.00	4.87	0.83	1.55	4.06	7.58	3.52
Secondary-6	3340	16.50	1.27	0.83	1.55	1.05	1.97	0.92
Total			61.85			51.53	95.86	44.33

Table 14 Seepage loss from main canal

Date	Water level in ft (PWD)	Evaporation (in)	Cumulative evaporation (in)	Rainfall (in)	Cumulative rainfall (in)
7.4.77	15.479	-	-	-	-
8.4.77	15.456	0.112	0.009	0.04	0.003
9.4.77	15.446	0.133	0.020	0.35	0.032
10.4.77	15.567	0.000	0.020	1.78	0.181

From page 42

Wlf + E + Sp - R = WLi

(i) 15.456 + 0.009 + SP - 0.003 = 15.479

or SP = 0.017 ft. for one day

(ii) 15.446 + 0.020 + SP - 0.032 = 15.479

or SP = 0.045 ft. for 2 days

(iii) 15.567 + 0.020 + SP - 0.181 = 15.479

or SP = 0.073 ft. for 3 days

Cumulative SP = 0.135 ft. for 6 days

SP = 0.0225 ft. for a day

= 0.27 in. a day

Table 15 Properties of soils of the project area

SL. No.	Reach length of main canal	Name and No. of soil association	Texture of soil	Permeability (ft/sec)
1	1855	Demra-Jatrabari -3	Silty clay loam	49.85×10^{-8}
2	7920	Demra-Matuail -4	Silty clay loam	46.90×10^{-8}
3	20726	Siddhirganj -7	Silty clay loam	48.10×10^{-8}
4	6499	Disturbed -10	Silty clay loam	46.33×10^{-8}
Total	3700			

Table 16 Seepage loss from main canal

A = 1.875 from Fig. 14

= 33.69

SL.No.	Month	Average ground water level in ft (PWD)	Average W.L. in main canal in ft (PWD)	Bed level in main canal in ft (PWD)	Depth to G.W.T. (ft)	Width of water surface (ft)
1	2	3	4	5	6	7
1	January	+ 3.73	+ 15.50	- 5.00	11.77	35.31
2	February	+ 3.51	+ 15.50	- 5.00	11.99	35.97
3	March	+ 4.22	+ 15.50	- 5.00	11.28	33.84
4	April-4	+ 5.89	+ 15.50	- 5.00	9.61	28.83
Average		+ 4.34	+ 15.50	- 5.0	11.16	33.49

Contd.

	For Reach length of soil Association -3				For reach length of soil Association - 4			
SL. No.	Permeability K (ft/sec)	q = k(b+Ad) (cfs/ft)	Reach length (ft)	Loss of water for reach (cfs)	Permeability K (ft/sec)	q = k(b+Ad) (cfs/ft)	Reach length (ft)	Loss of water for reach (cfs)
1	8	9	10	11	12	13	14	15
1	48.85×10^{-8}	29.30×10^{-5}	1855	0.055	46.90×10^{-8}	26.90×10^{-8}	7920	0.213
2	49.85×10^{-8}	29.10×10^{-5}	1855	0.054	46.90×10^{-8}	27.40×10^{-5}	7920	0.217
3	49.85×10^{-8}	27.40×10^{-5}	1855	0.051	46.90×10^{-8}	25.80×10^{-5}	7920	0.204
4	49.85×10^{-8}	23.30×10^{-5}	1855	0.043	46.90×10^{-8}	22.00×10^{-5}	7920	0.174
Average								

Contd.

	For Reach length of Soil Association - 7				For Reach length of Soil Association -10				Total Loss	
SL. No.	Permeability K (ft/sec)	q = k(b+Ad) (cfs/ft)	Reach length (ft)	Loss for the reach (cfs)	Permeability K (ft/sec)	q = k(b+Ad) (cfs/ft)	Reach length (ft)	Loss of water for the reach (cfs)	Q_T Cfs	Q_T Acre-ft
1	16	17	18	19	20	21	22	23	24	25
1	48.10×10^{-8}	27.60×10^{-5}	20726	0.572	46.33×10^{-8}	26.60×10^{-5}	6499	0.173	1.013	62.81
2	48.10×10^{-8}	28.10×10^{-5}	20726	0.582	46.33×10^{-8}	27.10×10^{-5}	6499	0.176	1.029	57.62
3	48.10×10^{-8}	26.50×10^{-5}	20726	0.548	46.33×10^{-8}	25.40×10^{-5}	6499	0.165	0.968	60.02
4	48.10×10^{-8}	22.5×10^{-5}	20726	0.467	46.33×10^{-8}	21.70×10^{-5}	6499	0.141	0.825	6.60
Average										187.05

Table 17 Water level in drain intake/project area,ft(PWD) Yeat 1977

Date	Months					
	January	February	Marah	April	May	June
1	2.21	3.60	3.30	5.50	6.20	5.85
2	2.20	3.70	3.10	5.50	6.30	5.45
3	2.21	4.60	3.00	6.00	6.20	5.80
4	2.00	5.10	3.40	6.80	6.30	5.60
5	2.60	6.20	3.40	6.90	6.30	5.58
6	3.00	5.00	3.70	7.10	6.30	5.72
7	3.30	4.00	4.70	7.00	6.30	5.90
8	3.40	3.50	5.20	6.80	6.00	5.70
9	4.60	4.20	6.20	5.50	6.00	5.60
10	3.90	4.20	6.40	5.00	5.80	5.45
11	3.90	4.70	6.50	5.20	5.90	6.50
12	3.70	3.00	5.80	5.20	6.10	5.80
13	3.40	4.50	5.30	5.50	6.30	5.62
14	3.40	4.70	4.60	5.20	6.80	5.65
15	4.70	4.70	4.10	6.40	5.80	5.40
16	5.00	3.90	4.50	6.20	6.00	5.60
17	4.80	3.30	5.30	5.20	5.40	5.40
18	4.90	3.50	5.50	5.60	6.50	5.65
19	4.50	3.80	5.40	5.40	5.60	5.70
20	5.80	3.80	5.60	6.40	5.40	5.05
21	5.50	3.90	5.30	5.90	7.50	5.80
22	6.00	4.10	5.70	3.90	7.40	6.80
23	6.20	4.00	5.30	5.80	7.60	7.20
24	6.00	4.20	5.50	5.90	7.20	7.30
26	6.00	4.60	6.40	5.70	6.60	7.32
27	6.00	4.30	6.60	5.70	5.90	7.00
28	5.80	3.80	6.40	5.80	6.00	6.60
29	6.20	-	6.40	5.70	5.40	6.80
30	5.62	-	6.10	5.90	6.00	6.60
31	5.10	-	5.60	-	6.40	7.80
Total:	137.70	119.10	160.70	174.60	194.00	189.34
Average:	4.44	4.25	5.18	5.82	2.26	6.11

Table 18 Water level in river intake (Lakhya river), ft(PWD)

Year: 1977

Date	January	February	March	April	May	June
	Months					
1	2.40	1.95	2.13	4.10	5.50	10.10
2	3.40	2.25	2.27	5.00	7.30	10.30
3	3.20	2.13	2.12	5.30	6.70	10.35
4	2.85	2.55	2.40	5.85	7.55	10.75
5	3.10	2.70	2.85	7.05	7.70	11.10
6	3.25	3.00	3.37	7.00	8.10	11.28
7	3.55	2.75	3.53	6.40	8.30	11.45
8	3.60	2.80	3.90	6.25	8.30	11.60
9	3.80	3.94	3.88	6.15	8.15	11.80
10	3.50	2.65	3.95	6.05	8.15	11.95
11	3.53	2.50	3.70	5.50	8.20	11.90
12	3.45	2.40	3.40	5.06	8.15	12.00
13	3.40	2.24	3.22	5.53	10.23	12.15
14	3.25	2.34	2.90	5.20	9.65	12.15
15	3.00	2.35	2.90	6.04	9.05	12.25
16	3.20	2.50	3.15	6.35	8.82	12.20
17	3.15	2.75	3.55	6.25	8.45	12.70
18	3.00	2.97	3.65	6.25	8.85	12.80
19	3.22	3.15	3.55	6.00	8.60	13.00
20	3.35	3.36	3.60	6.10	8.80	13.88
21	3.28	3.60	3.73	6.25	9.05	13.16
22	3.00	3.38	3.95	6.00	9.00	13.40
23	3.86	3.30	3.80	6.20	8.92	13.45
24	3.00	3.26	3.40	6.00	8.70	13.55
25	2.95	3.20	3.25	5.60	8.80	13.50
26	2.78	2.95	3.32	6.45	8.80	13.62
27	2.60	2.55	3.10	6.32	8.85	13.70
28	2.30	2.10	3.05	6.10	9.10	14.00
29	1.96	-	3.20	6.20	9.40	13.80
30	1.48	-	3.28	6.25	9.70	14.20
31	1.65	-	3.07	-	9.70	14.20
Total:	93.38	77.52	101.17	178.80	255.45	386.26

