IRRIGATION SCHEDULING OF VARIED FLOW IN IRRIGATION CANAL SYSTEMS: A CASE STUDY OF RUAHA MBUYUNI IRRIGATION SCHEME, IRINGA, TANZANIA

BY

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL ENGINEERING OF SOKOINE UNIVERSITY OF AGRICULTURE, MOROGORO, TANZANIA.

2000

ABSTRACT

A study in irrigation scheduling of varied flow canal systems is considered in this research. A mathematical model was modified to suit irrigation scheduling of varied flow in irrigation canal systems. Four out of seventeen field canals and twelve fields plots were selected randomly on the basis of location representation. Different sets of data were collected at Ruaha Mbuyuni traditional irrigation scheme was taken as a case study.

A modified model for prediction of water volumes in the scheme during irrigation event was developed. Irrigation intervals and water volumes computed using the model were termed as simulated irrigation intervals and simulated water volumes respectively. Comparison between the simulated, designed and observed parameters was performed, using t-student distribution test. The test showed that, canal one, three and four the difference is not significant at 1% significant level. In canal two, the difference is significant at 5% significant level. It may be because the agricultural management practiced in the irrigation area is not similar for the whole farm. Thus the model can be adopted to predict the irrigation intervals. Similarly, simulated and observed irrigation intervals for selected canals were compared using t-student distribution test. The test revealed that, in canal one and three the difference is not significant at 5% significant level. In canal two and four the test showed that there is a significant difference at 5% significant level. However, comparison between the measured and the simulated water volumes using the same t-test distribution was

performed. The test showed that, in canal one and three the difference is not significant at 5% significance level. In canal four the difference is no significant at 1% significant level.

It was concluded that, the irrigation intervals (scheduling) and water volumes in the fields are fairly well predicted by the model, provided the agricultural management is maintained similar for the whole farm under irrigation.

A computer program was developed to reduce the tedious calculations involved in the process of computing/determining the irrigation intervals by simply entering the raw data or some processed data and hence serves some time. It also helps to eliminate some simple errors that could be encountered in the calculation process.

Further study is necessary in different traditional irrigation schemes so as to validate the model as a useful tool for predicting irrigation interval for the varied flow canal systems. The model used in this study was tested in a traditional lowland paddy only, and performed sufficiently for varied flow canal system in one scheme, therefore, research work is needed to test it in other traditional irrigation schemes, so as to make it more widely applicable.

DECLARATION

I, **NESPHORY KISYERI SUBIRA,** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and it has never been submitted for a degree award in any other University.

Signature:...Subira...........................

Date:..........13/11/2000...................

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ACKNOWLEDGEMENTS

First and foremost I wish to express my sincere gratitude to Dr. Tarimo, A.K.P.R., my supervisor, who was singularly most instrumental in encouraging me to undertake this work, and for generously providing the facilities and logistics that enabled this work to be completed. I appreciate his criticism at the various stages of the preparation of this dissertation.

Grateful acknowledgement is also due to the National Agriculture Extension Program II (NAEP II) though Ministry of Agriculture and Cooperatives for financial support rendered to this study

I thank the farmers at Ruaha Mbuyuni traditional irrigation scheme for their cooperation and TIP workers who provided useful information during the data collection period. I will be ungrateful if I don't mention Mr. Mapepele and his family who provided me an accommodation during the whole duration of my stay at Ruaha-Mbuyuni.

I will be ungrateful if I don't mention my fellow classmates, Sipho Shiba, Nnko, Lauwo, Hamad, Kongola, Dereck and the late Mr. Siatembo. I too appreciate the help from all staff at the Department of Agricultural Engineering and Land Planning.

Finally but not least, the deepest thanks and heartfelt appreciation go to my wife Neema Semwaiko and my sons Robert and Richard for their encouragement in undertaking this course.

DEDICATION

This dissertation is dedicated to my father, the late mum and my family

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis Of Variance
ASAL	Arid and Semi-arid Lands
df	Degrees of freedom
ET	Evapotranspiration
ETc	Crop Evapotranspiration
ETo	Reference evapotranspiration
FAO	Food and Agriculture Organization of United Nations
IRRI	International Rice Research Institute
IWRn	Net Irrigation Water Requirement
Kc	Crop coefficient
LMS	Least Mean Square
NAEP II	National Agricultural Extension Project Phase II
NS	Non Significance
Pe	Effective Rainfall
Ra	Rainfall
S	Significance
S&P	Seepage and Percolation
SDV	Standard Deviation
SNV	The Netherlands Financing Organization
TIP	Traditional Irrigation Improvement Programme
WUA	Water User's Association

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CHAPTER ONE

1.0 INTRODUCTION

1.1Background of the study

In arid and semi-arid lands (ASAL), where rainfall is unreliable, irrigation is the best alternative for crop production. Though the availability of water for irrigation and the availability of capital for agricultural investment are decreasing simultaneously, still there is a growing need to increase food production. Hence, designs of irrigation systems that are economic and simple to manage are exceedingly important (USAID, 1973). Thus, there is a need to improve and modernise the existing conventional and traditional irrigation methods for efficient water management.

Farmers without scientific knowledge, practised irrigated agriculture using locally available technology and resources. Such agricultural practices have been evolving over a number of years before they were finally adapted to local conditions. A new technique must promise quite a substantial increase in yield, or reduction in cost, to be acceptable to most farmers (Mosher, 1966). The farmer knows what his past practices have yielded, but is not sure of the new ones. They know how to apply established methods, but may not be confident of his ability to handle the new ones. The best that researchers can do to overcome the wise conservatism of farmers in the light of these risks and uncertainties, is to develop combinations of traditional and modern scientific practices that work reasonably well (Mosher, 1966).

1.2 Irrigation scheduling

Irrigation scheduling is the process of determining when to irrigate, where to irrigate and how much water to apply per irrigation in a given geographical area, to a given crop during the growing season (James, 1988). Its objectives are efficient use of water, energy and other production inputs, such as fertiliser. It allows irrigation to be co-ordinated with other farming activities including cultivation and farming inputs, also to optimise some measure of performance of the crop production under a set of specified conditions, such as limited or unlimited amount of water for the growing season (Alonso and Bras, 1981). Among the benefits of proper irrigation scheduling are improved crop yield, energy conservation and lower production costs.

Scheduling may be affected by improper design of an irrigation system. Although the flow in irrigation canals vary, i.e. flow is non-uniform, designers tend to use uniform flow analysis in designing irrigation schemes (Misra, 1996). Using the uniform flow criteria, designers tend to ignore or overlook effects of seepage and actual canal conditions. During the system operation, the design parameters are used to estimate irrigation interval. This may result in under-irrigation or over-irrigation. In fact, this has led to the deterioration of some irrigation schemes through waterlogging, silting and salinisation (Tod *et. al.*, 1990). These adversities stem from inefficient management, as a result, crop development may be impaired, and overall system's efficiency decreased. There are several factors that influence irrigation water distribution, these include, climate, soil, crop, irrigation water, irrigation technology and the water users. These factors can interact in space and time in a rather complex way (Alonso and Bras, 1981).

Proper scheduling of irrigation water and evaluations of canal irrigation systems are profoundly essential in assisting farmers to attain greater system's efficiency. These evaluations will invariably lead to better design criteria for local soils, crops and climatic conditions.

Ruaha Mbuyuni irrigation scheme is one of the traditional schemes that use surface irrigation method for upland and lowland crops mainly onions, maize and paddy. Traditional irrigation scheme refers to an improved indigenous irrigation initiated locally by farmers. It consists of the application of water on soil surface without taking into account of soil water content in the root zone, total actual evapotranspiration that is moisture depletion in the root zone, thus no planned irrigation water scheduling (Hillel, 1979). Ruaha Mbuyuni is within a semi arid area, whereas water is scarce and regarded as the most important single factor in crop production. The area experiences an annual rainfall ranging from 430-500mm. The amount of rainfall leads to agricultural activities entirely depend on irrigation throughout the year (TIP, 1991). Hence, there is a need of utilising the available water to attain optimum yield production.

A number of models for scheduling irrigation under limited water supplies have been developed in recent years (Rao *et al.*, 1992). However, there have also been some limited attempts to develop mathematical models for scheduling irrigation based on the varied flow and actual field conditions in canals. Such analysis may be useful for instance in irrigation scheduling which often requires an evaluation of the discharge in the canal and from turnouts/or laterals. Hence, there is a need to test the modified model by investigating the scheduling of varied flow as applied in irrigation schemes.

The present study is aimed at assessing the scheduling of irrigation water at Ruaha-Mbuyuni irrigation scheme, using a modified mathematical model that will be useful to farmers in scheduling irrigation water more efficiently under varied flow condition. Apart from that, the study is intended to help in planning and design of future irrigation canal systems.

1.3 Objectives

The main objective of the study is to determine irrigation scheduling of a varied flow canal system.

To achieve the objective, the following specific objectives are considered

(i) to adopt and modify an equation for varied flow condition

(ii) to asses the water delivery system

(iii) to validate the model using data obtained from the field condition

(iv) to develop a computer program for the model

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This section reviews some of the work done in modelling irrigation water scheduling of varied flow canal systems. It also covers views towards varied flow in canal systems and how design conditions affect on farm water distribution.

2.2 Design condition

In the initial stages of project formulation, the primary emphasis in irrigation is on planning, design and construction of new systems and not how the management of the system will be. Decisions are made on water allocation and distribution. The method for allocating water is pre-determined either on demand, arranged or rotation basis (Zimbelman, 1987; Malhotra *et al* 1984).

Misra, (1996), noted that, canal design stress much on uniform flow standards (IS 4745, 1968; IS 7112, 1973). Basing on these standards, effects of canal seepage, initial infiltration into dry banks, dead storage, and short-term bank breaches are not considered. Rao *et al* (1992), concluded that, irrigation design are planned for the entire season using historical and climatic data. These data are always subject to change, hence unreliability of the prediction conditions.

The distributary canals are designed on the assumption that farmers should irrigate during the 24 hours daily. Due to the change in farmer's behaviour and the majority of them decline to irrigate during night, consequently most of the night discharges are wasted. In the day hours, the delivered discharges are not sufficient due to the rush of farmers to irrigate. The night losses through canals's tail and farm ditches during night are estimated to be about 30% of the total discharge mainly in winter season.

2.3 Field condition

On farm use is a complex function of physical, social and economic factors, therefore the accurate prediction of farm irrigation requirements for design purposed is extremely difficult. In reality on-farm water use is highly variable. Tod *et al* (1990) noted that there is a considerable variability even where the same crop is being grown in the same locality, because all of the parameters influencing the irrigation system may not be known in advance.

Trout and Bowers, (1981) evaluated the conveyance systems and reported that seven to fifteen percent loss of the inflow is due to transient phenomena, such as wetting dry channels, dead storage, and short term breaches. Misra, (1996) reported that with the passage of time and due to inadequate maintenance, the condition of the canals deteriorate. The canals become irregular in shape due to non-uniform silting, erosion and weed growth, changing the roughness and seepage characteristics.

Bhutta and Van der Velde, (1992) observed that, the original operation assumptions of water surface level at or near to design full supply level are no longer valid. The flow velocities in the researched distributaries varied from 20% to 75% of the original design velocities between head and tail reaches. There is a need to review the designed conditions during the operation, because as it has been observed, the actual characteristics of canals are different from designed values. Tod *et al,* (1990) concluded that, with surface irrigation, it is only after irrigation has started that the appropriate water to apply can be determined accurately.

2.4 Problems of irrigation interval under varied flow

In the system whereby irrigation schemes depend on the available stream flow, which varies from year to year or season to season is termed as run-of-the river type irrigation system. The management of these schemes is very difficult because of their varying nature of the flow condition. If the available flow in a season exceeds the demand, the excess water is passed through the intake, while causing excessive irrigation and these may result into deep percolation or/and soil erosion. On the other hand, if the available water supply is less than the demand, optimum use of the water is necessary. Rotational irrigation method may be applied (Momtazuddin, 1988).

The study was conducted in the Manu river project in the northeast region of Bangladesh. The project utilises the run-of-the river type system. The available flow of the river during the dry season is inadequate to cover the entire irrigable area of the project. Therefore, optimum use of the available supply is essential. Mirjaham and Momtazuddin, (1992), studied four workable alternative management strategies during the study. The alternatives were; i) reducing the service area and applying the water at yield maximising level, ii) staggering of planting date, iii) crop diversification and iv) deficit irrigation water delivery according to crop sensitivity to water stress. It was concluded that crop diversification was the best among the four alternatives considered for each level of deficit supply. The alternative of deficit irrigation and water delivery according to the crop's sensitivity to water stress found to be the second best. Staggering of planting date according to optimum land preparation rate was found to increase rice area by about 10% to 15%, but this was not found to be better than the other three. Deficit irrigation water delivery according to crop sensitivity to water stress was found to give a larger area as well as greater return than those under full irrigation.

Clemmens, (1991) observed that, the irrigation interval tend to vary with time during the growing season, due to different factors, such as: i) variations in intake opportunity time caused by differences in advance and recession curves, ii) variations in soil infiltration properties, iii) variations in the surface retention of water, and iv) variations in volumes of water applied to different areas of a field, example different application times for different irrigation sets.

2.5 Effect of varied flow on crops

Several studies have been conducted on the effect of varied flow on crops. Letey, 1985; Hunsaker and Bucks, 1986; and Solomon, 1985 observed that the non-uniformity of irrigation water application has an effect on crop yields. Scheierling, *et al*, (1997) studied the effect of varied flow on maize grain and edible dry beans (Phaseolus vulgaris) in relation to evapotranspiration and noted that the scheduling has a relatively adverse effect on crop production.

The study was conducted on the effect of varied flow on the yields of lowland rice in the Philippines. Wickam (1973) selected eleven sites within the irrigation system and collected data under the existing farm conditions to establish yield response to rice to the number days of moisture stress. Considerable variations on water use were observed between sites. Well irrigated sites generally had low water use efficiencies and few stress days, while poorly irrigated sites had very high efficiencies but large numbers of stress days. It was concluded that, the low yields observed were because of the systems' failure to irrigate all farms adequately.

2.6 Irrigation water requirement in paddy fields

Water requirements for crops have been determined by various methods at different research institutes and agricultural universities (Nkhoma, 1998). However, some of the aspects like depth, growing stage, depletion of available soil moisture, have produced results that are location specific. Because of their dependence on variations in local climate, moisture characteristics of the soil, and effective rooting depth, irrigation method used, rainfall pattern, variation in crop coefficient, extent of capillary contribution or deep percolation, initial soil moisture reserve carried forward from previous season.

2.7 Varied flow

Researches have been conducted on varied flow condition, however, most of them are on canals with control structures and gated pipes. Misra (1996), studied the effect of seepage, canal condition, backwater and drawdown on a varied flow discharge in canal systems, performance of turnouts and spatial variability of flow. It was observed that even for design roughness and seepage parameters, the actual depth and discharge in the canal is significantly different from the designed ones. The governing equations of varied flow used by Misra (1996) during the study in canal systems are as follows:

$$\frac{dQ}{dx} = q_s + Q_L \delta(x - x_L) \tag{2.1}$$

and,

$$\frac{dy}{dx} = \frac{S_o - \dfrac{n^2 Q^2}{A^2 R^{4/3}} - \dfrac{2\beta Q}{g A^2}\left[q_s + Q_L \delta(x - x_L)\right]}{1 - \beta \dfrac{Q^2 T}{g A^3}} \tag{2.2}$$

Where;

x	=	the distance along the canal (m)
Q_L	=	the discharge into the lateral/turnout per unit length
Q	=	the discharge (m^3/s)
y	=	depth of flow (m)
g	=	acceleration due to gravity (m/s^2)
T	=	canal top width (m)
A	=	canal area cross- section (m^2)
So	=	canal bed slope (%)
β	=	momentum correction coefficient, which is taken as 1;
x_L	=	location of the turnout (m)
n	=	Manning's roughness

R = hydraulic radius (m)

qs = canal seepage loss ($m^3/s/m$)

2.8 Crop water requirement

The reference crop evapotranspiration (ET_o) is a measure of the effect of climatic condition on crop water use (Raes, 1996). The climatic data necessary for estimating the ET_o are temperature, wind speed, relative humidity, rainfall, and radiation, (Raes, 1996).

The crop water requirement (ET_c) is normally derived from the reference crop evapotranspiration (ET_o) calculated from climatic data and crop coefficient (Kc) values for the different crop growth stages. The ETc was estimated as suggested by Doorenbos and Pruitt (1977);

$$ET_C = ET_O \times K_C \qquad (2.3)$$

Where,

ET_c = crop water requirement (mm/day)

ET_o = reference crop evapotranspiration (mm/day)

K_c = crop coefficient

2.8.1 Net irrigation requirement

The soil acts as a bank or reservoir to store water for crop use. Rain and irrigation are deposits to the bank, and water used by the crop and soil evaporation is withdrawals. Like a checking account, a weekly or semi-weekly balance of these deposits and withdrawals will give the amount of water remaining in the soil profile. The bank has limitations, however and crop water stress can occur if the balance goes below a minimum allowable balance, which will be referred to as minimum balance. Each soil type also has a maximum deposit or water storage limit, which is called field capacity. Field capacity is defined as that soil water content, which is held by the soil matrix against the gravitational forces (Raes, 1996a). If the soil is filled beyond field capacity, the gravitational forces exceed the matrix forces enables excess water to be drained below the root zone by gravity. Available water capacity is the volume of water stored between the field capacity and the permanent wilting point.

Net irrigation requirement (IWR_n) is estimated using the general expression (Raes, 1996):

$$IWR_n = ET_C - P_e \qquad (2.4)$$

For upland crops;

and,

$$IWR_n = ET_C - P_e + (S\&P) \qquad (2.5)$$

For lowland paddy rice

Where,

IWR_n	=	net irrigation requirement (mm/day)
ET_c	=	crop water requirement (mm/day)
P_e	=	effective rainfall (mm/day)
S&P	=	seepage and percolation (mm/day)

2.9 Seepage

Sharma and Sharma, (1990) noted that there are several methods of measuring seepage and operational losses from canal systems. Normally, estimates are made with an "inflow-outflow" approach by using the records of diversion and delivery for the system. This approach gives an estimate of the total seasonal operational losses, which include canal seepage, canal spill, generous deliveries, and gains or losses from inaccurate measurements. Worstell, (1976) studied the seepage losses from canal system of different soils found in southern Idaho using different methods (Table 2.1). It was noted that published losses based on a percentage of total flow seldom include data on the size of the canals, soil types, or length of irrigation season. With demands on water supplies increasing, it is important that losses of various districts be compared and the magnitude of each aspect of operational losses in parts of the systems be identified to aid in deciding priorities for making improvements.

Table 2.1: Loss rates from canals in Southern Idaho

Type of soil	Loss rate, in metres per day
Medium clay loam	0.15 - 0.46
Impervious clay	0.15
Medium soils	0.3
Somewhat previous soils	0.46 – 0.61
Gravel (depending on porosity)	0.76 – 1.52

Source: Worstell, 1976

2.9.1 Canal seepage

Canal seepage is calculated as follows; (Sharma and Sharma, 1990).

$$S = C \times \frac{dQ}{A} = C \times \frac{(Q_1 - Q_2)}{A} \quad (2.6)$$

Where;

S = seepage (mm/hr)

Q_1; Q_2 = Inflow and outflow

A = canal area in contact with water (m^2)

C = unit constant (=1000 if Q_1 &Q_2 are in m^3/hr or 5/8 if Q_1&Q_2 are in l/s)

2.9.2 Paddy field seepage and percolation measurement

Seepage and percolation rate can be measured using simple techniques available for measuring seepage and percolation, the seepage and percolation gauge can be employed for most field applications. Lysimeter or tank method can be used in determining seepage and percolation rates but the results do not reflect the actual field conditions. Since the tank or lysimeter technique entails removing the soils from the fields and subsequent placing of the disturbed soil samples in drums, it creates unnatural boundary conditions that enhance seepage and percolation rates. Undisturbed soil sample can be used but Michael (1993) noted that, this method does not give accurate results. To overcome these problems, the water management in the International Rice Research Institute (IRRI) developed and field-tested a simple sloping gauge for measuring seepage and percolation of a representative paddy on whole farm. It indicates the amount of change in paddy water level between two time periods (Moya, 1990).

2.10 Infiltration and soil water movement during irrigation

Water primarily moves downwards at a rate determined by the presence and distribution of macropores in the soil as well as by the thickness, air exchange capacity, and hydraulic conductivity of the top two layers of soil. The downward movement of excess water in the soil profile to the underlying layers is referred to as percolation (Smedema and Rycroft, 1983). The rate of percolation of the water can be measured somewhat indirectly by the change in depth of surface water at times when there is no rainfall or flow of surface water into or out of the system (Juo and Lowe, 1986). Alternatively, percolation losses can be estimated by measuring the dimensions of the conveyance system and its infiltration capacity and checking the results against existing data which relate conveyance system, soil type and percolation losses (Bredero, 1991). By the time infiltration rate has become constant, the final infiltration rate becomes approximately equal to the K_{sat} of the soil as shown in Figure 2.1. The steady state percolation reaches its maximum attainable value when soil profile has become saturated and the percolation rate equals K_{sat} (Smedema and Rycroft, 1983).

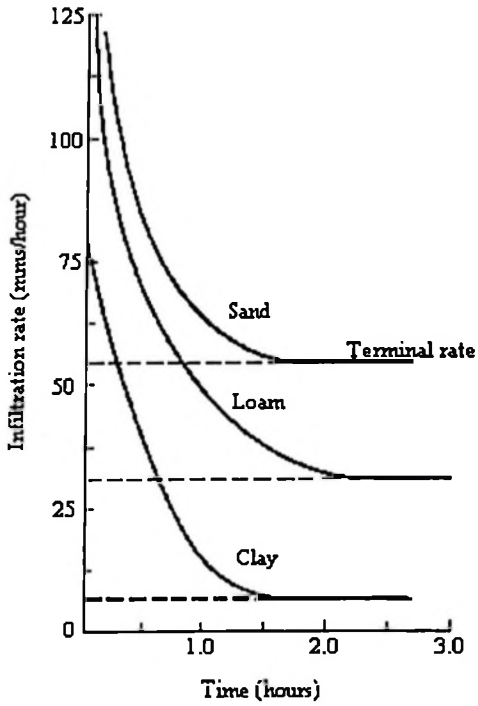


Figure 2.1 Typical infiltration rates for various soils (Source: Withers and Vipond 1974)

2.11 Water management

Irrigation water management can be defined as, the integrated process of diversion, conveyance, regulation, measurement, distribution and application of the right amount of water at the right time, right place and the removal of excess water from the farms to promote increased crop production in conjunction with improved cultural practices.

The objectives of water management are as follows, (Schwab *et al.,* 1996);

–To maximise water utilisation through:

- Supply of the right amount of water to meet crop requirement
- More effective rainfall utilisation
- Control or reduction of conveyance, distribution and application losses
- Adoption of suitable scheme of water distribution and application of irrigation water
- Taping of return flow or re-use of water
- Reduce drainage problem
- Timely delivery of water to farms
- Active participation of farmers community

–To promote increased crop production through

- Proper land use
- Improved cultural practices
- Better farm management techniques

Irrigation water management has been weak in many of the traditional irrigation schemes in Africa (Speelman, 1990). For proper monitoring, the amount of water applied into the field should be measured and recorded. Such practices help in judging whether the amount of water deliveries match with the predicted quantities or distributed equitably, adequately, and timely among different farmers in irrigation canal systems.

2.11.1 Drainage a water management aspect

In any irrigated agriculture, drainage is very crucial aspect in water management. It helps in removing excess water. Also, helps in solving problems of water logging, soil erosion, and salinisation in irrigated area. It was noted that, there could be no suitable irrigated agriculture without proper attention to drainage (Kips and Ndondi, 1990). The significance of drainage, until very recently was not recognised as necessary practice in many traditional irrigation schemes (Baban, 1994). Still in many traditional irrigation schemes, farmers have been relying on natural drainage and land slopes to drain excess water caused by rainstorm and over-irrigation.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introduction

This chapter describes materials and methods used in this study. It gives the general background of the study area and instruments used to measure and obtain various parameters required to fulfill the study objectives.

3.2 The model

The models shown in equations 2.1 and 2.2 were modified and used in this study. The modifications are shown in appendix B. The purpose of the model modified is to estimate the irrigation interval of varied flow canal systems, at Ruaha Mbuyuni traditional irrigation scheme. A computer program in Turbo Pascal version 7.1 was developed to ease the tedious calculation required for the model. The designed and the observed irrigation interval were also compared with the intervals computed by the model.

3.3. Description of the study area

3.3.1 Location

The study was conducted in the southern highlands of Tanzania in Iringa region at Ruaha Mbuyuni traditional irrigation scheme. The scheme is located 200km from Morogoro town along Dar-es-salaam – Zambia highway. The area is located approximately at latitude

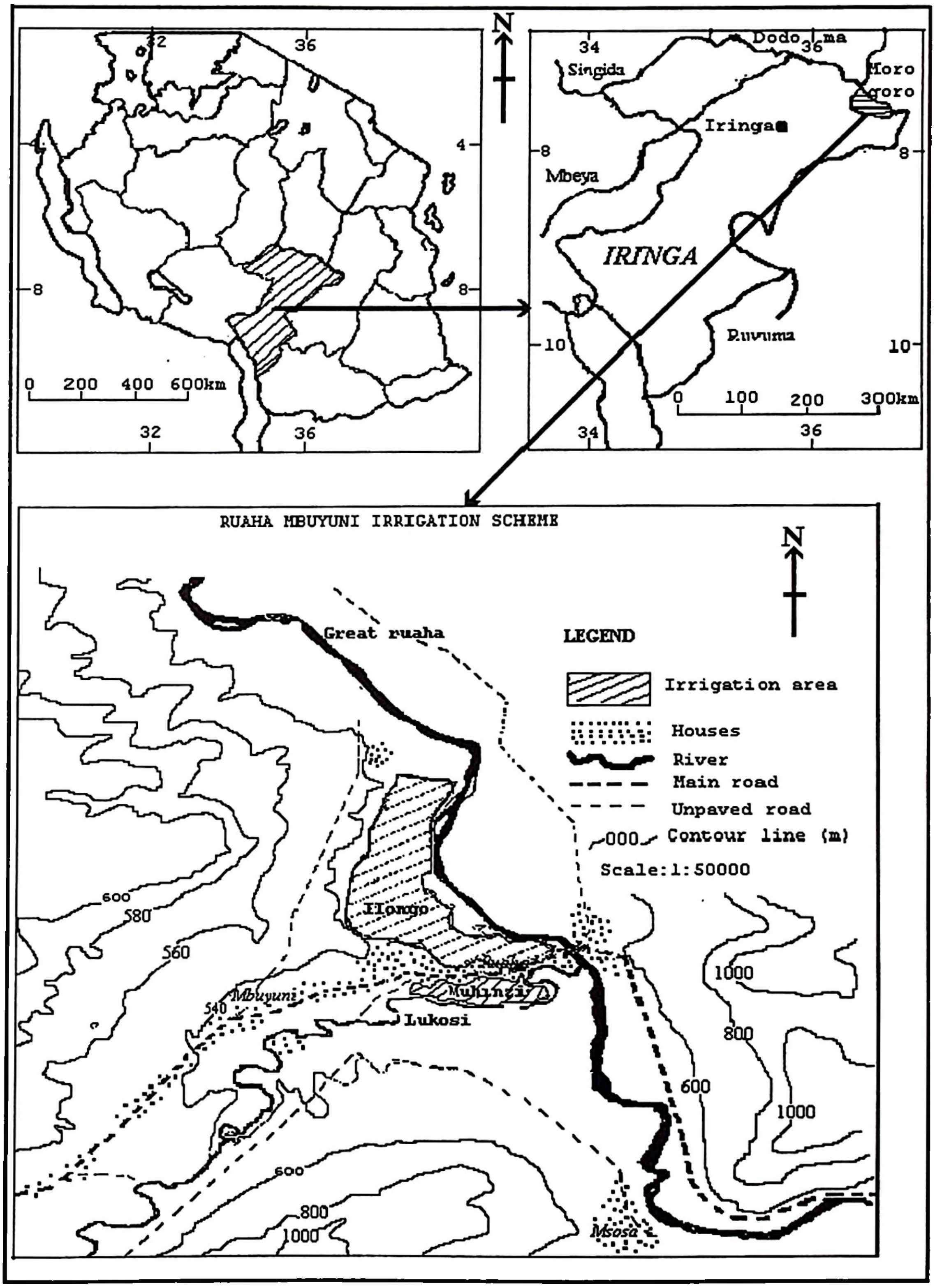


Figure 3.1 Location of Ruaha Mbuyuni

7.29degrees South and longitude 33.36degrees east, on the leeward side of Udzungwa mountains. The altitude ranges from 520m to 1000m above the sea level. The area is a relatively narrow strip along the great Ruaha riverbanks as shown in figure 3.1

3.3.2 Topography

The area consists of gently sloping lands developed along the rightbank of Great Ruaha River. A detailed topographical survey of the scheme at a scale of 1:50000 is shown in figure 3.1

3.3.3 Climate

The climate at Ruaha Mbuyuni scheme is semi arid. The annual rainfall ranges from 430mm to 500mm (Hydrological section in Iringa region, 1999). Air temperature ranges from 26°C to 30°C. The area experiences maximum temperature in May to December and minimum temperature in January and April. The mean daily maximum temperature is 31.2°C while, the mean daily minimum temperature is 18.1°C.Annual evaporation rates vary from 1450mm/day to 1500mm/day. Relative humidity is lowest during the day. It ranges from 22.5% in the dry season to 87.9 % in the rainy season.

3.3.4 Hydrology

The major source of irrigation water for Ruaha Mbuyuni scheme is the Lukosi river, which is a tributary of Great Ruaha river. The river has a large catchment area and therefore, the discharge is considerable. Maximum discharge of the river is 180m^3/s.

The water level of the river is fluctuating strongly and is directly related to the water level of the intake canal (TIP, 1992). The estimated difference in the lowest and highest water levels is 1.5metre. During big floods, the lowland areas are inundated and in rare cases, even the intake site is flooded. Due to high current of water during rain seasons, riverbanks in front of the intake are eroded.

3.3.5 Geology and Soils

The soil contains mostly gambisols, on account of which they show severe swelling and shrinkage with changing moisture conditions, causing heavy fissuring and deep cracking on drying. Some parts, the soil is alluvial because it has been deposited in the low laying basins of the Great Ruaha river and its tributary Lukosi river. The soils show a variation in texture within small areas but generally these soils range from coarse textured sand-loam to heavy cracking clay.

3.3.6 Land use

The climate of the Ruaha Mbuyuni favours most of the upland and lowland crops. However, the main crops grown are paddy, maize, beans and onions. Crops that are given priority are two; maize and paddy. The cropping season starts with maize and paddy in January. Available irrigation water has to supplement rain, after harvesting maize, and paddy in April onion is transplanted. In October, the canal is often dry, therefore, only about 10% of the area is cultivated between September, and October. The scheme covers a total area of about 600ha. Due to climatic condition and low soil fertility, the land use intensity is not very high (TIP, 1992). Although there is scarcity of land in the irrigated area, even in the rainy seasons a lot of land stays fallow. In the dry season, the scarcity of water restricts land use. There are some farmers who use small pumps to irrigate outside the scheme. Some of the farmers pump water from Lukosi river while others do the same from Great Ruaha river. Lowland paddy is cultivated in basins having permanent bunds. Upland crops, maize and onion are mainly cultivated in borders with temporary earthen bunds, whereby the land is divided into small plots of different sizes. To ease the hiring exercise, plots have been divided in a way that every plot has its hiring price.

3.3.7 Layout of paddy fields

The scheme area is divided into two main irrigable areas namely Mhinzi and Ilongo system as shown in Figure 3.2. The Mhinzi system has no water disputes compared to Ilongo and also its area is smaller than that of Ilongo. The study was mainly carried out at Ilongo system. The Ilongo field layout is as shown in Figure 3.2.

3.3.8 Farmers efforts in developing the Scheme

Several attempts were made by local people to divert irrigation water from Lukosi river into their farms, and they managed to dig the canal to Mhinzi area using hand hoes. To prevent the flow going back to the river they constructed a gabion weir made out of knotted grasses filled with stones. Due to water pressure, they were forced to rebuild frequently. Around 1969, under the assistance of the Government, Mafinga National Service Camp excavated Ilongo canal.

In 1978, a concrete weir was built at the same spot where the local weir had been. Just after completion, the weir felt into disuse because the elevation of the irrigable land was high as compared to the weir level. Apart from that, the river changed its course and bypassed the weir on the rightbank.