Table 19 Water level in Buriganga river, ft(PWD)

Year: 1977

Date	January	February	March	April	May	June
	Months					
1	3.18	2.65	2.55	4.22	6.93	
2	3.25	2.83	3.00	5.11	7.00	
3	3.20	2.95	3.15	5.50	7.17	
4	4.00	3.05	3.00	5.97	7.50	
5	4.00	3.05	3.10	6.35	7.60	
6	4.22	3.22	3.20	6.72	7.75	
7	4.65	3.53	3.67	6.72	8.32	
8	4.67	3.30	3.70	6.70	8.40	
9	4.60	3.02	4.07	6.77	8.42	
10	4.37	3.02	4.00	6.52	8.17	
11	4.15	3.00	3.95	5.80	8.07	
12	4.00	2.88	3.90	5.72	8.25	
13	3.75	2.98	3.37	5.70	8.45	
14	3.60	2.87	3.50	6.07	8.70	
15	3.75	2.80	3.12	6.30	8.30	
16	3.90	3.02	3.45	6.42	8.72	
17	4.08	3.40	3.65	6.60	8.95	
18	3.95	3.95	3.95	6.45	8.80	
19	4.05	4.12	4.17	6.35	8.70	
20	3.90	4.30	4.35	6.25	9.00	
21	3.80	4.55	4.50	6.10	8.85	
22	3.60	4.27	4.50	5.95	8.90	
23	3.45	4.20	4.25	5.88	8.95	
24	3.33	4.00	4.12	6.00	9.05	
25	3.20	3.60	3.85	5.95	9.10	
26	3.02	3.70	3.80	5.75	9.10	
27	2.98	3.05	4.20	5.95	9.20	
28	2.85	2.77	4.37	6.10	9.30	
29	2.72	-	4.10	6.15	9.30	
30	2.55	-	4.05	6.65	9.82	
31	2.45	-	4.20	-	10.02	
Average	3.09	2.79	4.18	6.05	9.24	

Table 20 Water level of periphery river and project area

Period	Month	Date	Average water level: Buriganga ft (PWD)	Lakhya ft (PWD)	Project ft (PWD)	Head difference: Project Lakhya (ft)	Project & Buriganga (ft)
Irrigation	Jan.	1-10	4.01	3.27	3.60	+ 0.33	+ 0.41
		11-20	3.91	3.25	4.42	+ 1.17	+ 0.51
		21-31	3.09	2.62	5.84	+ 3.22	+ 2.75
	Feb.	1-10	3.06	2.67	4.41	+ 1,74	+ 1.35
		11-20	3.33	2.65	3.99	+ 1.34	+ 0.66
		21-28	3.79	3.03	4.39	+ 1.36	+ 0.60
	Mar.	1-10	3.34	3.04	4.24	+ 1.20	+ 0.90
		11-20	3.74	3.36	5.26	+ 1.90	+ 1.52
		21-31	4.18	3.38	5.97	+ 2.59	+ 1.79
	Apr.	1-4	4.13	5.06	5.95	+ 0.89	+ 1.82
Average						1.65	1.23
Drainage	Apr.	5-10	6.63	6.48	6.38	- 0.10	- 0.25
		11-20	6.17	5.85	5.63	- 0.20	- 0.54
		21-30	6.05	6.14	5.61	- 0.53	- 0.44
	May	1-10	7.73	7.57	6.12	- 1.45	- 1.45
		11-20	8.58	8.85	5.98	- 2.87	- 2.87
		21-31	9.24	0.09	6.64	- 1.45	- 2.45
Average						- 1.37	- 1.44

Table 21 Amount of water drained-out by gravity flow

SL. No.	Date		Discharge (acre-ft)
1	19.1.77	...	78.37
2	30.1.77	...	114.28
3	31.1.77	...	105.06
4	1.2.77	...	80.09
5	5.2.77	...	104.62
6	6.2.77	...	56.57
7	7.2.77	...	28.52
8	15.2.77	...	64.16
9	16.2.77	...	61.46
10	17.2.77	...	32.94
11	25.2.77	...	41.32
12	26.2.77	...	51.05
13	27.2.77	...	84.08
14	28.2.77	...	69.69
15	1.3.77	...	4.31
16	11.3.77	...	75.66
17	12.3.77	...	83.68
18	13.3.77	...	82.49
19	14.3.77	...	37.07
20	15.3.77	...	33.10
21	16.3.77	...	47.71
22	28.3.77	...	49.41
23	29.3.77	...	111.76
24	30.3.77	...	51.87
25	31.3.77	...	84.41
26	1.4.77	...	66.43
27	2.4.77	...	60.95
28	3.4.77	...	21.01
29	4.4.77	...	26.33
30	6.4.77	...	17.21
Total:			1824.61

As there were two vents in operation,
Total drainage disposal = 1824.61 x 2
= 3649.22 acre-ft.

Table 22 Amount of water drained out form the project (by pump)

Date	Amount (acre-ft)	Date	Amount (acre-ft)
5.4.77	34.71	5.5.77	4.70
6.4.77	72.75	6.5.77	41.25
7.4.77	348.00	7.5.77	40.45
8.4.77	421.66	8.5.77	68.10
9.4.77	287.20	9.5.77	27.56
10.4.77	333.96	10.5.77	-
11.4.77	302.40	11.5.77	73.80
12.4.77	129.24	12.5.77	275.00
13.4.77	227.35	13.5.77	529.25
14.4.77	288.40	14.5.77	670.44
15.4.77	536.87	15.5.77	720.88
16.4.77	52.00	16.5.77	650.88
17.4.77	504.00	17.5.77	599.28
18.4.77	346.56	18.5.77	450.45
19.4.77	274.93	19.5.77	462.40
20.4.77	172.56	20.5.77	514.14
21.4.77	86.40	21.5.77	803.30
22.4.77	87.06	22.5.77	821.69
23.4.77	100.94	23.5.77	751.68
24.4.77	87.06	24.5.77	671.52
25.4.77	43.59	25.5.77	612.48
26.4.77	28.64	26.5.77	660.00
27.4.77	-	27.5.77	448.48
28.4.77	28.84	28.5.77	640.32
29.4.77	-	29.5.77	631.68
30.4.77	-	30.5.77	422.72
-	-	31.5.77	640.80
1.5.77	43.53	Total:	17163.6 acre-ft
2.5.77	86.28		
3.5.77	42.57		
4.5.77	69.95		

Table 23 Dead storage in drainage channels

Name of drainage channel	Length (ft)	Average channel section upto initial water level (ft^2)	Average channel section upto final water level (ft^2)	Initial storage Si (ft^3)	Initial storage Si (acre-ft)	Final storage Sf (ft^3)	Final storage Sf (acre-ft)
Primary-1	33400	115	229	3841000	88.17	7648600	175.59
Primary-2	24200	83	191	2008600	46.11	4622200	106.11
Fatullah Khal	8350	29	97	242150	5.56	809950	18.59
Pagla Khal	9190	31	103	284890	6.54	946570	21.73
Secondary-1	3340	29	77	96860	2.22	257180	5.90
Secondary-2	9185	34	103	312290	7.17	946055	21.72
Secondary-3	11690	34	81	397460	9.12	946890	21.74
Secondary-4	7520	35	85	263200	6.04	384300	8.82
Secondary-5	12530	65	134	814450	18.70	1679020	38.54
Secondary-6	3340	48	116	160320	3.68	387440	8.89
Total:					193.31		427.63

Table 24 Seepage loss from the lateral canal DL-3

SL. No.	Distance from off take (ft)	Reach length (ft)	Discharge Q (ft)	Loss in the reach (cfs)	Water loss per ft per day in each reach (cfs)
1	0		10.60		
		2125		0.25	10.165
2	2125		10.35		
		1545		0.15	8.390
3	3670		10.20		
		1930		0.24	10.74
4	5600		9.96		
Total:		5600		0.64	

Efficiency for whole length $= \frac{9.96}{10.60}$ = 93.96 percent

Loss for the whole length = 10.6 - 9.96 = 0.64 cfs.

Loss per foot per day = 0.64x60x60x24/5600

= 0.987 cft.