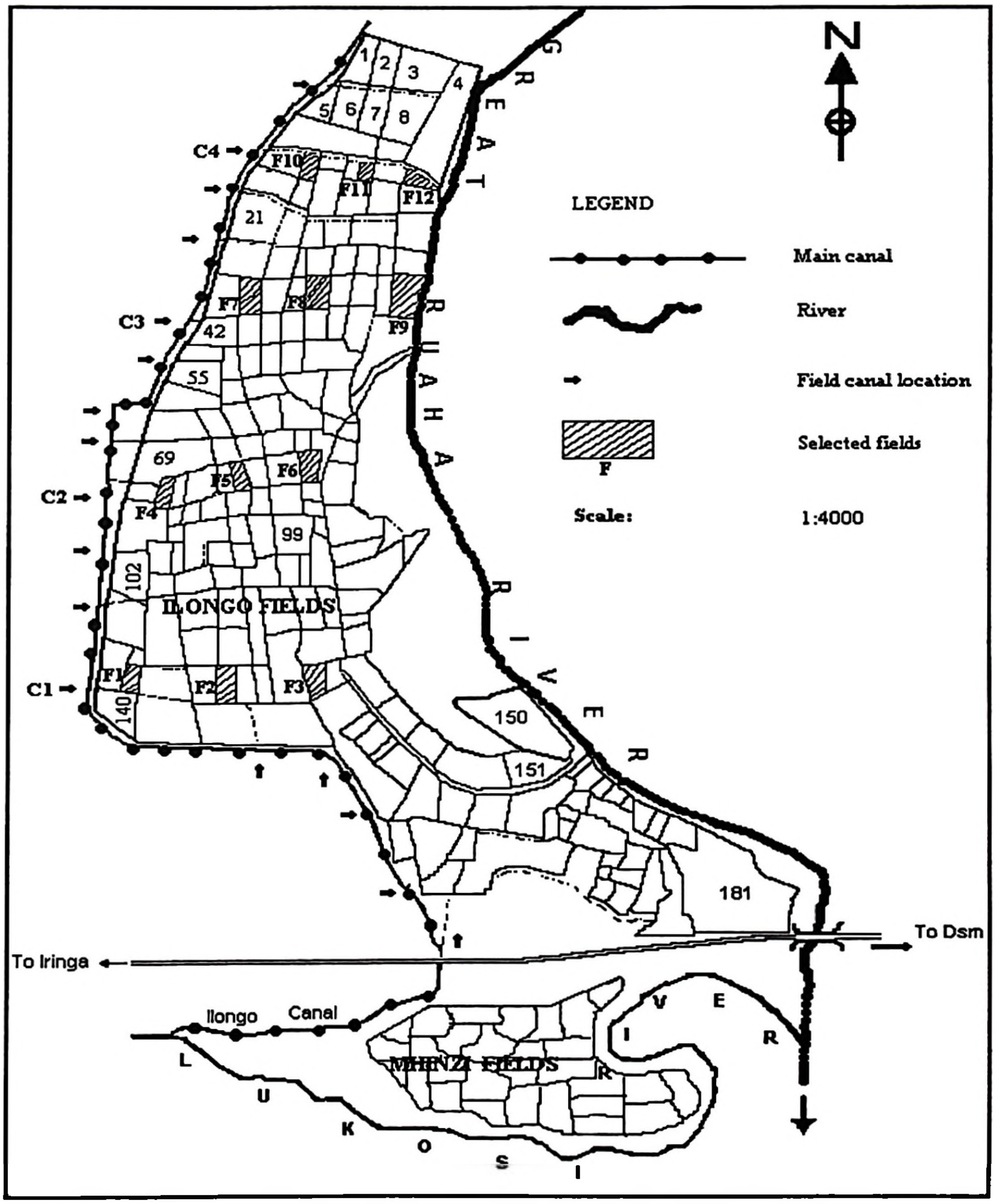


Figure 3.2 Farm layout for Ruaha Mbuyuni scheme

The weir was rehabilitated by rock filling and the walls were raised in height by 35centimeters. A new masonry diversion wall was built so as to direct the flow through a new intake gate and to a new section of the main canal. This work was completed in 1984. Despite the numerous rehabilitation works, the available quantity of irrigation water still was not satisfying. The people of Ruaha Mbuyuni in co-operation with the District authority constructed a second gabion weir, (see Figure 3.3). This weir raised the water level by about 1.0meter. The level of the weir is 1.5meter higher than the first weir, but a lot of water is passing through gaps in the weir. Water turbulence after the weir makes the gabion sink deeper in the sand riverbed, causing villagers to rehabilitate the weir every year by placing gabions or loose stones with the assistance of the Traditional Irrigation Improvement Project (TIP), financed by SNV- the Netherlands. TIP program started at Ruaha Mbuyuni in 1990 and was supposed to phase out in June 1999.

3.4 Methodology

The researcher undertook a field reconnaissance of the paddy plots and canals. It was realised that there are several canals and paddy plots at the head-reach, middle and tail end. In order to achieve the objectives of the study, the research was conducted using wide range of materials and methodologies. These included physical measurements, questionnaires (Appendix I), informal interviews and participant's observation. Different measurements were taken, such as, depth of flow, distance along the canal, canal top widths, canals cross-section area, and canal bed slopes, canal discharges, infiltration rate in the field and soil moisture content.

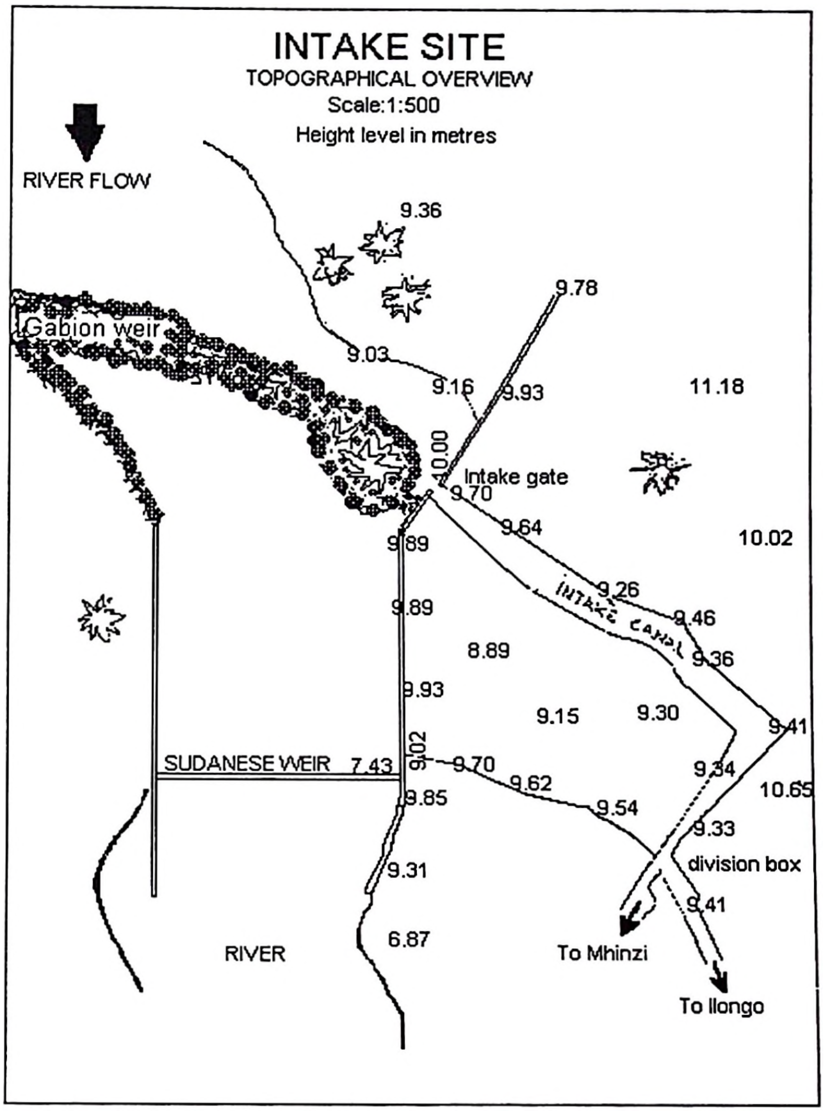


Figure 3.3 Intake topographical map

The amount of water diverted into the field, crop evapotranspiration, canal seepage, time used to irrigate and the area of the field, were used to compute the constants of proportionality, K_1, K_2 and K_3 for every sampled canal (Equation B-16. in Appendix B). Equation B.6 (Appendix B) was also used. Different (designed, modelled and observed) irrigation intervals were calculated for every sampled canal, since they had different hydraulic parameters. That's why the process was repeated in every canal. The results were used to compute equations B.14 and B.15. This resulted into the change in water depth in relation to distance as shown in equation B.14 and B.15 in Appendix B.

3.4.1 Field measurement and Sampling

Four out of seventeen canals supplied by the Ilongo main canal and twelve paddy plots were selected randomly on the basis of location representation. All canals and paddy plots were sampled from Ilongo block as shown in Figure 3.2 These canals were labelled C1, C2, C3, and C4 as shown in Figure 3.2, likewise, the paddy fields sampled are indicated in Figure 3.2. The conducted study was done on the basis of on-farm trial.

3.4.1.1 Climatic data collection

After consultation with the regional meteorological officer in-charge, the Mtera meteorological station was chosen as relevant to represent the weather conditions of the area. The station has a self-recording unit of which the technician downloads the data after every three months. A raingauge and a thermometer were installed at the station during the research period. The collected data were compared with the data from Mtera station and no variation was realised. The ETo was calculated using the IRSIS computer programme. ETc was computed from the modified Penman equation (2.3) as suggested by Doorenbos and Pruitt, (1977).

3.4.2 Water diverted from the intake weir

There are several approaches with which the current metre can be used to determine the velocity at verticals. However in this study, a wading propeller type current meter, and the 0.6 method was used for measurement of velocity of water at the verticals in the canal. Velocities were calculated using governing equations. Values obtained were taken as the mean velocity of water for the vertical, (Boyer, 1964). The graduated staff was then calibrated. Graduated staff was placed vertically at the right side bank in the canal. The amount of water diverted from the intake into Ilongo main canal was measured using the graduated staff. Different gauge heights with corresponding discharge values were used to calibrate the gauge station.

3.4.3 Water flowing in irrigation canals

The area suitable for measuring the discharge was selected. Control width was measured. Due to the size of the canals, the method used in measuring the velocity was the same as the method used in measuring the flow diverted into the intake. Graduated staff was placed at the right side bank in the canal. Likewise, in corresponding gauge heights canal discharges were recorded, a curve was established for calibration.

In assessing the amount of water in the selected secondary canals, Washington S.C flumes H 26-5, H 26-1 and H 26-4 were used. These flumes were chosen because of the availability and do provide a simple, convenient and reliable method of measuring the rate of irrigation water flowing in the field. It is simple to install, easy to operate and gives quick flow rate information, (Moya, 1990). The readings were taken and recorded accordingly.

3.4.4 Measurement of canal seepage

Canal seepage losses were determined using the inflow-outflow method (Sharma and Sharma, 1990). Two Washington flumes placed 30 metres apart were put in the canal during the irrigation event and gauge readings were recorded. Using the calibration chart, readings were converted into corresponding discharges, at the head the discharge was denoted as Q_1, and at the end of the reach as Q_2. Average canal seepage in litres per hour per unit length was calculated.

3.4.5 Seepage and Percolation in paddy fields

Paddy plot seepage and percolation rates were monitored using sloping gauge method. Two sloping gauges were located in the selected paddy plots. These two were considered as representatives of the whole Ilongo block. The daily changes in water depth was monitored and recorded then used to calculate seepage and percolation losses as suggested by Moya, (1990).

3.4.6 Water applied in the root zone

Paddy crop is normally grown under saturated condition, however, this was not the case at the study area. During the period of water scarcity, water in some plots dried completely on the surface before the next irrigation turn. Gypsum blocks were used to measure moisture before and after irrigation event. The Washington flume was located at the entrance of the plot to monitor the amount of water entering into the plot during the irrigation event. Three gypsum blocks were located in each of the selected plot, at right, middle and left of the basin, the average was taken as the moisture reading in each paddy plot. During the period of abundant water, the whole area was flooded, thus gypsum blocks were removed from the fields. Areas of the selected paddy plots were measured.

3.4.7 Canal bed slopes

Simple method of estimating slopes using "line level" was used to estimate canal bed slopes. For accurate measurement the line level is only capable of measuring slopes in 10metre length interval, therefore, the canals were divided into portions of ten metre's length and average of the slopes were taken as the overall canal bed slope for every selected canal.

3.4.8 Soil infiltration rate

Soil infiltration measurements were carried out using double ring infiltrometer method. The double ring infiltrometer has been found to be a rapid and simple technique (British Society of Soil Science, 1997). However, it suffers from several disadvantages, for instance the overestimation of sorptivity due to the flow through macropores (British Society of Soil Science, 1997), and divergence due to lateral gradients in capillary pressure. Both disadvantages can be minimised by reducing the water depth over the soil surface and increasing the ring diameter (British Society of Soil Science, 1997). This method of reducing the error was considered in the test. Generally, the infiltration test in the field was conducted according to the procedure outlined by Klute, A (1986). Infiltration tests were conducted once in every growing stage of the paddy crop. Depth readings were taken at periodic intervals and recorded, (Appendix E).

3.4.9 Drainage

Through physical observations and interview conducted to individual farmers and leaders showed that the organization has experienced a number of problems related to irrigation management. There are no proper controls of water within the scheme. Farmers were still using irrigation water without control. Different indicators of improper water management were observed in the field, one of the observed indicators were some big erosion gullies leading into great Ruaha river.

3.4.10 Computation procedure

EXCEL spreadsheet was used to solve equation B.6 in the appendix B. The calculated canal cross sectional areas, hydraulic radius and other parameters were substituted into the equation and the constant C was computed. The procedure was repeated for every canal. Thereafter, other parameters from the collected data were substituted in equation B.13 to obtain the modelled irrigation interval for representative canals. The results were tabulated.

3.4.11 The computer program

The computer program in Turbo Pascal version 7.1 is developed for the model, (Appendix G). The program calculates the irrigation interval of a varied canal system using the collected data from the scheme as input data. The computed intervals are then substituted in equation B.14 and B.16 for solving the equations. The output of the program becomes the change in depth (Δy) over the change in canal length (Δx). Likewise, the designed and practiced irrigation intervals were also substituted in the equation B.14 and B.16, the output were recorded.

3.5 Data analysis

The collected data were substituted in Equation B.13 in Appendix B. constants in Equations B.14 and B.15 were established. Then, design and simulated irrigation intervals were compared using a t-student distribution test. However, the simulated and observed irrigation intervals were also compared using t-student distribution test. Observed volumes were compared by simulated volumes using the same t-test student distribution.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This section presents and discusses the results obtained in the data analysis and in using the model equations. The irrigation intervals and volumes resulted from the models are compared with the observed and designed values.

4.1 Model adoption and modification

The adopted model that is equations 2.1 and 2.2 used by Misra, 1996 were modified to incorporate the irrigation interval, rainfall and volume of irrigation water added in the field during the irrigation event. The change in flow depth over the change in distance along the canal is inversely proportional to the irrigation interval, and also is proportional to the square volumes of water entering the field (Appendix B).

4.2 Field characteristics

4.2.1 Infiltration

The infiltration test results were tabulated and are shown in appendix F (Table F-1). The infiltration rate and cumulative infiltration were plotted against cumulative time, the graphs showed a relationship which made it possible to estimate the infiltration rate. Basically, for clay soils, infiltration rate is below 10mm/h (FAO, 1979). From the results obtained in the field, it is observed that, the infiltration rate of the soil ranges between 3-6mm/h., which concurs with results obtained by Withers and Vipond (1974) for various soils as shown in Figure 2.1.

4.2.2 Canal Slopes and Seepage

Equation 2.6 was used in the estimation of canal seepage. Seepage values for the selected canals are shown in Table 4.1. The values obtained were used to establish the modified model equation. The seepage rates measured in the field are as shown in Table 4.1. For the type of soil found in the scheme, the values are within the acceptable range as shown in Table 2.1.

Table 4.1: Canal Seepage

Canal name	Canal slope	Seepage
Canal 1	2.00%	0.125m/day
Canal 2	1.20%	0.345m/day
Canal 3	1.00%	0.324m/day
Canal 4	0.68%	0.107m/day

4.2.3 Field Seepage & Percolation

Field seepage and percolation rate was estimated using the methodology explained under Section 3.4.5. The results found were tabulated and are shown in Table 4.2 .The values in Table 4.2 were used to estimate the amount of water stored in the field, (Appendix M).

Table 4.2: Field Seepage and Percolation

Date	S & P (mm/day)
2.6.99	4
3.6.99	7
4.6.99	15
5.6.99	13
6.6.99	14
7.6.99	15
9.6.99	4
10.6.99	6
11.6.99	8
12.6.99	4
13.6.99	8
14.6.99	8

4.3 Water management

The scheme is divided into two blocks namely Ilongo and Mhinzi as shown in Figure 3.4. Each block operates independently from each other. The irrigation schedule for Ilongo block is rather complicated, but in Mhinzi there is no complication in water distribution. Because, it was noted that, at Mhinzi block the farmers are almost, all of the same family and the availability of water among them is better (Amo, 1999). Apart from those reasons, the irrigable land is small. Therefore, if somebody needs more water, he/she arranges with a relative. In Ilongo block, however, farmers are of different ethnic groups, and the irrigation water is not enough during the peak season. There are no control structures in the main canal leading into the blocks. Even in the field canals there are no distribution structures, farmers use grass and mud (earth distribution boxes) to divert water during their irrigation turn as shown in Plate 4.1. Plate 4.2 shows how farmers are using mud and grass to block the canal during an irrigation event. The materials used arc improper because they allow water to seep into unintended canals (as seen from Plate 4.2, towards the reader's direction). Hence, rehabilitation of the scheme is important.

Proper rehabilitation of traditional irrigation scheme provides the means to control water abstractions. It helps to improve the hydraulic performance of the irrigation and drainage canal system and leads to a decrease in water loss and increase in the commanding area. The objective of rehabilitation is to improve the traditional irrigation schemes in three ways, (Baban, 1994): (i) to secure reliable source of irrigation water by rehabilitating permanent intake weirs; (ii) to increase canal system's efficiencies; and (iii) to increase field irrigation efficiency though proper training of field extension staff and farmers.

Field observations in the north and west of India Sub continent have shown that discharge variation at the head greatly exceeds the original design criteria, (Bhutta *et al*, 1992). For example, head reaches commonly draw 3 to 6 times greater share of total supplies than do tail outlets, and that variation in water distribution is caused by several interactions between several conditions like the markedly changed canal physical condition resulting from low levels of maintenance inputs. For the case of Ruaha Mbuyuni scheme variations in water distribution may be contributed by the distribution structures used which are irregular and do change every day of irrigation event depending on who operates the earthen distribution box.

Plate 4.1 Earthen distribution box

Plate 4.2 Distribution of water using grass and mud (earthen distribution box).

4.3.1 Drainage

A study conducted by Kips and Ndondi (1990) on soils and land suitability for irrigated agriculture revealed that some of the drainage problems are due to soil type of the agricultural land. The drainage problems now affecting the scheme are said to have been caused specifically by the following factors: (i) lack of proper irrigation water control facilities; (ii) poor irrigation water management; (iii) type of soils ; (iv) topography of the land; and (v) lack of adequate drainage facilities.

The above factors have long been recognised however, the problem has not yet been solved mainly due to lack of funds for training farmers on proper water management aspects and the necessity of levelling/grading of their fields including provision of adequate drainage facilities. Farmers in the scheme have been relying on natural drainage and land slopes to drain excess water caused by rainstorm, (Amo, 1999).

Rainfall in this area is erratic and it does not often rain in quantities enough to recover the soil moisture to its field capacity. When the rate of rainfall exceeds the infiltration rate of the soil, water will fill in the surface depressions and move laterally as run-off, hence the scheme needs drainage facilities.

4.3.2 Irrigation scheduling

Ruaha Mbuyuni scheme has a registered Water User's Association Committee (WUA) that is responsible for the management of the irrigation system. The committee has selected water distributors, and every distributor has 3 to 4 secondary canals that supply water to their respective farmers. However, during the period of water scarcity, supply is highly inadequate to meet the irrigation requirement of the total cultivable area, thus, water is distributed on rotation basis including at night. Night irrigation is not favourable to old people and women farmers in particular.

Irrigation interval in the scheme is fixed primarily to provide protection against drought and not for maximising crop production per unit area (Amo, 1999). In periods of water scarcity, problems occur when farmers are not able to irrigate their land within the limited allocated time. In order to avoid water disputes, farmers tend to discuss their problems among themselves with the help of water distributors. Sometimes, after a compromise, water can be borrowed from a neighbouring farmer or wait for another irrigation event. Otherwise, other farmers upstream tend to steal water during the nights. Existing irrigation by-laws on irrigation matters are often not enforced, and many established operational rules and procedures are now ignored, something that has encouraged some farmers to steal water.

The mean irrigation intervals with standard deviation for different canals are shown in Table 4.3. The irrigation intervals obtained by using the modified model are high in canal 1 as compared to others, but the value does not differ significantly (α=1%) with the observed intervals. This may be contributed by the parameters considered when calculating irrigation intervals. For instance, in designing, they considered climatic conditions and predicted parameters like, seepage loss, hydraulic radius, canal cross section area and shape of the conveying canal, while in the actual operating conditions, these parameters have changed completely. The same trend is also observed in canal two, whereby the model has high value but do not differ significantly (α=1%) with the values observed. Canal three does not follow the above trend, the observed value is the same as model interval. The results obtained by the model and observed values are not significantly different at (α=1%). Observed irrigation interval was constant throughout the canals. The farmers primarily with regard to the availability of irrigation water fixed the irrigation interval. Basically, farmers decided that way to protect crops from wilting and not for the increase of crop production. In canal two and three, the designed irrigation intervals are low as compared to modelled and observed intervals. Because of the conditions considered in computing the modelled intervals. In canal four, the modelled irrigation intervals have the lowest value, because it is located at the tail and the actual field conditions has been taken into account. The model considers the existing field conditions existing during the irrigation event, such as rainfall, canal's slope, and other parameters. In achieving irrigation intervals using the model, various parameters like, canal seepage, canal slope, canal cross-sectional area and others were given priority. In the other methods, these were not considered. In original design, the parameters considered in determining irrigation intervals had greatly changed (e.g. canal seepage, canal slope, canal's shape). Table 4.3 in the modelled interval, the figures (9, 8, 7, and 5 days) show that, tail end canals are favoured by allocating water at shorter intervals of 5 days as compared to upstream canals. From the above observation, it can be concluded that, adoption of the model is necessary in order to ensure that, end canals are also getting irrigation water.

Table: 4.3 Irrigation intervals by different methods (M ± SDV)

Canal name	Method		
	Design Intervals (days)	Model Intervals (days)	Observed Intervals (days)
1	8.00 ± 2.70	9.00 ± 1.01	7.00 ± 0.00
2	6.00 ± 1.25	8.00 ± 1.14	7.00 ± 0.00
3	6.00 ± 1.25	7.00 ± 1.06	7.00 ± 0.00
4	6.00 ± 1.25	5.00 ± 1.47	7.00 ± 0.00
MEAN	6.50 ± 1.25	7.25 ± 1.53	7.00 ± 0.00

From Table 4.3 it can be noted that in canal one, the observed intervals is lower than the modelled intervals by two days. The observed interval is higher than the modelled interval by one day in canal two. Canal four, the observed interval is lower than the modelled interval by two days. Canal three observed interval tallies with the modelled irrigation intervals. As long as the modelled intervals do not differ significantly (α=5%) with the intervals practised by the farmers, It is suggested that farmers under the assistance of the extension officers use the model to schedule irrigation events, so as to improve crop production especially in end canals and fields. Though it may bring inconveniences to their used practises, but it will be for their own advantage. Due to the fact that always a farmer is getting his water allocation from the water distributor, the extension officer is supposed to work very closely with water distributors so as to ensure that water distributors become competent in using the model. It may take time for the water distributors to catch up in using the model. But it will be useful to them because by knowing the change in depth of flow over the change in canal length, the distributors may estimate the next irrigation interval for that particular area.

Trout and Bowers (1981) studied the operational evaluation of the irrigation conveyance systems and noted that nearly half of the water that is diverted into the watercourse systems is lost before reaching the fields. Also, the losses are dependent upon the length of the canal and field in case of border irrigation. Seven percent of the inflow to the extensively used conveyance systems is lost due to transient conditions such as initial infiltration into dry banks during channel filling, dead storage, and short term bank reaches or outlet breaches. Thus, to meet the farmers requirements it was suggested that irrigation intervals should be arranged on-demand water distribution systems, not otherwise.

Table 4.4: Least square mean for Irrigation interval from different methods on different canals.

Canal	Method			Std Error
	Design	Model	Observed	
1	7.67^a	8.58^b	7.00^a	0.24
2	5.56^a	8.44^b	7.00^c	0.23
3	5.56^a	6.51^b	7.00^b	0.23
4	5.56^a	4.96^a	7.00^b	0.23

^{a,b,c}, Least Square Mean (LSM) bearing different superscripts in the same row are significantly different (at 5 % significant level).

In canal one, designed and observed irrigation intervals are not significantly different, but significantly different with modelled irrigation interval. In Table 4.4 canal two, irrigation intervals are all significantly different in all aspects. In canal three, irrigation intervals in modelled and observed are not significantly different but are significantly different with the design irrigation interval. In canal four, the designed and modelled irrigation intervals are not significantly different, but are significantly different with the observed irrigation interval. From Table 4.4, it is not clear as to whether the model should be used to predict the irrigation intervals. Further statistical analysis is required to validate the suitability of the model.

Table 4.4 and 4.3, show that the least square mean for irrigation interval, derived using the model decreases downward. This implies that the model may have a tendency of favouring the end canals. Because it considers different losses including conveyance losses. Sharma and Oad (1990) studied the effect of conveyance losses on water distribution existing in Warabandi system. Their proposed model was used to equitably distribute water by increasing the irrigation time per unit area for the downstream land holdings on a canal. The increase in irrigation time was determined in proportion to the seepage loss rate.

Malhotral *et al* (1984) studied the methodology for monitoring the performance of large scale irrigation systems in Warabandi systems of northwest India and noted that, only farmers located favourably in the canal system, mostly at the head reaches, get supplies and they over use it. They do not care for the farmers situated lower down. This implies that irrigation interval for the farmers situated at the lower down should be re-considered.

4.3.3 Organisation structure

The village government has different development committees. One committee known as "Kamati ya mtaro" deals with all irrigation matters. It literally means "furrow committee" However, it is a Water user's irrigation committee whose work is to organise and supervise the irrigation water distribution and maintenance work. Furthermore, it has the mandate to identify problems and to report them to the village government. There are water distributors whose work is to distribute water to the farmers. Farmers seem to be satisfied with the water distributors although they do have criticisms on the irrigation committee and the village government on the way they are managing irrigation system. An example mentioned was that, during maintenance work, there is poor participation, which is caused by the fact that, the committee has no mandate to maintain law and order. For every action they undertake, they must get an approval from the village government.

This threatens the sustainability of the scheme as no proper maintenance work is being carried out. The water user's association (WUA) established by-laws concerning irrigation practices, such as for a person who does not attend the maintenance work for the first time is fined 300/=, for the second time 500/= and for the third time, he will be taken to the court of law. Anyone selling a plot without the village government permission is fined 1000/=. Feeding animals around the canals or at the intake site is fined 1000/=; stealing of water, the fine is 400/= and 600/= for first and second offenders respectively. Third time offenders are taken to court of law. On the contrary, if someone has acted against the by-laws, the operational rules are not followed. This has contributed much to demoralisation of farmers. In 1994 the village government promised that, land would be distributed to people who don't own land in the scheme area under the condition that, those in need of land may participate fully in clearing bushes to open new areas and to maintain the weir and canals. Since then no land distribution has been effected thus, people's morale has been turned down. These have lead to poor participation into the development activities and complains that WUA is not active. The overview of the organisation structure is shown in Figure 4.1.

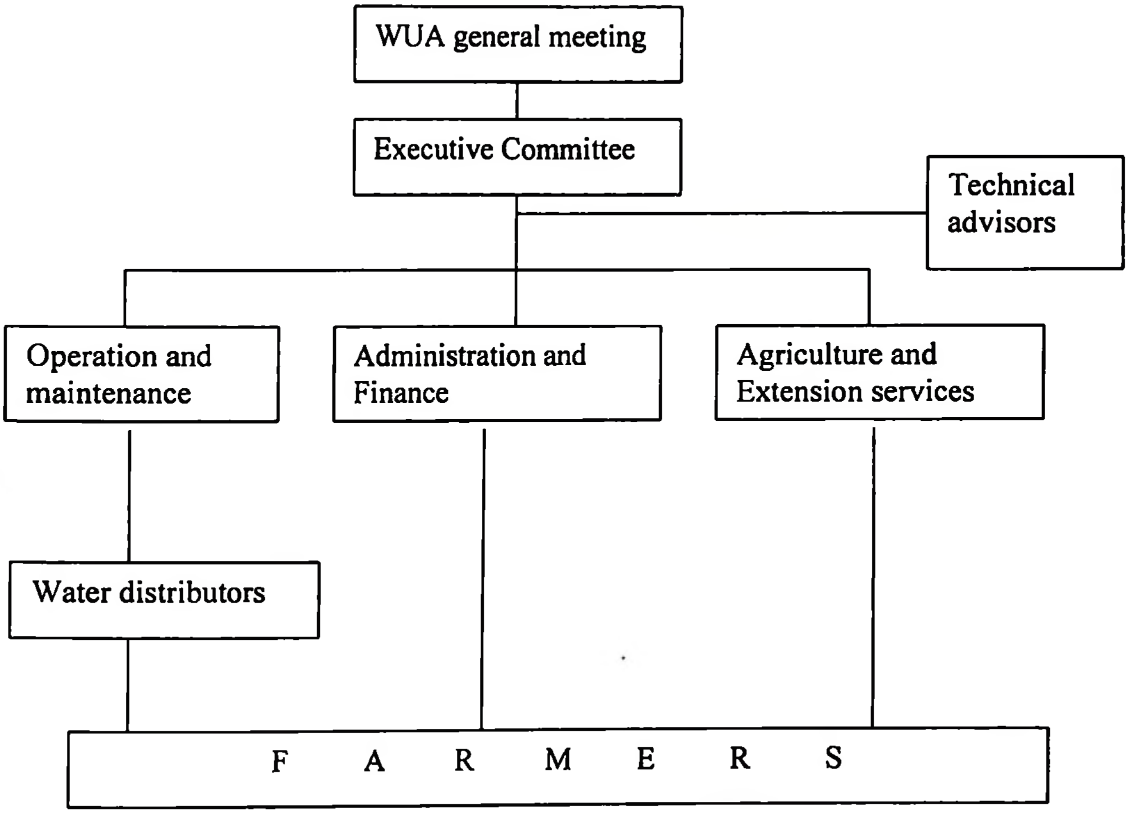


Figure 4.1 WUA organisational structure

4.3.4 Land ownership

The village government is the owner of land in Ruaha Mbuyuni. The original inhabitants (Wasagara) own the major part of the irrigation area, however, it has been noted that there are few landowners having 6 to 20 acres and a lot owning land less than one acre. Almost all of the big landowners had good connections with the former or existing village leaders or they were leaders themselves. These people are renting out their plots or parts of their plots. They seem to be not very interested in cultivating the land themselves although it is more profitable than renting out (TIP, 1992). There are also people from other villages (commuters) renting plots in the scheme. Like other renters, they are not registered but the village government charges levy to outsiders equivalent to Tshs 10,000/= per season. This is because it is believed that, the profit of agricultural production will be taken out from Ruaha Mbuyuni after harvest. The village government has the right to expel people from their plots in case of improper utilization of the land, or leaving the land uncultivated for longer than two years. Although land often stays unused for a while no cases of expelling have been reported so far. Renting system has some effect on management of the scheme. Once the person has rented the land, most of them have no sense of land ownership, thus, they just consider high production only regardless of the proper management skills required. As long as they have money, once land has depleted they can just rent another piece. Among the interviewed people, 8.7% are owning land through inheritance, 39.1% have hired land, 39.1% have bought land and 13% have been given by the village government, see Appendix J.

It has been noted that most women have a lot of activities in the agricultural production but are not directly earning their income from the agricultural production because they don't own land. This has a great impact on irrigation management of the scheme. Once there is a sensitisation/seminar/meetings concerning any irrigation practise to be attended to landowners, women are not involved but in actual fact are the ones who get involved fully in the irrigation management aspect of the schemes. Many women have their income from brewing local beer. Some others have smaller activities like making buns, breads, chapati or supplying cooked food for surrounding or local restaurants.

4.3.5 Water Right

Water from the river is distributed to the farmers freely and every farmer has the same water right regardless on the location of his farm. Currently, the farmers in the scheme are using customary rights, but are now processing water right (Appendix J). It is only outsiders who rent land have to pay levy for the service. The amount is fixed to 10,000/= Tanzanian shillings, (equivalent to US$ 12.5).

4.3.6 Consideration of the Model in Organisation structure, Land tenure and Water right

Section 4.3.3. has shown some weakness which contributes a lot in increasing high water losses, decreasing of daily discharge in the system. Section 4.3.4 shows that, most farmers have hired the land. With this system, there is no sense of land ownership, thus, once a farmer has hired for one cropping season he/she is not sure for the same piece of land for the next season. That's why most of them are not willing to maintain the canals. All these are grouped together as factors leading to poor management of the scheme. The model considers the actual existing conditions including conveyance losses, daily discharge. The model has taken into account the poor management of the scheme because it has considered the daily discharge, rainfall and daily seepage losses.

4.3.7 Extension Services at Ruaha Mbuyuni

At Ruaha Mbuyuni irrigation scheme, there is an irrigation technician stationed at the area, his duties are to transfer messages and knowledges from researchers to farmers. Example, paddy agronomic practices like improvement of higher yielding seed varieties from Lower Moshi, irrigation water management.

4.4 Crop water requirement

Under the same climatic conditions, different crops require different amount of water, and the quantities of water used by a particular crop vary with its stage of growth. Likewise, reference crop evapotranspiration (ETo) values vary over the crop-growing period. Daily reference crop evapotranspiration was calculated using the IRSIS computer package. The input parameters for the computer package were; daily minimum and maximum temperatures, daily minimum and maximum relative humidity, wind speed and crop growing periods in days. The outputs were the daily reference crop evapotranspiration in the whole growing period. Paddy crop coefficients were estimated from a drawn graph of crop coefficient (Kc) values against the paddy-growing period, thereafter, the values for a particular growing stage were multiplied by reference crop evapotranspiration. Equation 2.3 was used in this process, and results are shown in Appendix A.

4.5 Discharge calculation for the scheme

The location suitable for measuring discharge was selected. Flow measurements were conducted at different points using graduated staff. Intake discharges were computed and tabulated in Appendix C-1. Main canal discharges were also computed and tabulated in

Appendix C-2. Discharges for field canal (Canal 1to4)off-takes were also recorded, see Appendix N.

A current metre was used to calibrate the flow measuring station for Ilongo intake and the main canal. The established calibration curves for Ilongo intake and main canal are attached in Appendix D-1 and D-2 respectively.