Table 25 Topographical feature of the project area

SL. No.	Contour level in ft. (PWD)	Cumulative area (acres)	Cumulative volume (acre-ft)
1	5	0	0
2	6	750	375
3	7	2350	1923
4	8	4600	5400
5	9	8600	12000
6	10	11500	22050
7	11	12400	34000
8	12	12900	46650
9	13	13260	59730
10	14	13500	73110

Table 26 Distribution system of the project area

SL. No.	Name of canals	Length (ft)	Command area (acres)	Irrigable area (acres)	Irrigating area (acres)
1	Main canal	37000	18401.25	15124.73	12977.36
2	Lateral canal-DL1	19600	2737.68	2648.80	2073.40
3	Lateral canal-DL2	7700	1105.75	933.09	771.09
4	Lateral canal-DL3	5600	842.24	755.00	612.00
5	Lateral canal-DL4	9200	1288.98	1142.68	886.26
6	Lateral canal-NR1	19500	2807.04	2318.92	1757.02
7	Lateral canal-NR2	13800	1680.30	1570.30	1260.35
8	Lateral canal-DR1	12800	3033.48	2537.29	2042.05
9	Lateral canal-DR-2	9500	2394.66	1947.07	1568.83
10	Lateral canal-DR3	2000	478.40	302.15	259.10
11	Direct turnout 9 nos.	27200	2047.19	2042.19	1747.12
Total:			18401.25	15124.73	12977.36
	Area I		12040.25	9884.40	8719.14
	Area II		6361.00	5240.33	4258.22
Total:			18401.25	15124.73	12977.36

Gross area of the project:

Area I = 14500 acres
Area II = 6100 acres

Total: = 20600 acres

Table 27 Description of soil in Dacca-Narayanganj-Demra Project (Area I)

SL. No.	No. of soil association	Name of soil association	Depth of soil layer (in)	Texture of soils	Average texture
1	1	Payanti-Kazla	0-3 3-5 5-23 23-54	Silty loam Silty loam Silty clay Silty clay	Silty clay
2	2	Jatrabari-Kazla	0-3 3-5 5-11 21-27 27-40	Silty clay Silty clay Loam Silty loam Sandy loam	Loam
3	3	Demra-Jatrabari	0-6 6-12 12-19 19-34 34-43	Silty clay loam Silty clay loam Silty clay Silty clay loam Silt	Silty clay loam
4	4	Demra-Matuail	0-3 3-5 5-10 10-21 21-31 31-44 44-50	Clay loam Clay loam Silty clay loam Silty clay loam Silty loam Clay Silty loam	Silty clay loam
5	5	Silmundi	0-4 4-6 6-11 11-36 36-60	Clay Silty clay Clay Clay Clay	Clay
6	6	Jalkuri-Godnail	0-6 6-11 11-18 18-34 34-60	Silty clay Silty clay Silty clay Clay Clay	Clay

Contd.

SL. No.	No.of soil association	Name of soil association	Depth of soil layer (in)	Texture of soils	Average texture
7	7	Siddhirganj	0-3 3-5 5-11 11-21 21-32 32-37 37-44 44-50	Clay Silty clay Silty clay Silty clay Silty loam Silty clay Silty clay loam Silty loam	Silty clay loam
8	8	Jalkuri	0-4 4-8 8-21 21-33 33-37	Silty clay loam Clay Clay Clay Clay	Clay
9	9	Pagla-Kazla	0-2 2-6 6-16 16-28 28-36 36-41 41-52 52-62	Silty clay Clay Clay Clay Clay Silty clay Silty loam Silty loam	Silty clay
10	10	Disturbed land	Undefined	Undefined	Silty clay loam

APPENDIX - C

(Figures)

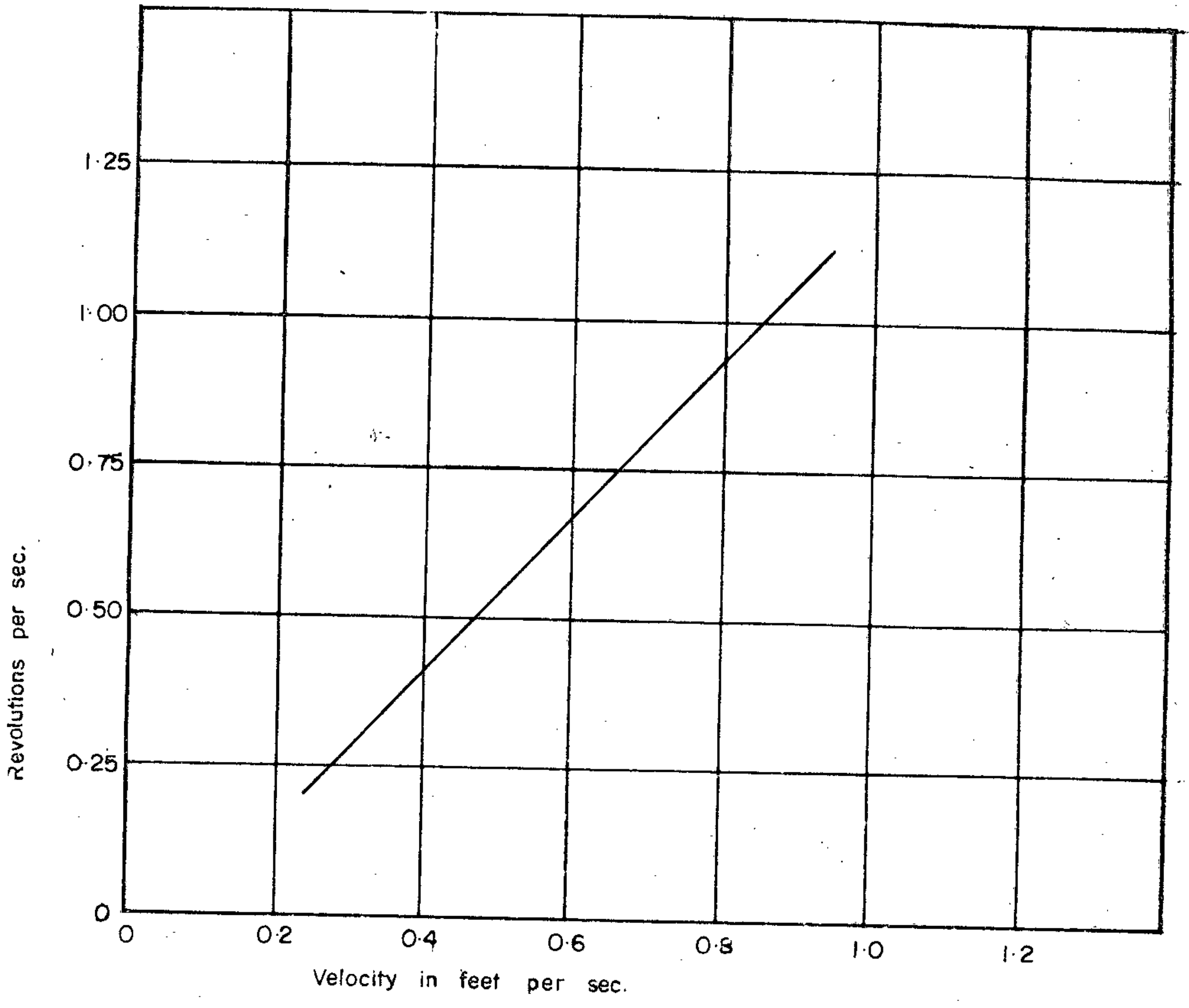


Fig. 13 Relationship between revolutions of current meter and velocity.