4.6 Model testing and validation

4.6.1 Prediction of irrigation intervals

Equation B.13 in Appendix B was used to calculate the irrigation intervals using data collected in the field. The calculated irrigation intervals are presented in Appendix K and L as modelled irrigation intervals. Equation B.13 is complex, tedious and can not be used directly in the field by farmers or technicians. Thus, it was felt that the model need to be simple and convenient to apply using the possible minimum available resources, hence a need to establish constants for the model that could enable simplicity and easiness to use in the field.

Constants in equation B14 and B15 in Appendix B, i.e. K_1, K_2 and K_3 were computed (Appendix M) and mathematical relationship established for every location in canal 1, 2, 3, and 4 respectively. The mathematical relations established using the constants are presented in Table 4.5: -

Table 4.5: Mathematical model for the sampled canals

Canal name	Mathematical relation
Canal 1	$\frac{dy}{dx} = \frac{0\cdot 0104 + R_a}{I_n} - 1\cdot 544 \times 10^{-5}$
Canal 2	$\frac{dy}{dx} = \frac{0\cdot 00213 + R_a}{I_n} - 9\cdot 734 \times 10^{-6}$
Canal 3	$\frac{dy}{dx} = \frac{0\cdot 00813 + R_a}{I_n} - 2\cdot 238 \times 10^{-5}$
Canal 4	$\frac{dy}{dx} = \frac{0\cdot 0082 + R_a}{I_n} - 1\cdot 198 \times 10^{-5}$

From the four equations in Table 4.5, the overall mathematical relationship for the scheme for the determination of irrigation intervals was obtained by taking the mean of the constants for the four equations. The obtained mathematical relationship is: -

$$\frac{dy}{dx} = \frac{0\cdot 00722 + R_a}{I_n} - 1\cdot 488 \times 10^{-5} \quad (4.1)$$

Where;

dy = Change in depth of flow (m)

dx = Change in length along the canal (m)

I_n = Irrigation interval (days)

R_a = Rainfall (m)

Equation 4.1 was termed as the mathematical model for the prediction of scheme's irrigation interval. Technicians stationed in the scheme can use the model to determine irrigation intervals by measuring the change in depth of flow and change in the distance along a canal during the irrigation event and rainfall. The obtained values are then substituted in Equation 4.1 to give the irrigation interval (I_n) for that particular plot.

The overall mathematical model was validated over the four canals at each of the three positions i.e. upper, middle and end, by comparing the irrigation intervals determined by it and the designed intervals. The irrigation intervals calculated using the model (Equation. 4.1) were termed as the simulated irrigation intervals. The simulated intervals were compared with the designed intervals. The arithmetic mean, corrected sum of squares and the pooled variance within each group were computed, and degrees of freedom determined, hence, comparison using t-student distribution test at 0.1%, 1% and 5% significance levels (Freese, 1980) was performed. The comparison tests at different significance levels are shown in Table 4.6:

The test showed that in canal 1, 3 and 4 there is no significant difference between the simulated and the designed irrigation intervals at the 5% significance level. In canal 2 there is a significance difference between the two at 5% significance level. The probable reason for this outcome is the extension services rendered by the extension officers. In the context of farming, extension is defined as assistance to farmers to enable them identify and analyse their production problems and become aware of opportunities for improvement by changing their outlook towards their difficulties (Adams, 1984; Keregero, 1988).

Table 4.6 Locations comparison between the design and simulated intervals.

Canal name	Location	df	t-calculated	t-tabulated (Freese, 1980)			Remarks
				0.1%	1%	5%	
	U		2.9971				NS(0.1%)
1	M	14	1.2778	4.140	2.977	2.145	NS(1%)
	E		1.2588				NS(5%)
	U		5.3297				
2	M	16	6.1270	4.015	2.291	2.120	S(5%)
	E		8.8712				
	U		3.9005				NS(1%)
3	M	16	1.3808	4.015	2.291	2.120	NS(5%)
	E		0.3521				NS(5%)
	U		0.4175				NS(5%)
4	M	16	0.8825	4.015	2.291	2.120	NS(5%)
	E		0.1329				NS(5%)

Note: df = Degrees of freedom; NS = Non significance; S = Significance U,M,E = Upper, Middle and End respectively.

The major role of the extension officer is to change the farmer's way of farming by introducing new ideas whereby farmers will increase their productivity as well as improve their standards of living. Similarly the comparison was made for every sampled canal using the same t-students distribution test. The test results are presented in Table 4.7.

Table 4.7 Comparison between designed and simulated irrigation intervals for canals

Canal name	df	t-calculated	t-tabulated			Remarks
			0.1%	1%	5%	
1	46	2.5368	3.5237	2.6908	2.0147	NS(1%)
2	52	12.7844	3.4964	2.6776	2.0008	S(5%)
3	52	2.4361	3.4964	2.6776	2.0008	NS(1%)
4	52	2.1881	3.4964	2.6776	2.0008	NS(1%)

Note: df = Degrees of freedom; NS = Non significance; S = Significance.

Table 4.7 shows that there is no difference at 1% significant level in canal 1, 3 and 4. But in canal 2 there is a difference at 5% significant level between the designed and simulated irrigation interval at specified significance level. This may be contributed by the fact that, farmers using canal two are aware of the modem agricultural practices due to extension services rendered by an extension officer residing in the scheme. The irrigation technician stationed at the scheme, own some plots along this canal, sometimes the technician organizes farmers and use-hired labour to clean and maintain the canal. By doing so, farmers tend to learn by adopting skills from the technician. Farmers use polythene bags filled with sand and mud to divert water during their irrigation event thus reducing amount of water lost through improper blocking of the canal. By using the polythene bags, farmers create sufficient head at the canal's head and hence increasing the efficiency of water utilization in their canal. This means, more water is stored in the soil hence longer interval before the stored water is depleted. This may be the major reason on why the two intervals are significantly different at 5% significance level. Other contributing factor may be the canal slope being uniform throughout the canal, while in other canals the slope along the canal is non-uniform.

The comparison between the simulated and the observed irrigation intervals was also performed using the t-students distribution test. The test results are tabulated in Table 4.8.

Table 4.8 Comparison between simulated and observed irrigation intervals for canals

Canal name	df	t-calculated	t-tabulated			Remarks
			0.1%	1%	5%	
1	46	1.7824	3.5237	2.6908	2.0147	NS(5%)
2	52	12.3861	3.4964	2.6776	2.0008	S(5%)
3	52	1.6375	3.4964	2.6776	2.0008	NS(5%)
4	52	4.6602	3.4964	2.6776	2.0008	S(5%)

Note: df = Degrees of freedom; NS = Non significance; S = Significance.

From Table 4.8 it can be seen that, in canal 2 and 4 the difference is significant at 5% level between the observed and the simulated irrigation intervals. However, canal one and three the difference is not significance at 5%. From the results, it can be interpreted that, the fixed irrigation interval of seven days is not worth adopting in canals two and four, instead that model should be used to predict irrigation intervals. However for other canals, the model and the observed intervals can be used in the scheme, because there is no significant difference (at 5% level) between the two. From Table 4.3, the results obtained by the model and observed values are not significantly different at (α=1%), also, the intervals from the model do not differ significantly at ($\propto$=1%). Likewise, the intervals from the model do not differ significantly ($\propto$=1%), with the values observed.

The model predicts well the irrigation intervals for the varied flow in canal systems. Thus, it is suggested that, the derived model be used in the field directly to predict next irrigation event just by measuring the change in flow depth over the distance along the selected canal, provided the flow in canal systems is varied.

4.6.2 Prediction of water volumes

Similarly, it was observed that, there was a need to establish the relationship for determining the amount of water diverted in the fields during the irrigation event. In this case the rainfall factor was taken into account (Appendix L). Constants, K_2 and K_3 (Appendix L) were substituted in Equation B 15. The mathematical relationships were established for every field. However, the general equations for each selected canal were achieved by taking the mean of the constants in every equation of the canal. The equations are presented in Table 4.9.

Table 4.9: Model for prediction of water volumes for the sampled canals

Canal name	Mathematical relation
Canal 1	$\frac{dy}{dx} = 0 \cdot 221(V_u + R_a)^2 - 1 \cdot 544 \times 10^{-5}$
Canal 2	$\frac{dy}{dx} = 0 \cdot 0632(Vu + R_a)^2 - 9 \cdot 734 \times 10^{-6}$
Canal 3	$\frac{dy}{dx} = 0 \cdot 214(Vu + R_a)^2 - 2 \cdot 238 \times 10^{-5}$
Canal 4	$\frac{dy}{dx} = 0 \cdot 267(Vu + R_a)^2 - 1 \cdot 198 \times 10^{-5}$

From Table 4.9, the mathematical model for estimation of water volumes was found by taking the mean of the constants for all the canals' models. The overall mathematical model for the estimation of water volumes is: -

$$\frac{dy}{dx} = 0 \cdot 1913(Vu + R_a)^2 - 1 \cdot 488 \times 10^{-5} \qquad (4.2)$$

Where;

dy = Change in depth of flow (m)

dx = Change in length along the canal (m)

V_u = Water volumes (m^3)

Equation 4.2 is the overall equation that can be used to predict water volumes in the field by measuring the change in depth of flow over the change in length along the canal. The overall equation for water volumes was then validated over the selected canals and fields by calculating the volumes using equation 4.2 then compare them with the volumes measured in the field. Volumes computed using equation 4.2 were termed as simulated volumes. The validation results are presented in Table 4.10.

Table 4.10 Comparison between measured and simulated water volumes using the t-test distribution

Canal name	df	t-calculated	t-tabulated			Remarks
			0.1%	1%	5%	
1	46	1.3077	3.5237	2.6908	2.147	NS(5%)
2	52	11.0299	3.4964	2.6776	2.0008	S(5%)
3	52	0.1899	3.4964	2.6776	2.0008	NS(5%)
4	52	0.5520	3.4964	2.6776	2.0008	NS(1%)

Note: df = Degrees of freedom; NS = Non significance; S = Significance.

From Table 4.10, there is no significant difference between the simulated and measured volumes in canal one, three, and four. Still, in canal two the difference is significant between the two volumes. The reason is as stated previously. The model for estimation of water volumes, can be used directly in the field to predict water volume during the irrigation event, simply by measuring the change in surface flow over the change in distance along the selected canal, provided the flow in canal systems is varied and not otherwise.

Table 4.11: Simulated and measured volumes (M ± SDV)

Canal Name	Simulated volume (mm depth)	Measured volume (mm depth)
1	84.29 ± 3.21	77.78 ± 2.01
2	35.73 ± 4.63	70.16 ± 1.29
3	84.77 ± 1.27	83.27 ± 1.18
4	88.75 ± 1.36	86.90 ± 1.52
MEAN	73.38 ± 2.62	79.53 ± 1.50

The mean water volumes with standard deviation for different canals are shown in Table 4.11. The water volumes obtained by using the model do not differ significantly at ($\propto$=1) with the observed volumes.

Both derived mathematical models i.e. model for irrigation interval (Equation 4.1) and model for prediction of water volume (Equation 4.2) predicts well the results in varied flow canal systems. As stated earlier farmers in canal two are organized and are voluntarily organized under the assistance of the irrigation technician. It was also observed that, the majority of farmers in canal two are commuters from outside so they ensure that, the renting money used to acquire the field is re-cycled beneficially, also they are very keen in practicing the advice given to them by the extension officer. Other farmers, from different canals claim that the adoption of the technology is very expensive in terms of labour and cost, still the extension officer is putting much effort in demonstrating the effectiveness of the improved water management practice so that other farmers can acquire and adopt the skill slowly.

4.6.3 Change of canal characteristics

Equation 4.1 has been derived from equation B.13. The equation can no longer predict well if the considered parameters in establishing irrigation interval have changed. Once there is a sense that the canal hydraulic characteristics such as shape, roughness, slope, and seepage have greatly changed. It is suggested that, field measurement be taken to update the model.

4.7 Computer program testing

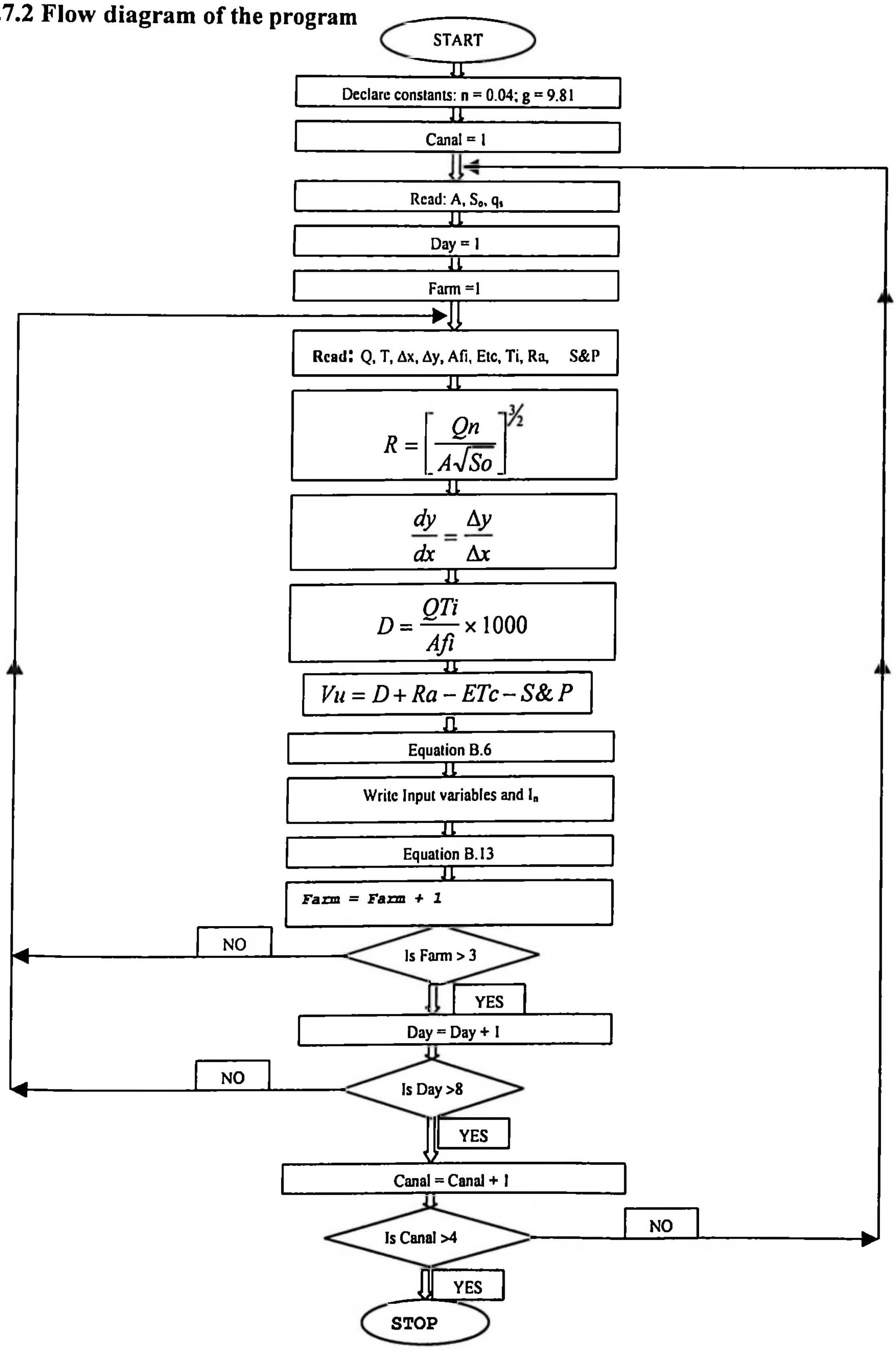
A Computer program was tested using data input collected from the field. The output results from the program together with the results processed by a spreadsheet are attached in Appendix L and M respectively. The results from the computer program are almost the same as those processed by the spreadsheet. Therefore, the computer program developed can be used to calculate the irrigation interval in varied flow canal systems

4.7.1 Input data

Data required for the model comprises of the following parameters:

- Water entering in the field (discharge per irrigation event)
- Acceleration due to gravity
- Canal top width
- Canal cross section area
- Canal bed slope
- Canal seepage rate
- Manning's roughness coefficient
- Hydraulic radius
- Change in the water depth flow in the canal
- Change in the distance along the canal
- Soil moisture content on volume basis if not saturated
- Crop type
- Crop development stage
- Optionally, crop evapotranspiration
- Paddy field area
- Rainfall during the growing season
- Duration (time) during irrigation event
- Wind speed
- Relative humidity
- Temperature

4.7.2 Flow diagram of the program



CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter summarises the major study findings and conclusions from the case study and recommendations for further investigation as appears in the subsequent sections.

5.1 Conclusion

(i) Traditional canal systems, in most cases, do not have discharge measuring facilities. This leads to misuse of water resources resulting in loss of revenue

(ii) The developed computer programme can be used to determine amount of water applied in the field and irrigation scheduling as long as the flow condition in the canals is varied. This can be implemented by measuring the change in depth of flow in the canal and distance along the canal, then substitute the values into the model to obtain irrigation intervals and water volumes respectively.