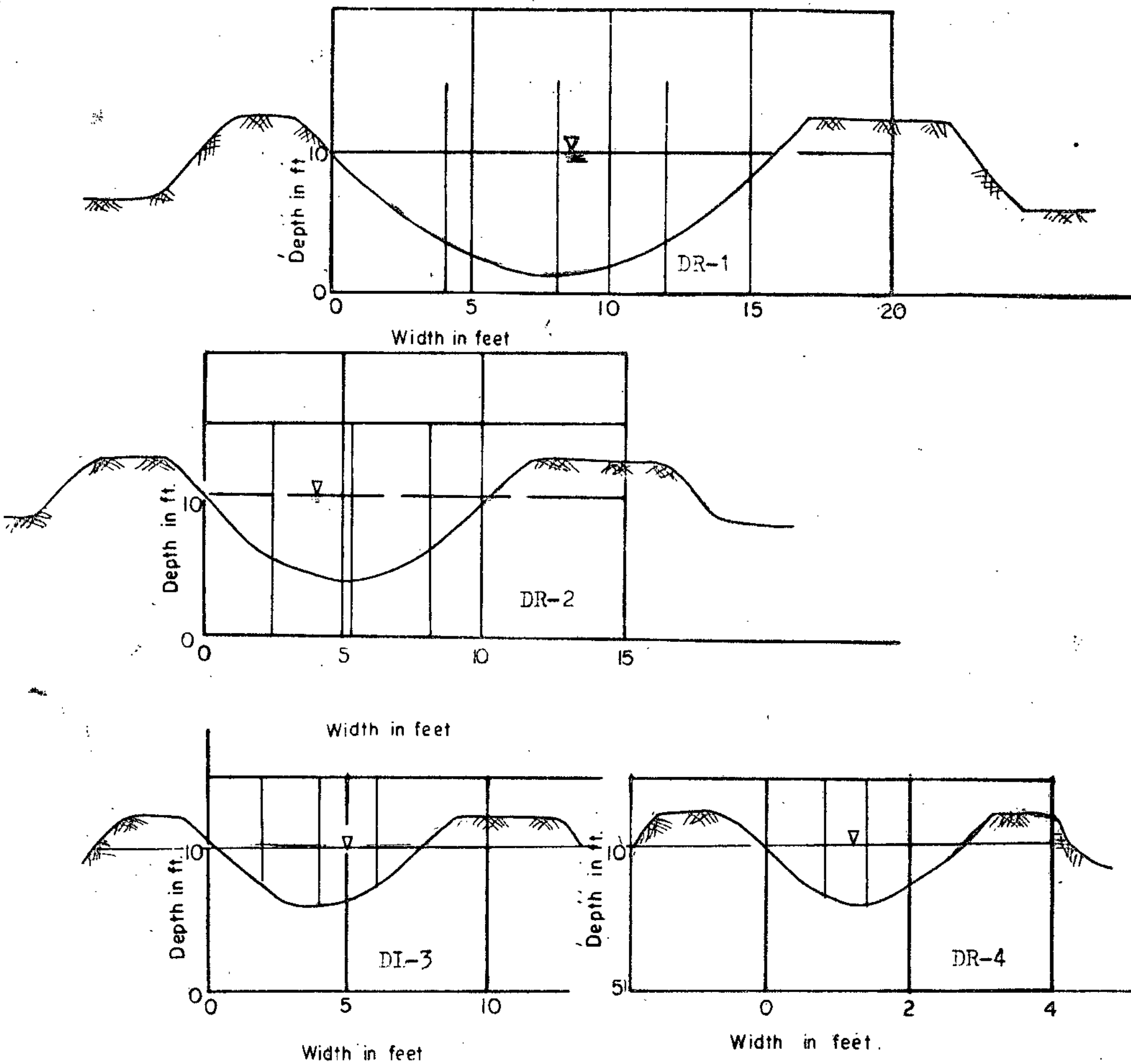


Fig. 14 Cross sections of irrigation canals.