(iii) In order to meet the objective of the study the achieved model for prediction irrigation intervals for a varied flow canal systems is in the following form:

$$\frac{dy}{dx} = \frac{0 \cdot 00722 + R_a}{I_n} - 1 \cdot 488 \times 10^{-5}$$

(iv) Likewise, the model for prediction of water volumes in the scheme during and irrigation event was achieved by establishing constant and the model is in the following form:

$$\frac{dy}{dx} = 0 \cdot 1913(Vu + R_a)^2 - 1 \cdot 488 \times 10^{-5}$$

(v) The comparison t-student distribution test between the simulated and designed irrigation intervals, showed that, canal one, three and four the difference is not significant at 1% significant level. In canal two, the difference is significant at 5% significant level. This implies that, with the exception of canal two the model could be used interchangeably with the design intervals.

(vi) Similarly, simulated and observed irrigation intervals for selected canals were compared. The test revealed that, in canal one and three the difference is not significant at 5% significant level. In canal two and four the test showed that there is a significant difference at 5% significant level.

(vii) Comparison between the measured and the simulated water volumes using the same t-student distribution was performed. The test showed that, in canal one and three the difference is not significant at 5% significance level. In canal four the difference is not significant at 1% significance level. Like in the test for irrigation intervals, the test showed that in canal two the difference is significant at 5% significance level

(viii) As stated in section 4.3.3, one of the roles of Water Users Association is to supervise the distribution of irrigation water in the scheme. The committee is doing the activity on the basis of agreed timetable. Thus, in order to perform its work fairly well, it is advised that, they use the model to predict irrigation scheduling for the whole scheme.

Thus, it is concluded that, the irrigation intervals (scheduling) and water volumes in the fields are fairly well predicted. Hence, the model developed can be used in predicting irrigation intervals and water volumes in the varied flow canal systems provided that, the agricultural management is similar for the whole farm under irrigation.

5.2 Recommendations

In order to ensure that farmers get the most out of the modified model the following are recommended:

(i) Simple but permanent water measuring devices and distribution boxes should be installed on every canal. Water-regulating structures should be installed at heads of the canals to enable monitoring of flows conveyed to the fields. These will minimise the problem of water stealing among farmers and improve irrigation water management.

(ii) Water distributors should be motivated so as to keep them away from bribes (especially from commuters) and stick to the modified model's rule.

(iii) Field drains for removing excess water should be established to avoid water logging and erosion during rainy season. Excess water will be controlled not to overflow into irrigable fields.

(iv) The WUA committee should establish a system of collecting maintenance fees levied on a seasonal plot use basis as is required to pay for costs of materials and skilled labour for future maintenance. This system is better than charging costs ad-hoc as problems occur.

(v) Since skilled maintenance may be necessary, only every two to three years, farmers should be charged according to their utilisation of the scheme. Care must be taken to ensure that, charges levied are not construed as land lease fees or taxes in any form.

(vi) The model used in this study was tested in a traditional lowland paddy only, and performed sufficiently. Therefore, further research work is needed to test it in upland crops as well as in improved farm managed irrigation schemes, so as to make it more widely applicable, provided the flow in the canal systems is varied.

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LIST OF APPENDICES

APPENDIX A

CROP WATER REQUIREMENT

Month	Date	Day	ETo (mm/day)	K_c	ETc (mm/day)	S&P (mm/day)	Rainfall (mm/day)
January	1	1	3.7	1.10	4.07	2.30	0.0
January	2	2	2.8	1.10	3.08	2.30	1.5
January	3	3	2.1	1.10	2.31	2.30	1.2
January	4	4	4.9	1.10	5.39	2.30	0.0
January	5	5	4.5	1.10	4.95	2.30	0.0
January	6	6	4.6	1.10	5.06	2.30	0.0
January	7	7	5.2	1.10	5.72	2.30	0.0
January	8	8	4.5	1.10	4.95	2.30	0.0
January	9	9	5.5	1.10	6.05	2.30	0.0
January	10	10	5.0	1.11	5.55	2.30	0.0
January	11	11	4.7	1.11	5.22	2.30	0.0
January	12	12	5.6	1.11	6.22	2.30	0.0
January	13	13	5.3	1.12	5.94	2.30	0.0
January	14	14	3.3	1.12	3.70	2.30	0.0
January	15	15	1.2	1.12	1.34	2.30	1.2
January	16	16	1.5	1.12	1.68	2.30	1.3
January	17	17	3.5	1.13	3.96	2.30	2.1
January	18	18	4.1	1.13	4.63	2.30	0.0
January	19	19	4.2	1.13	4.75	2.30	7.0
January	20	20	3.6	1.13	4.07	2.30	0.0
January	21	21	3.0	1.14	3.42	2.30	28.2
January	22	22	3.6	1.14	4.10	2.30	0.0
January	23	23	2.8	1.14	3.19	2.30	1.4
January	24	24	2.8	1.14	3.19	2.30	110.4
January	25	25	2.5	1.14	2.85	2.30	1.0
January	26	26	3.8	1.15	4.37	2.30	0.0
January	27	27	4.3	1.15	4.95	2.30	0.0
January	28	28	4.9	1.15	5.64	2.30	0.0
January	29	29	4.6	1.16	5.34	2.30	0.0
January	30	30	4.8	1.16	5.57	2.30	0.0
January	31	31	5.0	1.16	5.80	2.30	0.0
February	1	32	4.4	1.17	5.15	2.30	0.0
February	2	33	2.9	1.17	3.39	2.30	0.0
February	3	34	4.5	1.18	5.31	2.30	0.0
February	4	35	5.1	1.18	6.02	2.30	0.0
February	5	36	3.7	1.19	4.40	2.30	0.0
February	6	37	4.7	1.19	5.59	2.30	0.0

February	7	38	5.1	1.20	6.12	2.30	0.0
February	8	39	5.2	1.20	6.24	2.30	0.0
February	9	40	5.1	1.20	6.12	2.30	0.1
February	10	41	5.1	1.20	6.12	2.30	0.0
February	11	42	4.1	1.21	4.96	2.30	22.7
February	12	43	1.8	1.21	2.18	2.30	0.1
February	13	44	3.9	1.21	4.72	2.30	0.0
February	14	45	4.3	1.21	5.20	2.30	0.0
February	15	46	4.7	1.21	5.69	2.30	0.0
February	16	47	5.0	1.22	6.10	2.30	0.0
February	17	48	5.3	1.22	6.47	2.30	0.0
February	18	49	5.4	1.22	6.59	2.30	0.0
February	19	50	5.5	1.22	6.71	2.30	0.0
February	20	51	4.9	1.22	5.98	2.30	0.0
February	21	52	3.6	1.23	4.43	2.30	0.0
February	22	53	2.1	1.23	2.58	2.30	1.9
February	23	54	4.6	1.23	5.66	2.30	0.0
February	24	55	5.0	1.23	6.15	2.30	0.0
February	25	56	5.0	1.23	6.15	2.30	0.0
February	26	57	4.3	1.23	5.29	2.30	0.0
February	27	58	3.1	1.24	3.84	2.30	0.6
February	28	59	3.4	1.24	4.22	2.30	0.0
March	1	60	4.1	1.24	5.08	2.30	0.5
March	2	61	4.5	1.25	5.63	2.30	0.0
March	3	62	4.2	1.25	5.25	2.30	0.0
March	4	63	4.3	1.25	5.38	2.30	0.3
March	5	64	3.9	1.26	4.91	2.30	0.1
March	6	65	4.0	1.26	5.04	2.30	0.0
March	7	66	2.9	1.26	3.65	2.30	27.6
March	8	67	2.9	1.27	3.68	2.30	0.7
March	9	68	1.1	1.27	1.40	2.30	7.6
March	10	69	3.5	1.28	4.48	2.30	1.4
March	11	70	4.1	1.29	5.29	2.30	0.4
March	12	71	2.5	1.30	3.25	2.30	0.3
March	13	72	4.1	1.30	5.33	2.30	0.0
March	14	73	3.7	1.28	4.74	2.30	0.0
March	15	74	3.0	1.27	3.81	2.30	0.5
March	16	75	0.9	1.27	1.14	2.30	30.2
March	17	76	4.2	1.27	5.33	2.30	0.0
March	18	77	1.7	1.27	2.16	2.30	0.0
March	19	78	3.9	1.26	4.91	2.30	0.0
March	20	79	2.3	1.25	2.88	2.30	23.4
March	21	80	4.0	1.25	5.00	2.30	37.7
March	22	81	2.3	1.24	2.85	2.30	0.6
March	23	82	4.0	1.23	4.92	2.30	37.8

March	24	83	3.3	1.23	4.06	2.30	0.0
March	25	84	4.5	1.22	5.49	2.30	0.0
March	26	85	2.8	1.20	3.36	2.30	0.9
March	27	86	3.2	1.20	3.84	2.30	72.8
March	28	87	3.7	1.18	4.37	2.30	0.0
March	29	88	3.8	1.17	4.45	2.30	0.8
March	30	89	4.4	1.17	5.15	2.30	0.0
March	31	90	4.4	1.16	5.10	2.30	0.0
April	1	91	3.7	1.15	4.26	2.30	0.0
April	2	92	3.3	1.14	3.76	2.30	0.0
April	3	93	3.4	1.14	3.88	2.30	0.0
April	4	94	3.9	1.13	4.41	2.30	1.6
April	5	95	3.1	1.12	3.47	2.30	2.4
April	6	96	2.6	1.11	2.89	2.30	2.4
April	7	97	4.0	1.10	4.40	2.30	2.4
April	8	98	2.7	1.10	2.97	2.30	2.4
April	9	99	3.1	1.10	3.41	2.30	2.4
April	10	100	4.4	1.09	4.80	2.30	2.4
April	11	101	4.0	1.08	4.32	2.30	2.4
April	12	102	3.8	1.07	4.07	2.30	2.4
April	13	103	4.8	1.06	5.09	2.30	2.4
April	14	104	3.8	1.07	4.07	2.30	2.4
April	15	105	3.6	1.05	3.78	2.30	1.1
April	16	106	4.3	1.04	4.47	2.30	0.0
April	17	107	3.8	1.04	3.95	2.30	0.0
April	18	108	4.5	1.04	4.68	2.30	0.0
April	19	109	3.4	1.03	3.50	2.30	0.0
April	20	110	4.0	1.03	4.12	2.30	0.0
April	21	111	4.0	1.03	4.12	2.30	0.0
April	22	112	4.7	1.03	4.84	2.30	0.0
April	23	113	4.5	1.03	4.64	2.30	0.0
April	24	114	4.1	1.02	4.18	2.30	0.0
April	25	115	5.7	1.01	5.76	2.30	0.0
April	26	116	4.1	1.01	4.14	2.30	0.0
April	27	117	3.6	1.01	3.64	2.30	0.0
April	28	118	3.3	1.00	3.30	2.30	0.0
April	29	119	3.9	1.00	3.90	2.30	0.0
April	30	120	3.5	1.00	3.50	2.30	0.0
May	1	121	3.5	0.99	3.47	2.30	0.0
May	2	122	3.4	0.99	3.37	2.30	0.0
May	3	123	3.6	0.99	3.56	2.30	0.0
May	4	124	3.0	0.98	2.94	2.30	0.0
May	5	125	3.2	0.98	3.14	2.30	0.0
May	6	126	3.3	0.97	3.20	2.30	0.0
May	7	127	2.4	0.97	2.33	2.30	0.0

May	8	128	3.2	0.96	3.07	2.30	0.0
May	9	129	4.0	0.96	3.84	2.30	0.0
May	10	130	3.2	0.95	3.04	2.30	0.0
May	11	131	3.9	0.95	3.71	2.30	0.0
May	12	132	3.6	0.95	3.42	2.30	0.0
May	13	133	1.9	0.95	1.81	2.30	0.0

APPENDIX B

The model

The model is developed from the modification equations 2.1 and 2.2. The model developed for irrigation scheduling requires canal slope, cross sectional area, hydraulic radius, top width, seepage and moisture in the field.

Assuming that no losses occurring in the field, the irrigation time required to deliver a given volume of water per unit land area within the command is given by Sharma and Oad, (1990) as:

$$T_i = \frac{V_U A_{fi}}{Q_1} \tag{B.1}$$

Where,

T_i	=	Irrigation time (hours)
V_u	=	Volume of water per unit land area (m^3/m^2) i.e. field moisture
Q_1	=	Flow rate entering in the field (m^3)
A_{fi}	=	Area land (m^2)

Irrigation time required for the whole command area under rotation system is: -

$$T_{WC} = \sum_{i=1}^{n} T_i \tag{B.2}$$

Where,

T_{WC}	=	Irrigation time for the whole command area (hrs)
n	=	Number of landholdings in the command area

Rearranging equation (B.1);

$$Q_1 = \frac{V_U A_{fi}}{T_i} \tag{B.3}$$

Substituting equation (B.1) into equation (2.1), the resulting equation is;

$$\frac{dQ}{dx} = q_S + \frac{V_U A_{fi}}{T_i} \tag{B.4}$$

Then substituting equation (B.4) into equation (2.2), the equation becomes;

$$\frac{dy}{dx} = \frac{S_o - \frac{n^2 Q^2}{A^2 R^{4/3}} - \frac{2\beta Q}{gA^2}\left[q_s + \frac{V_U A_{fi}}{T_i}\right]}{1 - \beta \frac{Q^2 T}{gA^3}} \tag{B.5}$$

Using equation (B.5), the discharge, depth of flow, distance along the canal and moisture content in the field will be measured. Moisture content in the field will be used to determine volume of water per unit land area in the field, V_u.

Let,

$$C = \frac{S_o - \frac{n^2 Q^2}{A^2 R^{4/3}} - \frac{2\beta Q}{gA^2}}{1 - \beta \frac{Q^2 T}{gA^3}} \tag{B.6}$$

Then, equation (B.5) becomes;

$$\frac{dy}{dx} = C\left[q_s + \frac{V_U A_{fi}}{T_i}\right] \tag{B.7}$$

Making T_i the subject;

$$T_i = V_U A_{fi}\left[\frac{1}{C}\frac{dy}{dx} - q_s\right]^{-1} \tag{B.8}$$

Before irrigation, $T_i = 0$; and moisture in the field is V_{u1}(mm); after irrigation $T_i = T_i$ and moisture is V_{u2} (mm), thus, the amount of water diverted into the field minus the losses occurring in the field (Q_f) is calculated using the following formula;

$$Q_f = \frac{V_{U2}A - V_{U1}A}{T_i} \tag{B.9}$$

Net irrigation depth d_n is expressed as the amount of water that is fully stored in the crop's root zone and used by the plant, is expressed as;

$$d_n = \frac{Q_f T_i}{A_{fi}} \tag{B.10}$$

Irrigation interval I_n (in days) is given by;

$$I_n = \frac{d_n}{ET_C} \qquad \text{(B.11)}$$

Thus,

Irrigation scheduling model will be as follows;

$$I_n = \frac{Q_f T_i}{A_{fi} \times ET_C} \qquad \text{(B.12)}$$

The modified model to be used in scheduling of a varied flow in irrigation canal system is as follows;

$$I_n = \frac{Q_f T_i}{A_{fi} ET_C} = \frac{Q_f V_U}{ET_C}\left[\frac{1}{C}\frac{dy}{dx} - q_S\right]^{-1} \qquad \text{(B.13)}$$

Rearranging equation (B.13) to find the constants of proportionality;

$$\frac{dy}{dx} = \frac{C}{I_n}\frac{Q_f V_U}{ET_C} + Cq_S \qquad \text{Or,} \qquad \frac{dy}{dx} = \frac{K_1}{I_n} + K_2 \qquad \text{(B.14)}$$

and,

$$\frac{dy}{dx} = C\frac{V_U^2 A_{fi}}{I_n T_i ET_C} + Cq_S \qquad \text{Or,} \qquad \frac{dy}{dx} = K_3 V_U^2 + K_2 \qquad \text{(B.15)}$$

Where;

$$K_1 = C\frac{Q_f V_U}{ET_C}; \qquad K_2 = Cq_S; \qquad \text{and,} \qquad K_3 = C\frac{A_{fi}}{I_n T_l ET_C} \qquad \text{(B.16)}$$

From the above equations, it is noted that the change in depth (dy) over change in the distance (dx) along the canal is inversely proportional to irrigation interval (In), and directly proportional to the square of the moisture content (Vu) in the field. The mathematical relation that explains the above is given as follows:

$$\frac{dy}{dx} \alpha \frac{1}{I_n} \tag{B.17}$$

and,

$$\frac{dy}{dx} \alpha V_u^2 \tag{B.18}$$

APPENDIX C

Table: C-1 Detailed discharge calculations for calibration curve for Ilongo intake

Control width (cm)	Gauge height (cm)	Flow depth (cm)	Rev/min	Rev/sec N	Velocity (cm/s)	Velocity (m/s)	X-area (m^2)	Discharge (m^3/s)
70	70	56	81	1.35	44.01	0.44	0.392	0.172
70	72	59	87	1.45	47.13	0.47	0.413	0.194
70	76	63	84	1.40	45.57	0.46	0.441	0.203
70	78	65	78	1.30	42.45	0.42	0.455	0.191
70	82	69	101	1.68	54.30	0.54	0.483	0.261