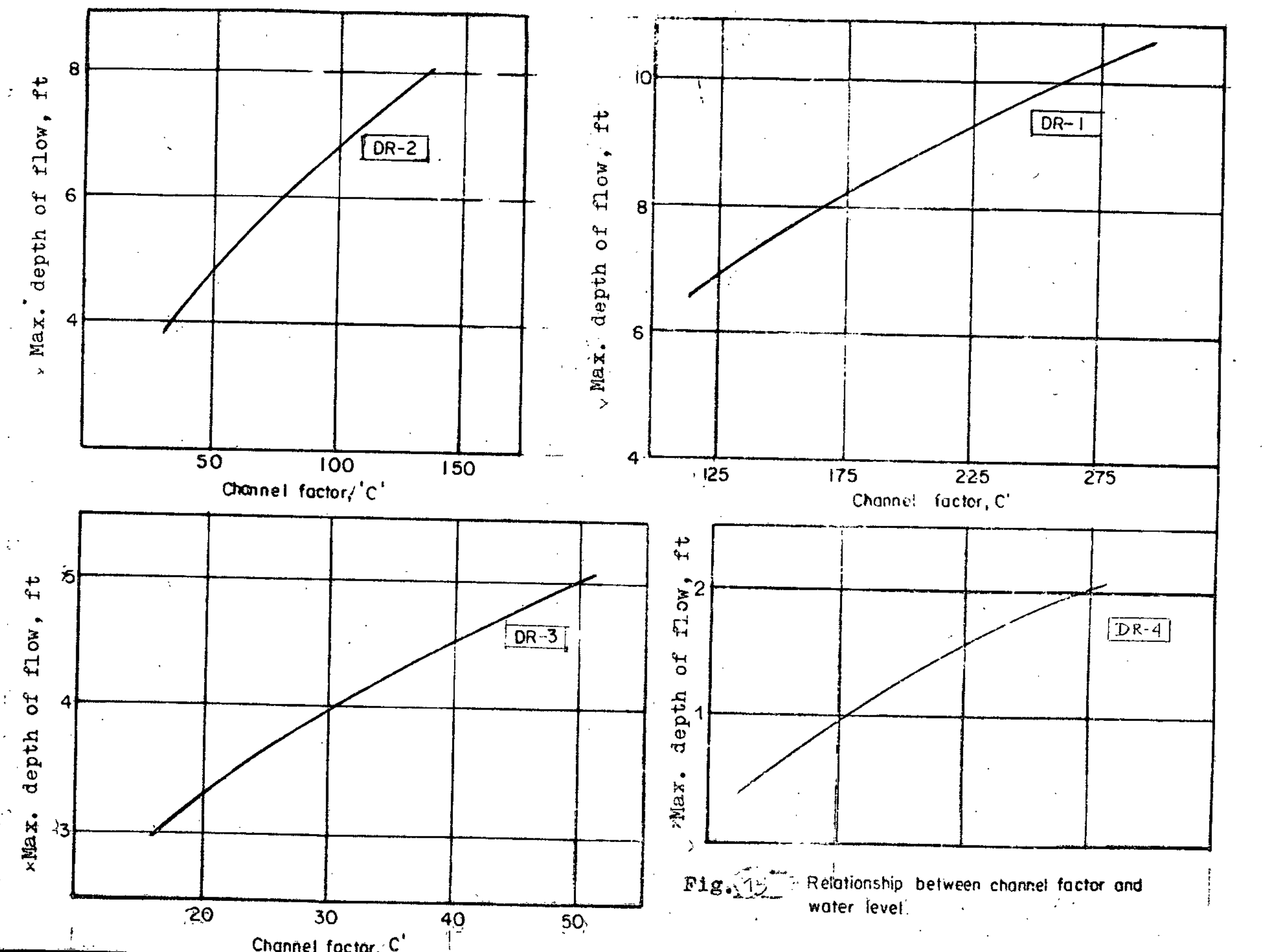
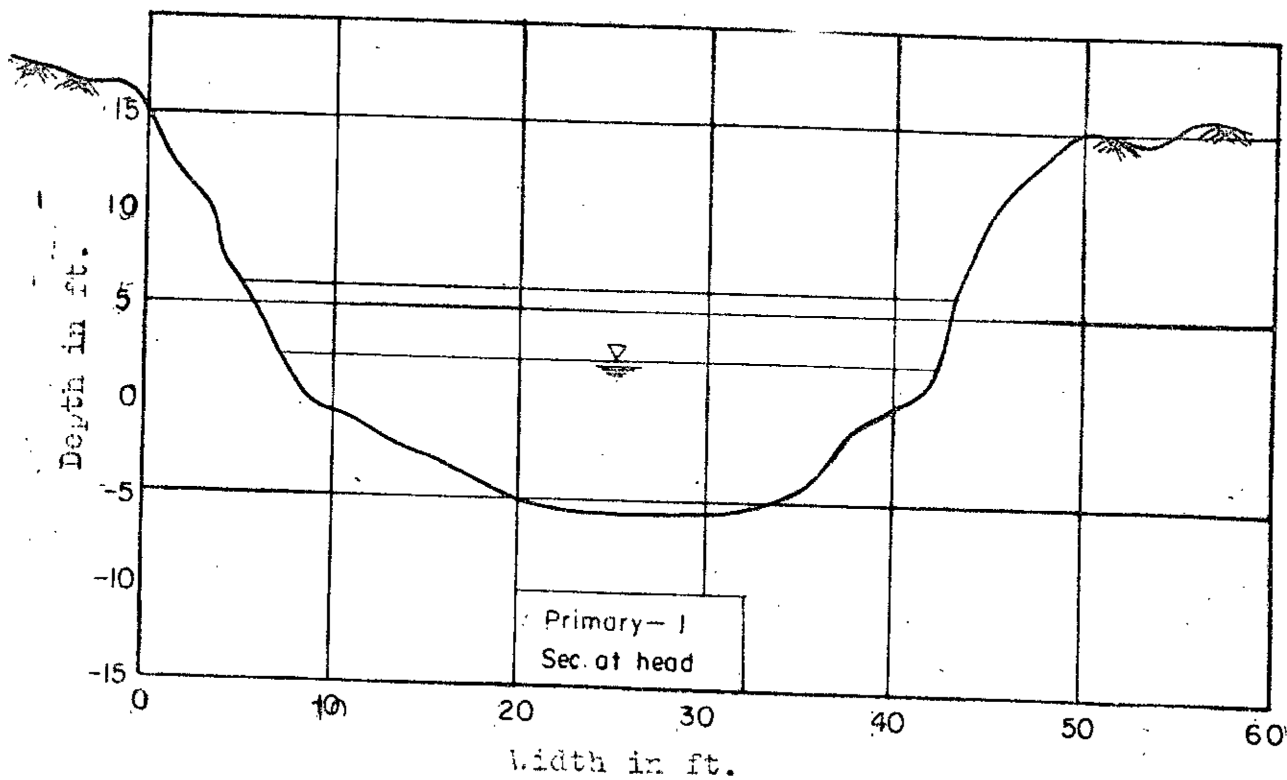
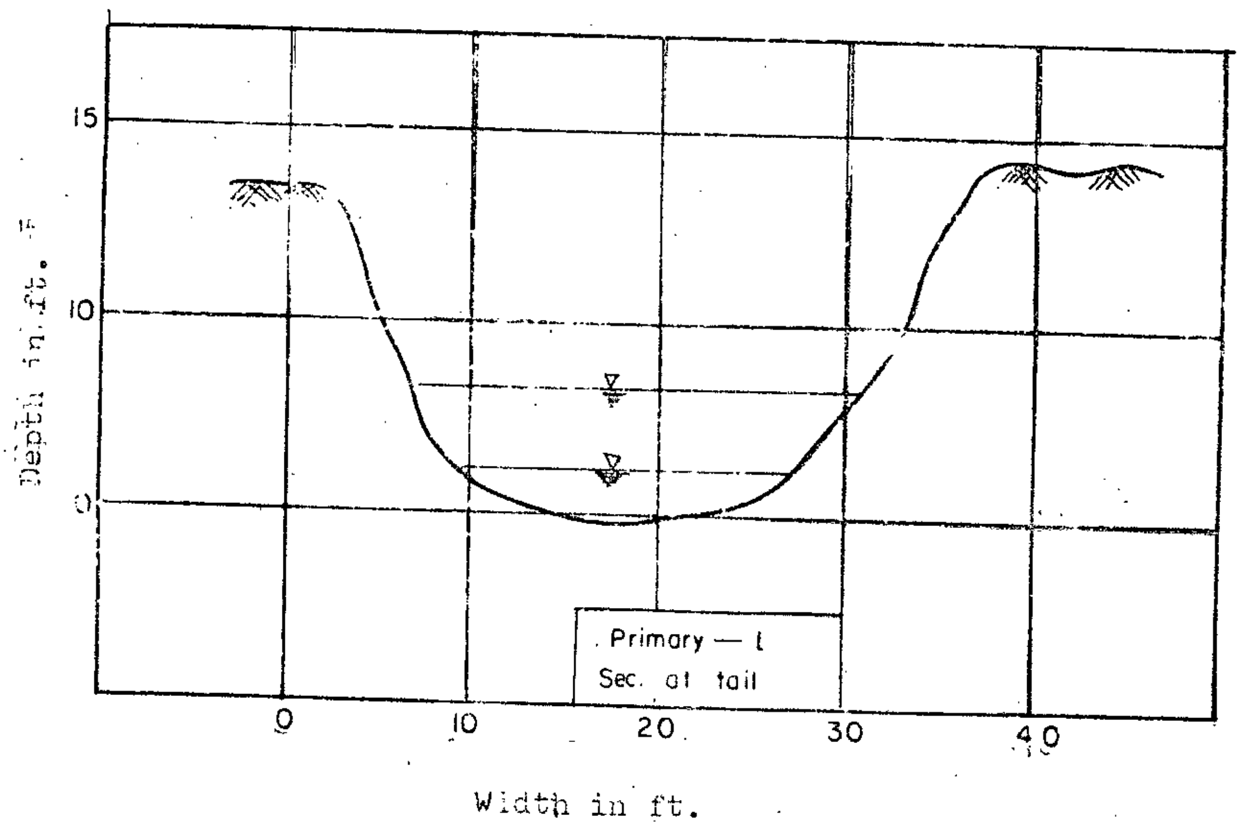
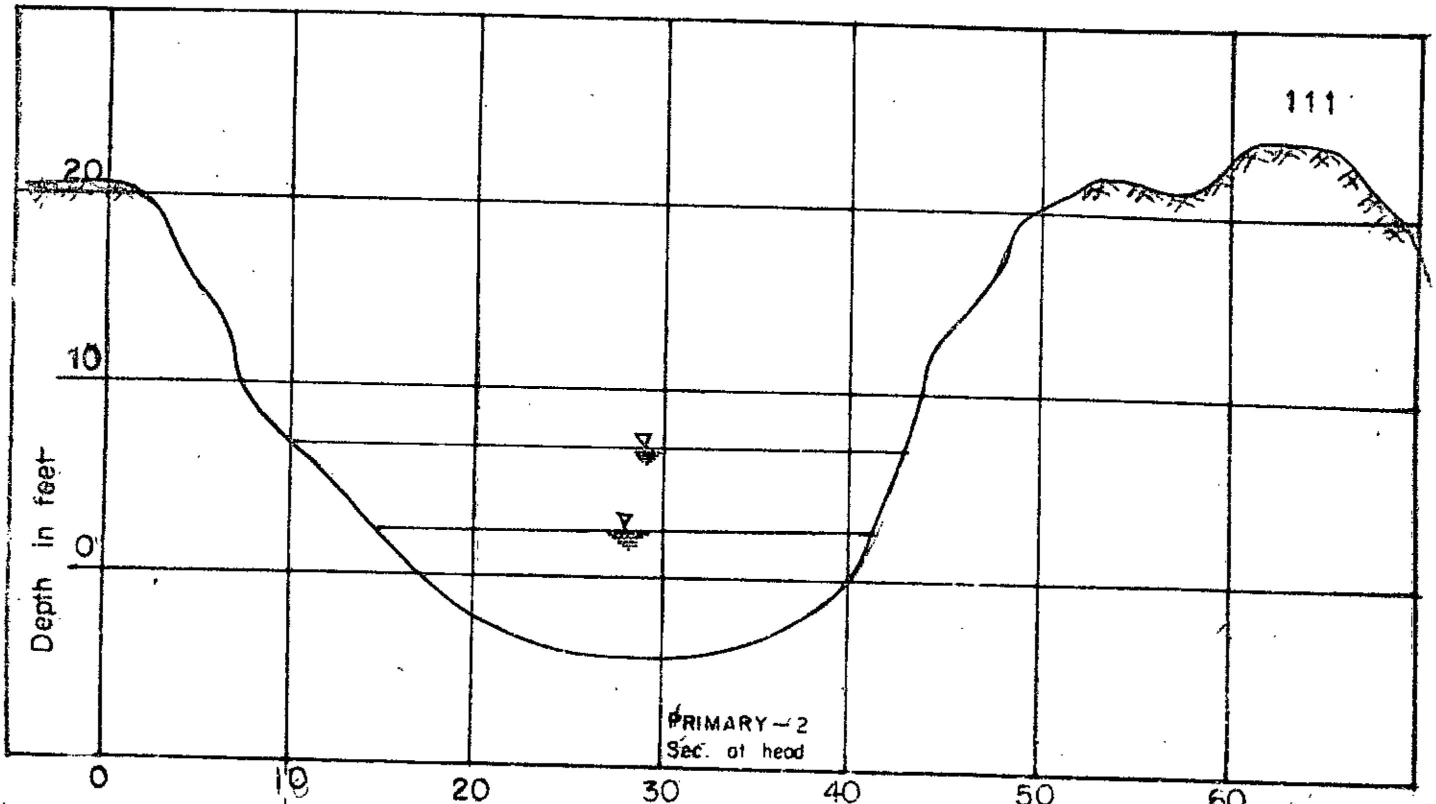


Fig. 15 Relationship between channel factor and water level.





16a Cross section of drainage channel.



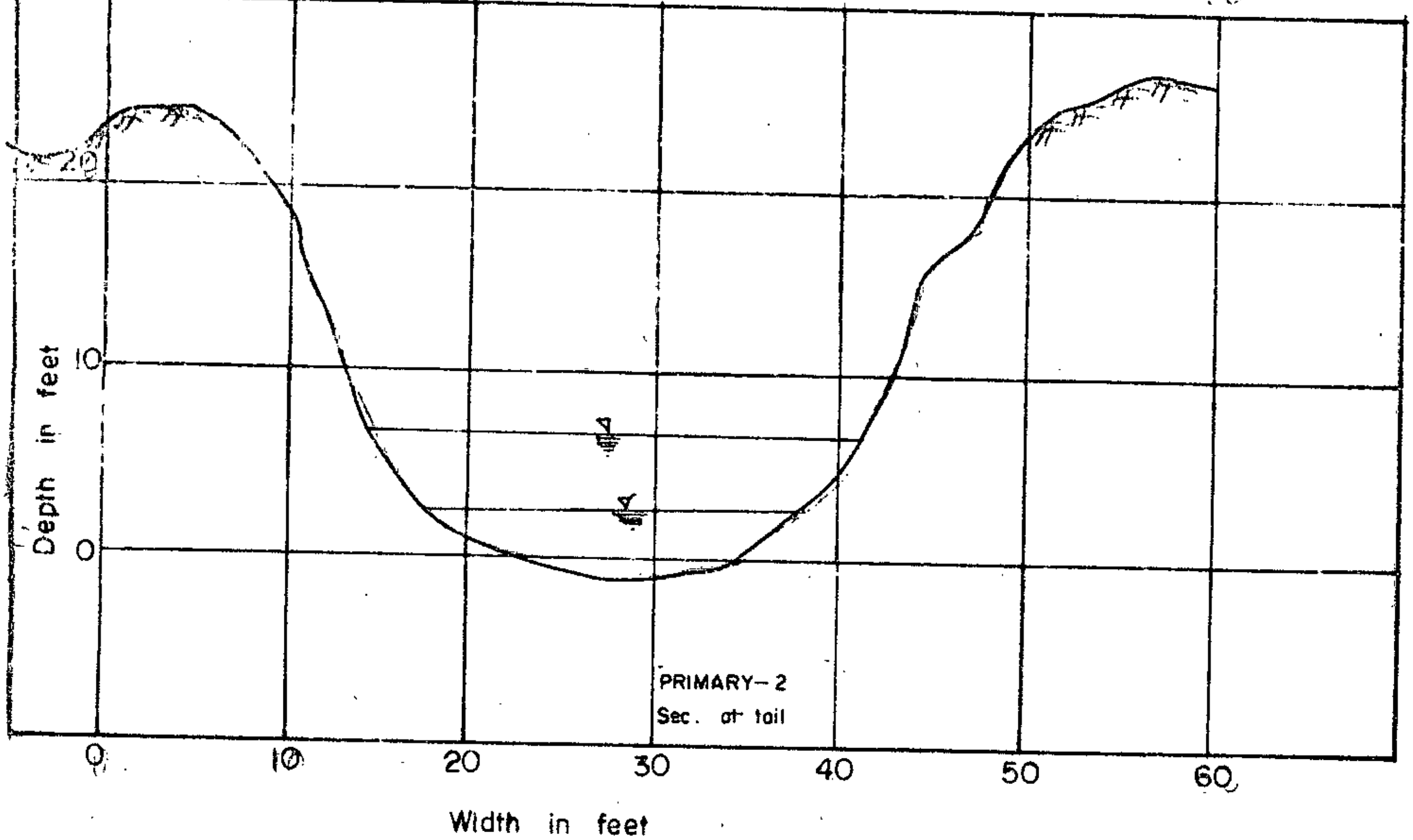
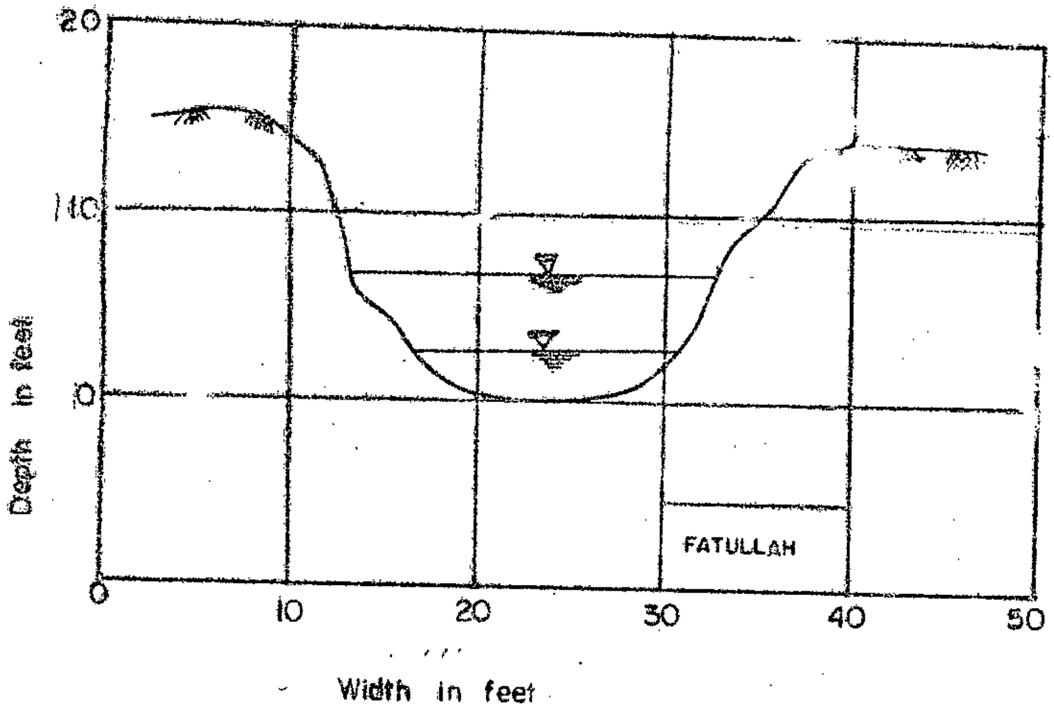


Fig. 16b — Cross sections of drainage channel.