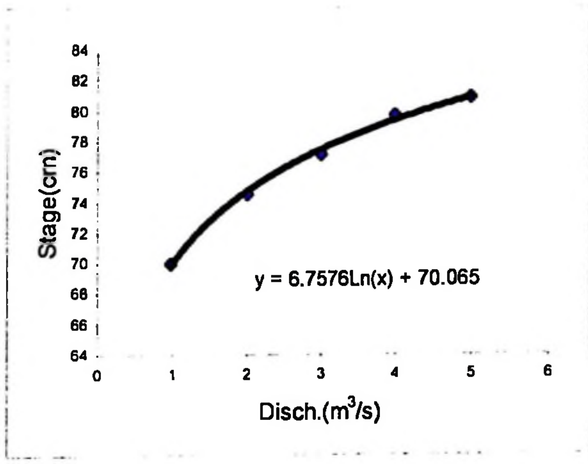
Table C-2:Discharge calculation for Ilongo main canal

Control width (cm)	Gauge height (cm)	Flow depth (cm)	Rev/min	Rev/sec N	Velocity (cm/s)	Velocity (m/s)	X-area (m^2)	Discharge (m^3/s)
160	34.5	32.0	66	1.10	36.23	0.36	0.128	0.046
160	34.5	33.0	59	0.98	32.48	0.32	0.132	0.042
160	34.5	32.0	78	1.30	42.45	0.42	0.128	0.054
160	34.5	30.0	56	0.93	30.92	0.31	0.100	0.031
						Total	0.488	0.173
160	51.5	42.5	72	1.20	39.33	0.39	0.170	0.066
160	51.5	43.5	86	1.43	46.50	0.47	0.174	0.082
160	51.5	42.5	85	1.42	46.19	0.46	0.170	0.078
160	51.5	37.0	91	1.52	49.31	0.49	0.148	0.073
						Total	0.662	0.300
160	52.0	44.0	71	1.18	38.71	0.39	0.176	0.069
160	52.0	44.0	79	1.32	43.07	0.43	0.180	0.077
160	52.0	44.0	80	1.33	43.39	0.43	0.176	0.077
160	52.0	44.0	65	1.08	35.59	0.36	0.14	0.050
						Total	0.672	0.273
160	49.0	42.0	65	1.08	35.59	0.36	0.168	0.060
160	49.0	43.0	66	1.10	36.22	0.36	0.172	0.062
160	49.0	42.0	69	1.15	37.78	0.38	0.168	0.064
160	49.0	36.0	70	1.17	38.40	0.38	0.144	0.055
						Total	0.652	0.241

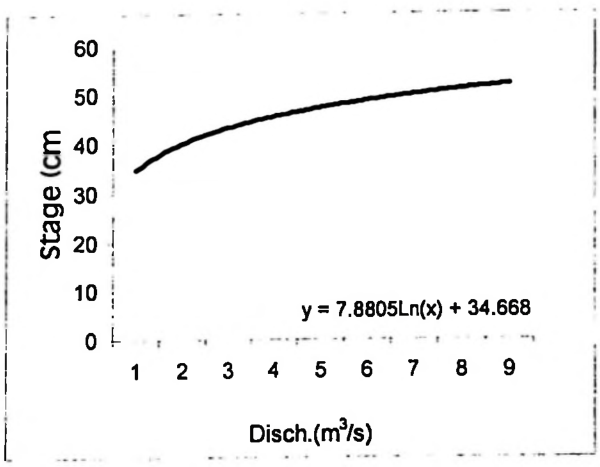
160	47.0	42.0	64	1.07	35.28	0.35	0.160	0.056
160	47.0	42.0	69	1.15	37.78	0.38	0.168	0.064
160	47.0	41.0	75	1.25	40.89	0.41	0.164	0.067
160	47.0	34.0	71	1.18	38.71	0.39	0.136	0.053
						Total	0.628	0.240
160	45.0	38.0	63	1.05	34.66	0.35	0.156	0.055
160	45.0	40.0	67	1.12	36.84	0.37	0.160	0.059
160	45.0	39.0	76	1.27	41.52	0.42	0.156	0.066
160	45.0	32.0	69	1.15	37.78	0.38	0.128	0.048
						Total	0.600	0.228
160	43.5	39.5	65	1.08	35.59	0.36	0.158	0.057
160	43.5	42.5	69	1.15	37.78	0.38	0.170	0.064
160	43.5	39.5	79	1.32	43.07	0.43	0.158	0.068
160	43.5	30.0	70	1.17	38.40	0.38	0.120	0.046
						Total	0.606	0.235
160	42.0	36.0	65	1.08	35.59	0.36	0.144	0.052
160	42.0	38.0	64	1.07	35.28	0.35	0.152	0.053
160	42.0	36.0	75	1.25	40.89	0.41	0.144	0.059
160	42.0	29.0	69	1.15	37.78	0.38	0.116	0.063
						Total	0.556	0.227
160	40.5	37.0	60	1.00	33.10	0.33	0.148	0.049
160	40.5	38.0	70	1.17	38.40	0.38	0.152	0.058
160	40.5	39.0	70	1.17	38.40	0.38	0.156	0.060
160	40.5	28.0	64	1.07	35.28	0.35	0.122	0.043
						Total	0.578	0.210

APPENDIX D

Appendix D –1 Rating curve for Ilongo intake



Appendix D-2 Rating curve for Ilongo main canal



Appendix E: Simulated and measured volumes

Canal 1: Date	Simulated Vol(mm.depth)	Measured Vol(mm.depth)
7.2.99	69.228	80.66
14.2.99	84.579	76.05
21.2.99	84.579	67.41
28.2.99	69.228	64.53
7.3.99	84.579	38.02
14.3.99	77.286	41.48
21.3.99	77.286	55.31
28.3.99	77.286	59.92
7.2.99	97.544	104.56
14.2.99	84.579	107.54
21.2.99	84.579	88.03
28.2.99	108.976	69.70
7.3.99	84.579	71.20
14.3.99	108.976	68.46
21.3.99	108.976	82.15
28.3.99	49.309	80.66
7.2.99	69.228	105.51
14.2.99	69.228	81.42
21.2.99	97.544	101.61
28.2.99	97.544	112.55
7.3.99	91.292	70.34
14.3.99	77.286	78.16
21.3.99	84.579	67.74
28.3.99	84.579	93.79
Mean	84.285	77.782
Sum X	2023	1867
Sum X^2	175229	0
$(\text{Sum } X)^2$	4091917.83	3484860

Canal 2: Date	Simulated Vol(mm.depth)	Measured Vol(mm.depth)
1.2.99	33.657	73.95
8.2.99	33.657	79.64
15.2.99	33.657	78.51
22.2.99	33.657	68.27
1.3.99	31.855	78.22
8.3.99	31.855	85.33
15.3.99	31.855	68.27
22.3.99	30.336	62.58
29.3.99	30.336	79.64
1.2.99	44.263	74.56
8.2.99	41.510	65.24
15.2.99	53.885	68.34
22.2.99	30.336	68.34
1.3.99	27.904	62.13
8.3.99	27.904	68.34
15.3.99	38.561	37.28
22.3.99	31.855	39.14
29.3.99	30.336	60.58
1.2.99	41.510	90.66
8.2.99	30.336	71.43
15.2.99	38.561	82.42
22.2.99	38.561	98.90
1.3.99	30.336	54.95
8.3.99	38.561	54.95
15.3.99	41.510	65.93
22.3.99	38.561	57.69
29.3.99	49.309	98.90
Mean	35.728	70.155
Sum X	965	1894
Sum X^2	35567	138625
$(\text{Sum X})^2$	930570.471	3587962

Canal 3: Date	Simulated Vol(mm.depth)	Measured Vol(mm.depth)
2.2.99	69.228	79.91
9.2.99	84.579	66.59
16.2.99	77.286	73.25
23.2.99	44.263	119.87
2.3.99	46.854	109.88
9.3.99	53.885	91.56
16.3.99	46.854	66.59
23.3.99	46.854	73.25
30.3.99	46.854	79.91
2.2.99	72.559	92.21
9.2.99	77.286	83.83
16.2.99	67.501	73.35
23.2.99	67.501	122.95
2.3.99	60.100	97.80
9.3.99	60.100	88.02
16.3.99	137.693	75.45
23.3.99	139.397	83.83
30.3.99	133.337	92.21
2.2.99	158.920	74.01
9.2.99	158.920	84.10
16.2.99	163.798	55.51
23.2.99	89.110	84.10
2.3.99	89.110	95.87
9.3.99	89.110	67.28
16.3.99	69.228	60.55
23.3.99	69.228	75.69
30.3.99	69.228	80.74
Mean	84.770	83.271
Sum X	2289	2248
Sum X^2	230847	194097
$(\text{Sum X})^2$	5238514.11	5054956

Canal 4: Date	Simulated Vol(mm.depth)	Measured Vol(mm.depth)
3.2.99	97.544	110.77
10.2.99	84.579	101.54
17.2.99	84.579	101.54
24.2.99	84.579	91.38
3.3.99	84.579	81.23
10.3.99	84.579	116.31
17.3.99	84.579	101.54
24.3.99	69.228	110.77
31.3.99	60.100	95.54
3.2.99	91.292	74.16
10.2.99	91.292	88.48
17.2.99	91.292	67.42
24.2.99	91.292	67.42
3.3.99	91.292	76.85
10.3.99	91.292	64.04
17.3.99	91.292	92.70
24.3.99	91.292	87.64
31.3.99	97.544	103.82
3.2.99	97.544	76.68
10.2.99	97.544	78.38
17.2.99	91.292	65.73
24.2.99	91.292	85.20
3.3.99	91.292	81.06
10.3.99	91.292	100.78
17.3.99	91.292	73.03
24.3.99	91.292	64.75
31.3.99	91.292	87.63
Mean	88.754	86.903
Sum X	2396	2346
Sum X^2	214398	210089
$(\text{Sum X})^2$	5742511.29	5505527

APPENDIX F

Table F-1: Infiltration data

Date	Cum.Time (Sec)	Infiltration. (mm)	Infil.rate (mm/hr)	Cum.infil. (mm)
3.1.99	0	0		0
	2	3	90	3
	4	2	60	5
	6	1.5	45	6.5
	10	2	30	8.5
	14	2	30	10.5
	20	1.5	15	12
	26	1.5	15	13.5
	36	1.5	9	15
	46	1.5	9	16.5
	56	1	6	17.5
	66	1	6	18.5
	86	2	6	20.5
	106	2	6	22.5
	136	2.5	5	25
	166	3	6	28
	196	3	6	31
	226	3	6	34
4.2.99	0	0	0	0
	2	3	90	3
	4	2	60	5
	6	1	30	6
	8	1	30	7
	10	0.5	15	7.5
	14	1	15	8.5
	24	1.5	9	1
	34	2	12	12
	44	1	6	13
	54	2	12	15
	64	1	6	16
	74	1	6	17
	84	1	6	18
	94	1	6	19
	104	0	0	19
	114	0.5	3	19.5
	124	0		19.5
	134	0.5	3	20
	144	1	6	21
	154	1	6	22
	164	0	0	22
	174	0	0	22
	184	0.5	3	22.5

29.3.99	0	0	0	0
	2	4	120	4
	4	2	60	6
	6	1	30	7
	8	2	60	9
	10	1	30	10
	12	1	30	11
	15	1	20	12
	20	1	12	13
	25	1	12	14
	30	2	24	16
	35	1	12	17
	40	1	12	18
	50	2	12	2
	60	2	12	22
	70	1	6	23
	80	1	6	24
	90	2	12	26
	100	1	6	27
	110	1	6	28
	120	2	12	30
	130	1	6	31
	140	1	6	32
	150	1	6	33
	160	1	6	34
	170	1	6	35
	180	1	6	36
25.4.899	0	0		0
	2	3	90	3
	4	2	60	5
	6	2	60	7
	8	1	30	8
	10	1	30	9
	20	4	24	13
	30	5	30	18
	40	4	24	22
	50	2	12	24
	60	1.5	9	25.5
	80	4	12	29.5
	100	2	6	31.5
	120	2	6	33.5
	150	2	6	34.5
	180	2	6	36.5
	210	2	6	38.5

APPENDIX G

Computer program

```
Program compute irrigation interval;
var
 i,cases:integer;
 n,g:real;
 R,dydx,D,Vu,C,Inn,can,day,field : array[1..100] of real;
 K1,K2,K3,A,So,Qs,Q,T,DY,DX,AFi,ETc,Ti,RA,SP : array[1..100] of real;
 fname,fnam1:string[12];infile:text;
 spa1:string[80];spa2:string[14];
 canal : integer;
procedure readdata;
begin
 write('ENTER CANAL NUMBER i.e 1 for canal no. 1 etc. :- ');
 readln(canal);
 write('ENTER FILENAME FOR INPUT DATA              :- ');
 readln(fname);
 assign(infile,fname);
 reset(infile);
 readln(infile,spa1);
 readln(infile,spa2,cases);
 readln(infile,spa1);
 for i:=1 to cases do
 begin
  readln(infile,can[i],day[i],field[i],A[i],So[i],Qs[i],Q[i],T[i],
  DY[i],DX[i],AFi[i],ETc[i],Ti[i],RA[i],SP[i]);
 end;
 close(infile);
end;
procedure compute;
begin
 n:=0.04;
 g:=9.81;
 for i:=1 to cases do
 begin
  R[i]:=exp((3/2)*ln((Q[i]*n)/(A[i]*sqrt(So[i]))));
  DYDX[i]:=DY[i]/DX[i];
  D[i]:=((Q[i]*Ti[i]*60)/(AFi[i]))*100;
  Vu[i]:=D[i]+RA[i]-ETc[i]-SP[i];
  C[i]:=(So[i]-(((sqr(n)*sqr(Q[i]))/(sqr(A[i])*exp((4/3)*ln(R[i]))))-
  ((2*Q[i])/(g*sqr(A[i])))))/(1-(sqr(Q[i])*T[i])/(g*A[i]*A[i]));
  Inn[i]:=((Q[i]*Vu[i])/(ETc[i]))/((1/C[i])*DYDX[i]-Qs[i]);
  K1[i]:=C[i]*((Q[i]*Vu[i])/(ETc[i]));
  K2[i]:=C[i]*Qs[i];
  K3[i]:=C[i]*(A[i]/(Inn[i]*Ti[i]*ETc[i]));
 end;
```

```
end;
procedure results;
begin
 write('ENTER FILENAME FOR OUTPUT/RESULTS          :- ');
 readln(fnam1);
 assign(infile,fnam1);
 rewrite(infile);
 writeln(infile,'RUAHA SCHEDULE');
 writeln(infile,'  ');
 writeln(infile,'OUTPUT DATA FOR CANAL NO. ',canal);
 writeln(infile,' ');
 writeln(infile,'DAY',' ','FIELD','':5,'A','':6,'SO','':7,'Qs','':6,'Q',
 '':7,'T','':7,'DY','':7,'DX','':7,'AFi','':6,'ETc','':6,'Ti','':6,'RA','':7,
 'SP');
 writeln(infile,' ');
 for i:=1 to cases do
 begin
  writeln(infile,round(day[i]),'    ',round(field[i]),'    ',A[i]:5:4,'  ',
  So[i]:5:4,'  ',Qs[i]:5:4,'  ',Q[i]:5:4,'  ',T[i]:5:4,'  ',
  DY[i]:5:4,'  ',DX[i]:5:4,'  ',AFi[i]:5:4,'  ',ETc[i]:5:4,'  ',
  Ti[i]:5:4,'  ',RA[i]:5:4,'  ',SP[i]:5:4);
 end;
 writeln(infile,' ');
 writeln(infile,'More results ...........');
 writeln(infile,' ');
 writeln(infile,'DAY',' ','FIELD','':5,'R','':6,'D','':8,'Vu','':6,
 'C','':7,'Inn','':6,'K1','':6,'K2','':7,'K3');
 writeln(infile,' ');
 for i:=1 to cases do
 begin
  writeln(infile,round(day[i]),'    ',round(field[i]),'    ',R[i]:5:4,
  '  ',D[i]:5:4,'  ',Vu[i]:5:4,'  ',C[i]:5:4,'  ',Inn[i]:5:4,'  ',
  K1[i]:5:4,'  ',K2[i]:5:4,'  ',K3[i]:5:4);
 end;
 writeln(infile,' ');
 writeln(infile,' ');
 writeln(infile,'THIS PROGRAM WAS DEVELOPED BY N.K. SUBIRA');
 writeln(infile,'DEPARTMENT OF AGRICULTURAL ENGINEERING');
 WRITELN(infile,'SOKOINE UNIVERSITY OF AGRICULTURE');
 writeln(infile,'MOROGORO');
 close(infile);
end;
begin
 readdata;
 compute;
 results;
end.
```

APPENDIX H

Table H-1 Analysis of variance for the results computed from equation B-15

SoV	Df	SS	MS	F-Value	Pr > F	Remarks
Canal	3	8342.38	2780.79	79.39	0.0001	***(0.01%)
Method	2	1240.01	620.00	17.70	0.0001	***(0.01%)
Canal*method						
(interaction)	6	1542.85	257.14	7.34	0.0001	***(0.01%)
Error	303	10612.83	35.03			
Total	314	21801.64				