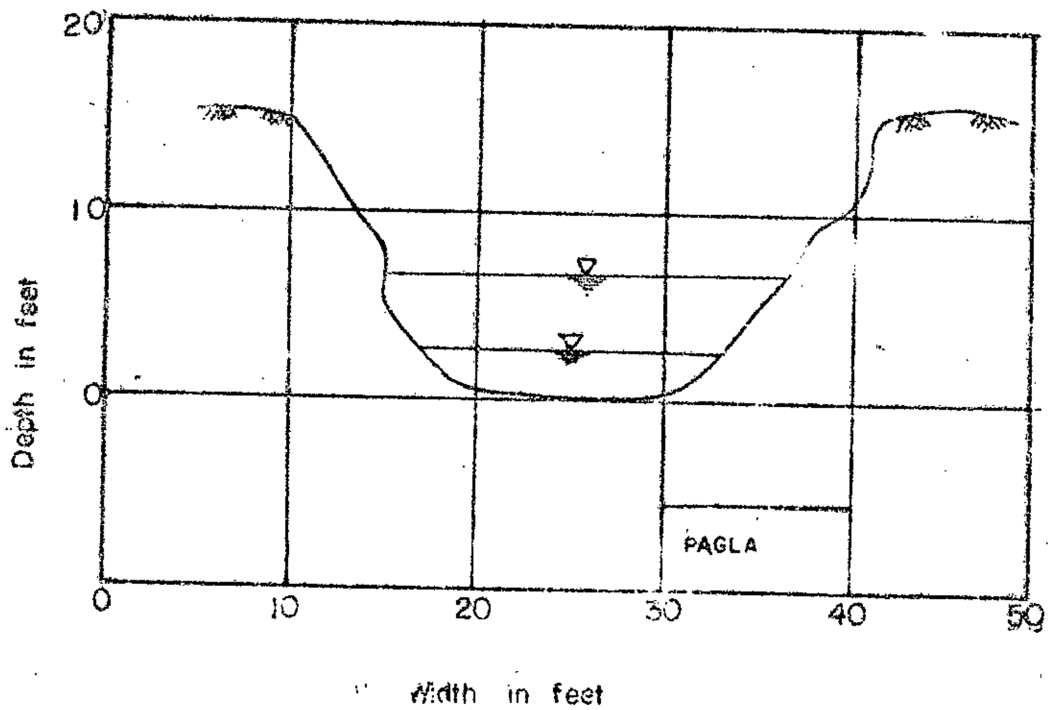


Fig. 16c Cross section of drainage channel

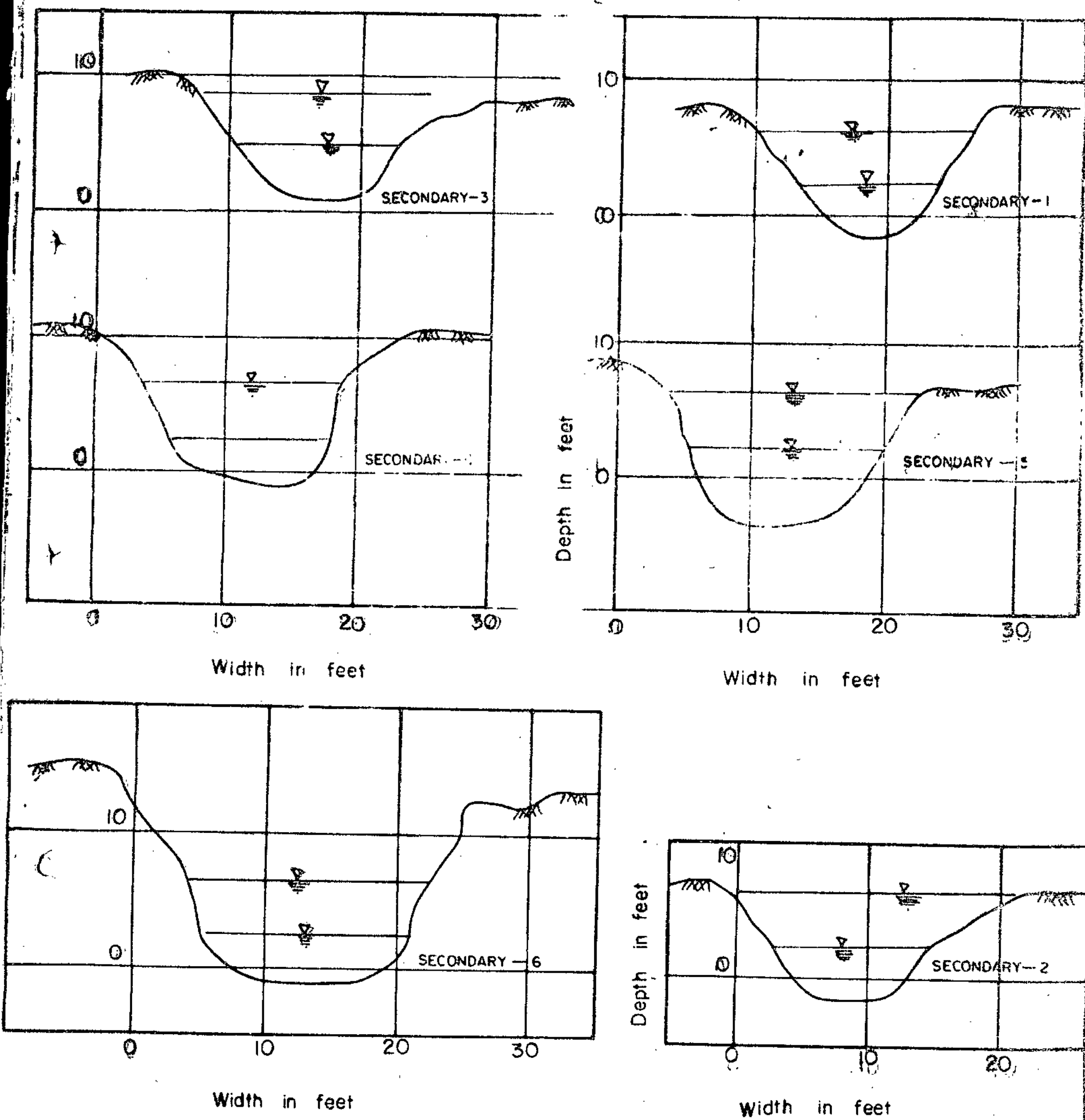


Fig. 16d Cross sections of drainage channel

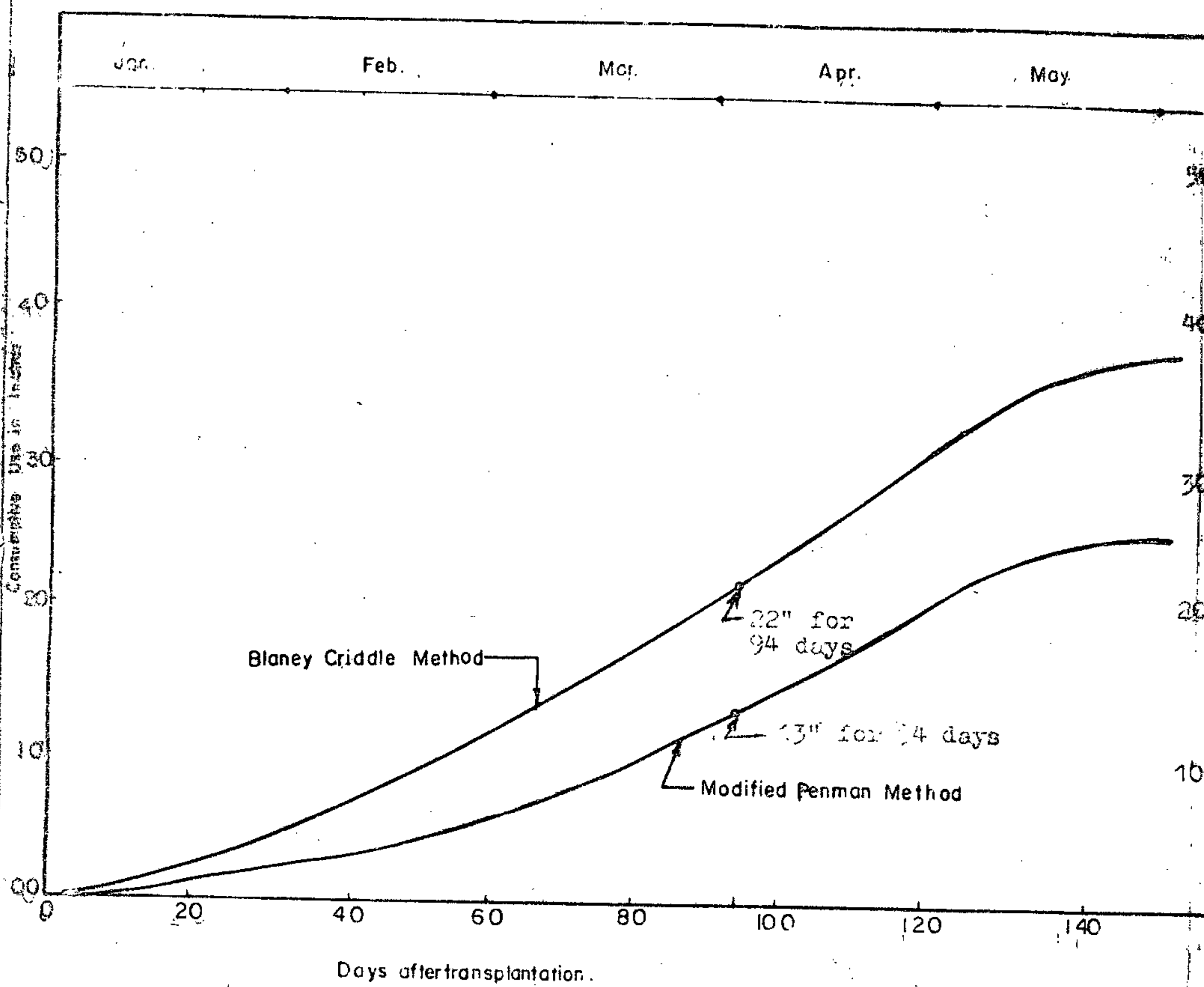


Fig.17 Consumptive use of water by Boro-rice (IR8)

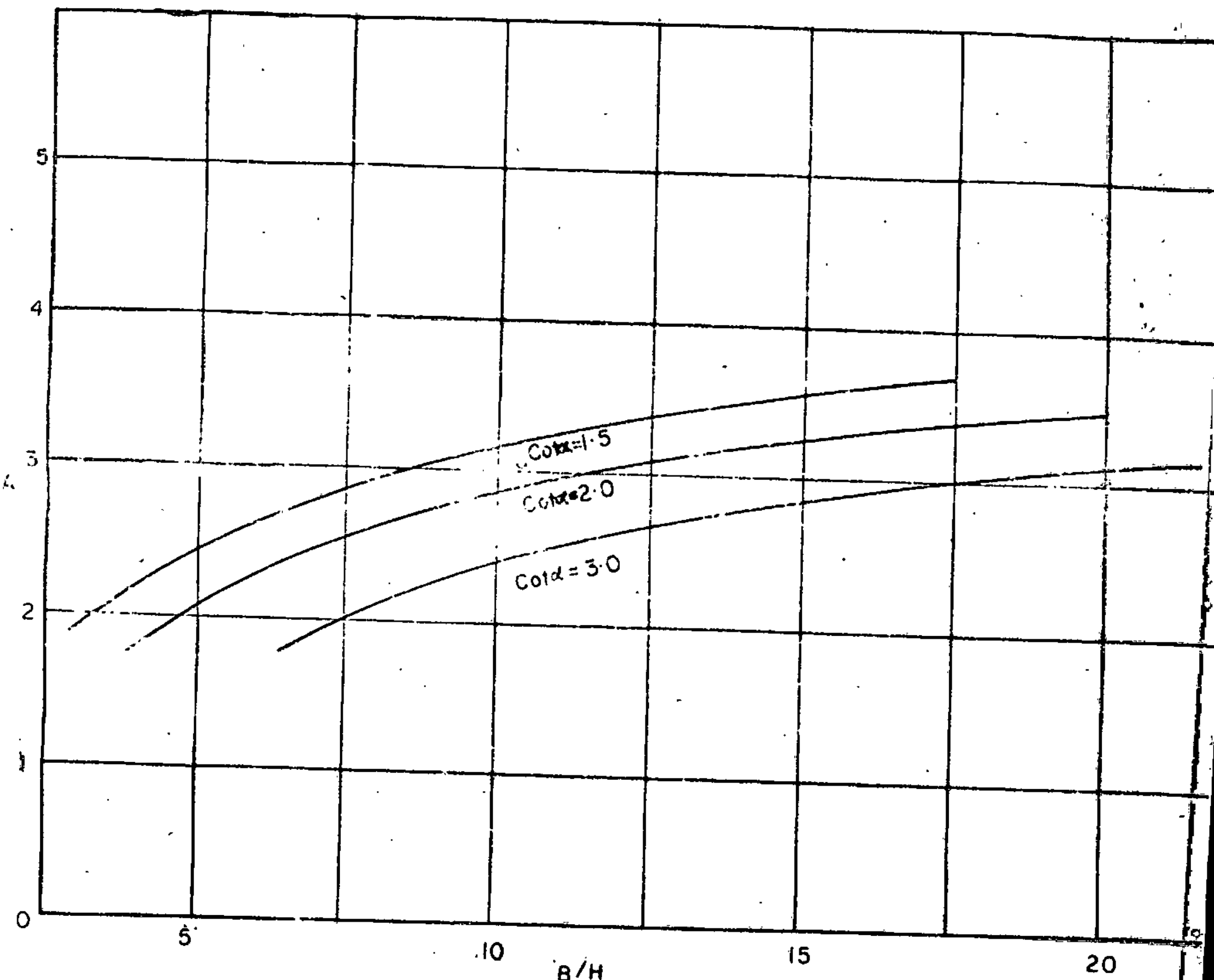


Fig. 18 Relationship between B/H and A for a trapezoidal canal (Fig 8)

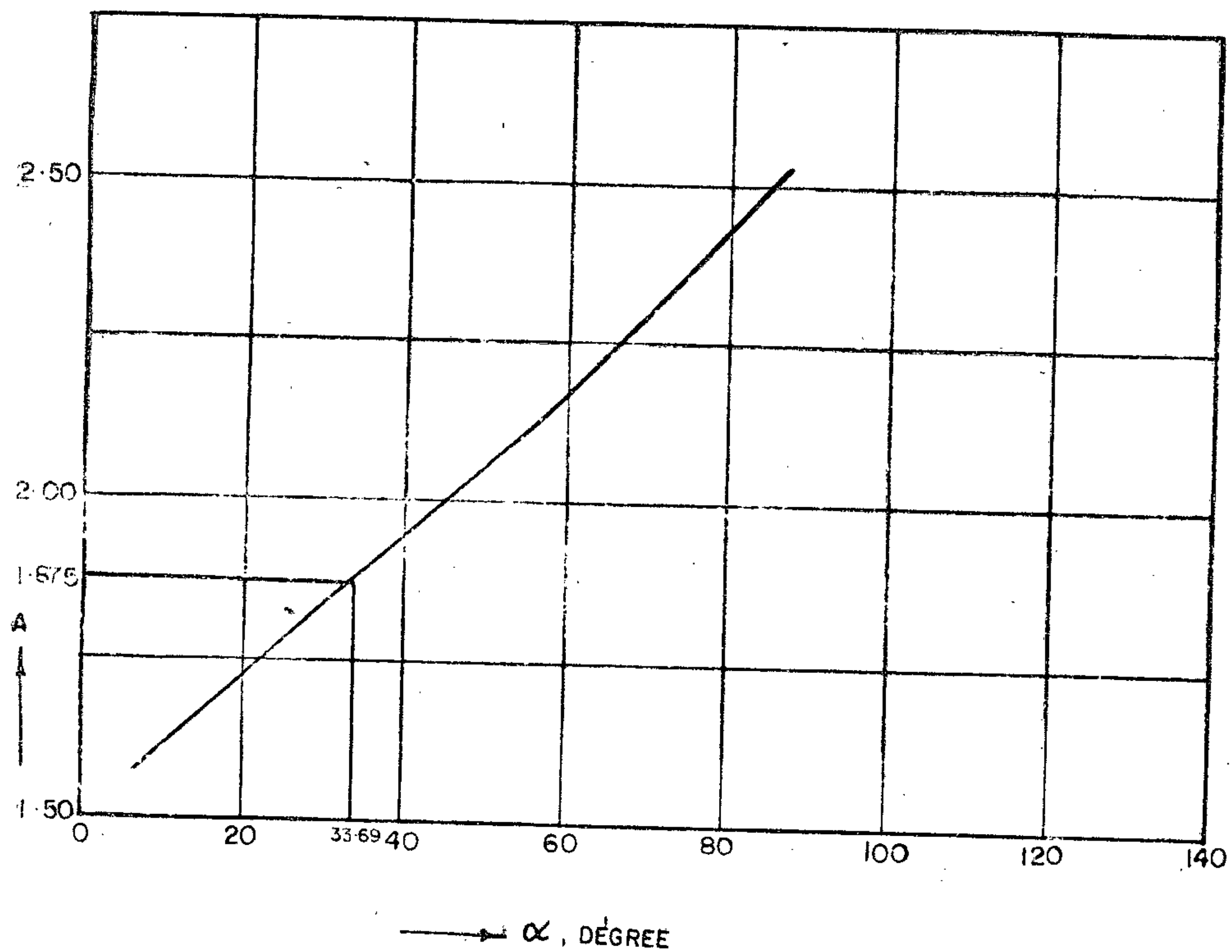


Fig. 19 - Relationship between A & α of Fig. 9

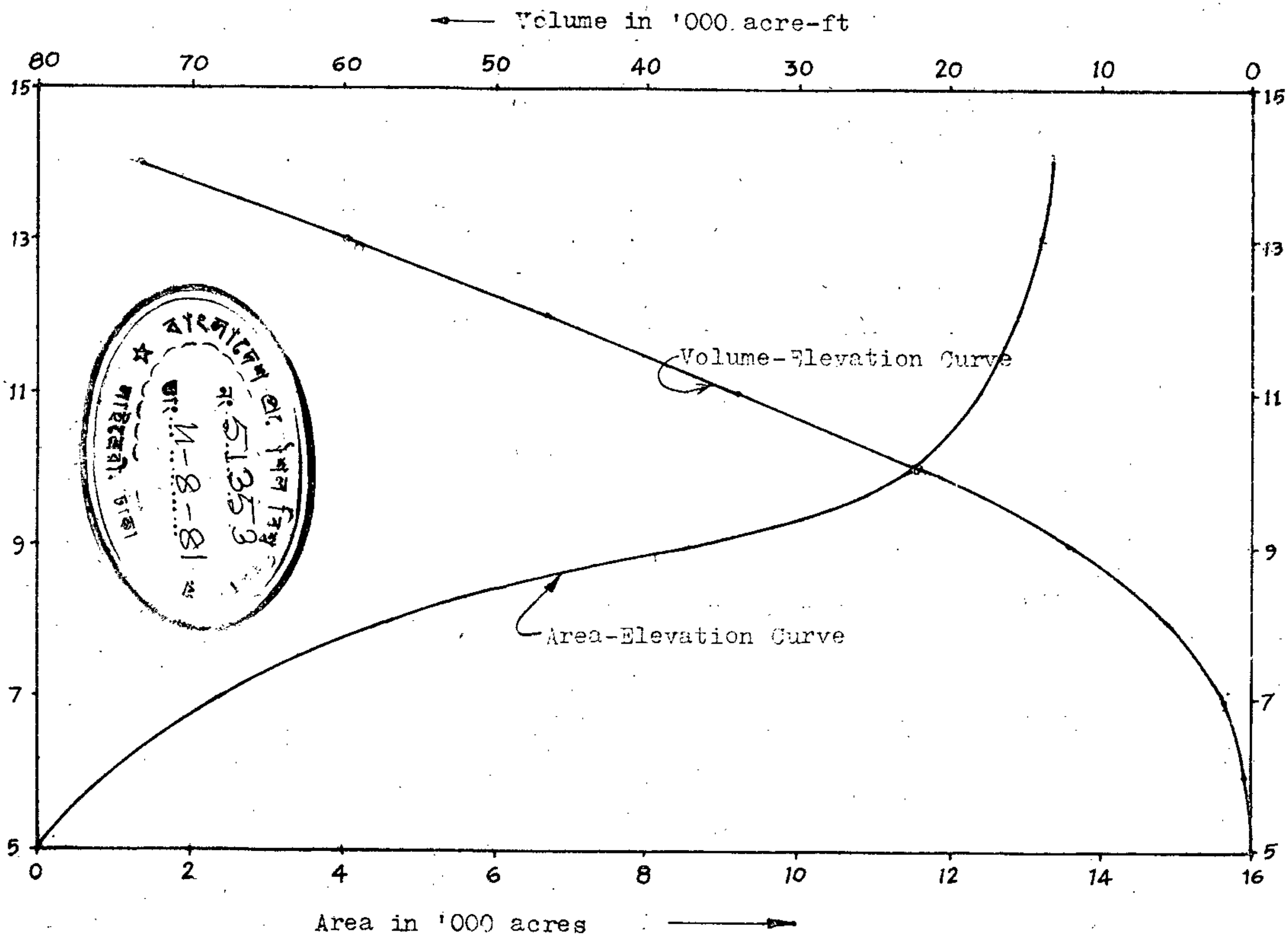


Fig. 20 Area elevation and volume elevation curves of the project Area - I