*** Significant different at 0.01%

R- square	CV	Root MSE	Method Mean
0.513	51.99	5.91	11.38

Table H-2 Analysis of variance for the Irrigation .interval on different canals

SoV	Df	SS	MS	F-Value	Pr > F	Remarks
Canal	3	156.10	52.03	37.40	0.0001	***(0.01%)
Method	2	67.94	33.97	24.42	0.0001	***(0.01%)
Canal*method						
(interaction)	6	160.44	26.74	19.22	0.0001	***(0.01%)
Error	303					
Total	314	809.13				

R- square	CV	Root MSE	Irr.interval Mean
0.479	17.58	1.18	6.71

APPENDIX I

Questionnaire for Ruaha Mbuyuni irrigation scheme

A. Background information

Name of Interviewer --Code-------------------
Date ---
Name of respondent---
Tribe---
---Religion---
Questionnaire No-----------

Village		Code
Ward		
Division		
District		
Region		

B. Respondent's information

Item	Value	Response
Gender of respondent	1 = male, 2 = female	
Marital status	1=married, 2=single 3=divorced 4=widowed	
Education of the respondent		
Where born		
Age of the respondent		
For how many years have you been living in this village	Years	
What is your occupation	(i) Agriculture (ii) Business (iii) No occupation (iv) Others, specify	
What is the size of your farm	Acres/hectares	
How did you acquire your land	(i) Inherited (ii) Hired (iii) Bought (iv) Rented (v) Others, specify	

C. History of the scheme

Item	type/value	Response
When was the scheme constructed	Year	
Has there been any government/NGO intervention since its inception	1=Yes 2=No	
If yes in what form	1= Funds 2=Techinical staff 3=Others specify	
When did the government/NGO assistance arrived and who requested it	Years 1=Village leaders 2=beneficiaries'committee 3=Others specify	
Was there any funds raised so as to supplement what the government/NGO had offered	1=Yes 2=No	
If yes how much	1=1-5million 2=5.1-10million 3=10.1-20million	
Was voluntary labour organised for the works which had to be carried out by the government/NGO staff	1=Yes 2=No	
Who organised for both the labour and the fund raising activity	1=Village dev. committee 2=CCM leaders 3= Water users group 4= Others specify	
Has the river changed its course in the scheme's life time	1=Yes 2=No	
If yes how frequently does it change	1=Once per every year 2=Every rainy season 3=Others specify	
How do you construct a new intake every time the river changes its course	1=Voluntary labour 2=Assistance from Gov/NGO 3=Others specify	

D. Irrigation water

Item	type/value	Response
What is the main water source	1=Dam2=River 3=Lake 4=Underground 5=Others specify	
What is the quality of irrigation water	1=Good 2=Medium 3=Poor	
Is the diverted water from the source enough	1=Yes 2=No	
If not what are the limitations in diverting more water	1=Not allowed by water right 2= Water level in the source is low as compared to intake level 3=Others specify	
Do you have a valid water right for the water currently being diverted	1=Yes 2=No	
If no have you started the process of obtaining one	1=Yes 2=No	

E. Plot location

Item	type/value	Response
What is the location of your plot in relation to water supply	1=UPSTREAM (i) Upstream (ii) Middle (iii) Downstream 2=MIDDLE (i)Upstream (ii)Middle (iii)Downstream 3=DOWNSTREAM (i) (i) Upstream (ii) Middle (iii) Downstream	

F. Water Users Association

Item	Value	Response
Do you have water users association	1=Yes 2=No	
If yes is it a registered one	1=Yes 2=No	
If no have you started to process the registration	1=Yes 2=No	

G. Water allocation

Item	Value	Response
By whom are water allocation, scheduling and delivery decisions made and implemented	1=Village CCM chairman 2=Villlage dev. Committee 3=Water users association 4=Individuals 5=Others specify	
How does individual farmer liase and interact with the body responsible for water allocation	1=Through meetings 2=Through dialogue 3=Others specify	
What incentives do the water allocation body have to manage badly or well	1=Salary 2=Others specify	

H: Crop and water relation

Item	type/value	Response
Which crop do you grow by irrigation method	1=Paddy 2=Onion 3=Maize 4=Others specify	
Do you receive enough water for your crops	1=Yes 2=No	
If no what measures do you take		

I. Irrigation scheduling

Item	Value	Response
After how many days do you get your allocation turn	1=1-5days 2=6-10days 3=Others specify	
For how many hours do you irrigate your plot	1=1-2hours 2=2-4hours 3=Others specify	

APPENDIX J

Analysis for questionnaire

A

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	.	24	100.0	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 0 Missing cases 24

B Tribe

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Msagara	1.0	13	54.2	54.2	54.2
Mgogo	2.0	2	8.3	8.3	62.5
Msukuma	3.0	1	4.2	4.2	66.7
Mvidunda	4.0	2	8.3	8.3	75.0
Mpogoro	5.0	3	12.5	12.5	87.5
Mhehe	6.0	3	12.5	12.5	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

C Religion

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Roman_Cat	1.0	4	16.7	16.7	16.7
Islam	2.0	17	70.8	70.8	87.5
Lutheran	3.0	3	12.5	12.5	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

D Gender

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Male	1.0	13	54.2	54.2	54.2
Female	2.0	11	45.8	45.8	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

E Marital status

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Married	1.0	19	79.2	79.2	79.2
Single	2.0	3	12.5	12.5	91.7
Divorced	3.0	1	4.2	4.2	95.8
Widowed	4.0	1	4.2	4.2	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

F Educational level

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
std 4	1.0	4	16.7	16.7	16.7
std 7	2.0	14	58.3	58.3	75.0
std 8	3.0	1	4.2	4.2	79.2
Adult Ed.	4.0	1	4.2	4.2	83.3
F IV	5.0	3	12.5	12.5	95.8
None	6.0	1	4.2	4.2	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

G Birth-place

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
R_Mbuyun	1.0	9	37.5	39.1	39.1
Ngambo ya Kilosa	2.0	1	4.2	4.3	43.5
Malolo	3.0	3	12.5	13.0	56.5
Ulanga	4.0	2	8.3	8.7	65.2

Mbinga	5.0	1	4.2	4.3	69.6
Mahenge	6.0	2	8.3	8.7	78.3
Nyanzwa	7.0	2	8.3	8.7	87.0
Morogoro	8.0	3	12.5	13.0	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

H Age

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
18-28	1.0	8	33.3	34.8	34.8
29-39	2.0	11	45.8	47.8	82.6
40-50	3.0	2	8.3	8.7	91.3
51-60	4.0	2	8.3	8.7	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

I Years stayed

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
1-10	1.0	7	29.2	30.4	30.4
11-20	2.0	3	12.5	13.0	43.5
21-30	3.0	7	29.2	30.4	73.9
31-40	4.0	6	25.0	26.1	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

J Occupation

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Agriculture	1.0	18	75.0	78.3	78.3
1+2	4.0	3	12.5	13.0	91.3
1+5	6.0	2	8.3	8.7	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

K Farm size

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
0.5	1.0	13	54.2	56.5	56.5
1	2.0	5	20.8	21.7	78.3
1.5	3.0	1	4.2	4.3	82.6
2	4.0	2	8.3	8.7	91.3
2.5	5.0	2	8.3	8.7	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

L Land ownership

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Inherited	1.0	2	8.3	8.7	8.7
Hired	2.0	9	37.5	39.1	47.8
Bought	3.0	9	37.5	39.1	87.0
G_by_Vil.com	4.0	3	12.5	13.0	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

M Water source

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
River	2.0	24	100.0	100.0	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

N Irrwater quality

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Good	1.0	24	100.0	100.0	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

O EnWaterSource

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	18	75.0	81.8	81.8
No	2.0	4	16.7	18.2	100.0
	.	2	8.3	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 22 Missing cases 2

P Limitations

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
No intake	3.0	4	16.7	100.0	100.0
	.	20	83.3	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 4 Missing cases 20

Q Water right

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	18	75.0	85.7	85.7
No	2.0	3	12.5	14.3	100.0
	.	3	12.5	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 21 Missing cases 3

R Started process

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	3	12.5	100.0	100.0
	.	21	87.5	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 3 Missing cases 21

S Plot location

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Upstream	1.0	7	29.2	30.4	30.4
Middle	2.0	10	41.7	43.5	73.9
Downstream	3.0	6	25.0	26.1	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

T Farm location

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Upper	1.0	9	37.5	39.1	39.1
Middle	2.0	6	25.0	26.1	65.2
End	3.0	8	33.3	34.8	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

U WUG

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	21	87.5	100.0	100.0
	.	3	12.5	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 21 Missing cases 3

V WUG registered

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	8	33.3	53.3	53.3
No	2.0	7	29.2	46.7	100.0
	.	9	37.5	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 15 Missing cases 9

W Processing

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	8	33.3	100.0	100.0
	.	16	66.7	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 8 Missing cases 16

X Gov/NGO supp.

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	16	66.7	100.0	100.0
	.	8	33.3	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 16 Missing cases 8

Y In what form

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Funds	1.0	2	8.3	12.5	12.5
Technical advice	2.0	10	41.7	62.5	75.0
1+2	3.0	4	16.7	25.0	100.0
	.	8	33.3	Missing	
	Total	24	100.0	100.0	

Valid cases 16 Missing cases 8

Z W_req_supp.

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Village leaders	1.0	16	66.7	100.0	100.0
	.	8	33.3	Missing	
	Total	24	100.0	100.0	

Valid cases 16 Missing cases 8

AA Fund raised

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	14	58.3	93.3	93.3
No	2.0	1	4.2	6.7	100.0
	.	9	37.5	Missing	
	Total	24	100.0	100.0	

Valid cases 15 Missing cases 9

AB How much

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Tshs.500-1000	2.0	10	41.7	66.7	66.7
Over 1000	3.0	5	20.8	33.3	100.0
	.	9	37.5	Missing	
	Total	24	100.0	100.0	

Valid cases 15 Missing cases 9

AC V_labor_Org

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	22	91.7	100.0	100.0
	.	2	8.3	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 22 Missing cases 2

AD Organiser

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Vil_Dev. com	1.0	4	16.7	18.2	18.2
CCM leaders	2.0	1	4.2	4.5	22.7
WUG	3.0	13	54.2	59.1	81.8
Vil. chairman	4.0	3	12.5	13.6	95.5
1+4	5.0	1	4.2	4.5	100.0
	.	2	8.3	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 22 Missing cases 2

AE RiverChange

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	22	91.7	100.0	100.0
	.	2	8.3	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 22 Missing cases 2

AF When

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
1998	2.0	11	45.8	50.0	50.0
1999	3.0	1	4.2	4.5	54.5
1+2	4.0	1	4.2	4.5	59.1
2+3	5.0	9	37.5	40.9	100.0
	.	2	8.3	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 22 Missing cases 2

AG Construction

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Assis from Gov/NGO	1.0	1	4.2	4.5	4.5
Vol. labor	2.0	11	45.8	50.0	54.5
1+2	3.0	10	41.7	45.5	100.0
	.	2	8.3	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 22 Missing cases 2

AH Water_aloc

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
WUG	4.0	24	100.0	100.0	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

AI

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	24	100.0	100.0	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

AJ F&Water_Distr

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Dialogue	2.0	24	100.0	100.0	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

AK Incentive

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
No incentive	3.0	24	100.0	100.0	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

AL Crop

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Paddy	1.0	23	95.8	95.8	95.8
	7.0	1	4.2	4.2	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

AM Crop water

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1.0	13	54.2	56.5	56.5
No	2.0	10	41.7	43.5	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

AN Scheduling

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
7	2.0	24	100.0	100.0	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

AO Irr_hrs

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
2	3.0	11	45.8	47.8	47.8
3	4.0	11	45.8	47.8	95.7
4	5.0	1	4.2	4.3	100.0
	.	1	4.2	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 23 Missing cases 1

AP not Water measures

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
W_scheduling	1.0	6	25.0	40.0	40.0
Steal	2.0	4	16.7	26.7	66.7
Compromise	3.0	5	20.8	33.3	100.0
	.	9	37.5	Missing	
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 15 Missing cases 9

AQ

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	2.0	24	100.0	100.0	100.0
		-------	-------	-------	
	Total	24	100.0	100.0	

Valid cases 24 Missing cases 0

This procedure was completed at 16:16:49

EXIT

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APPENDIX K:

Comparison between Simulated and Model irrigation intervals

Canal 1

Date	Location	Model I_n (days)	Intervals Simulated
7.2.99	C-1U	11	10
14.2.99	C-1U	9	9
21.2.99	C-1U	8	8
28.2.99	C-1U	8	7
7.3.99	C-1U	10	9
14.3.99	C-1U	8	9
21.3.99	C-1U	9	8
28.3.99	C-1U	7	7
7.2.99	C-1M	10	10
14.2.99	C-1M	9	7
21.2.99	C-1M	9	8
28.2.99	C-1M	9	7
7.3.99	C-1M	8	5
14.3.99	C-1M	7	5
21.3.99	C-1M	10	6
28.3.99	C-1M	8	7
7.2.99	C-1E	9	7
14.2.99	C-1E	8	7
21.2.99	C-1E	8	6
28.2.99	C-1E	8	4
7.3.99	C-1E	7	3
14.3.99	C-1E	8	6
21.3.99	C-1E	9	7
28.3.99	C-1E	9	9

NOTE: C-1:= Canal One; U = Upper; M = Middle; E End Locations

Canal 2

Date	Location	Model I_n (days)	Intervals Simulated
1.2.99	C-2U	9	12
8.2.99	C-2U	10	12
15.2.99	C-2U	9	12
22.2.99	C-2U	10	11
1.3.99	C-2U	9	12
8.3.99	C-2U	8	11
15.3.99	C-2U	7	11
22.3.99	C-2U	8	11
29.3.99	C-2U	9	11
1.2.99	C-2M	9	12
8.2.99	C-2M	9	12
15.2.99	C-2M	7	12
22.2.99	C-2M	10	12
1.3.99	C-2M	8	12
8.3.99	C-2M	10	12
15.3.99	C-2M	7	12
22.3.99	C-2M	7	11
29.3.99	C-2M	7	12
1.2.99	C-2E	10	12
8.2.99	C-2E	9	12
15.2.99	C-2E	8	11
22.2.99	C-2E	9	11
1.3.99	C-2E	7	10
8.3.99	C-2E	8	11
15.3.99	C-2E	8	11
22.3.99	C-2E	7	11
29.3.99	C-2E	7	10

NOTE: C-2:= Canal Two; U = Upper; M = Middle; E End Locations

Canal 3

Date	Location	Model I_n (days)	Intervals Simulated
2.2.99	C-3U	9	9
9.2.99	C-3U	7	8
16.2.99	C-3U	9	10
23.2.99	C-3U	8	9
2.3.99	C-3U	7	9
9.3.99	C-3U	7	8
16.3.99	C-3U	7	8
23.3.99	C-3U	7	7
30.3.99	C-3U	5	9
2.2.99	C-3M	7	7
9.2.99	C-3M	8	9
16.2.99	C-3M	8	8
23.2.99	C-3M	6	8
2.3.99	C-3M	7	8
9.3.99	C-3M	7	7
16.3.99	C-3M	6	8
23.3.99	C-3M	7	7
30.3.99	C-3M	6	9
2.2.99	C-3E	6	8
9.2.99	C-3E	6	7
16.2.99	C-3E	6	7
23.2.99	C-3E	6	9
2.3.99	C-3E	5	8
9.3.99	C-3E	6	6
16.3.99	C-3E	5	6
23.3.99	C-3E	5	7
30.3.99	C-3E	5	9

NOTE: C-3:= Canal Three; U = Upper; M = Middle; E End Locations

Canal 4

Date	Location	Model I_n (days)	Intervals Simulated
3.2.99	C-4U	6	6
10.2.99	C-4U	6	7
17.2.99	C-4U	5	7
24.2.99	C-4U	4	7
3.3.99	C-4U	4	6
10.3.99	C-4U	8	7
17.3.99	C-4U	5	6
24.3.99	C-4U	8	6
31.3.99	C-4U	6	6
3.2.99	C-4M	5	7
10.2.99	C-4M	5	7
17.2.99	C-4M	4	9
24.2.99	C-4M	3	7
3.3.99	C-4M	3	7
10.3.99	C-4M	4	7
17.3.99	C-4M	5	6
24.3.99	C-4M	6	7
31.3.99	C-4M	7	7
3.2.99	C-4E	5	7
10.2.99	C-4E	3	7
17.2.99	C-4E	5	6
24.2.99	C-4E	4	7
3.3.99	C-4E	3	7
10.3.99	C-4E	7	6
17.3.99	C-4E	4	7
24.3.99	C-4E	4	7
31.3.99	C-4E	5	7

NOTE: C-4:= Canal Four; U = Upper; M = Middle; E End Locations

APPENDIX L

Table L – 1 Canal 1 Results computed from the equation $dy/dx=(K_3V_u^2+K_2)$ Using different irrigation intervals

Date	Design I_n (days)	Design dy/dx	Model dy/dx	Model I_n (days)	Observed dy/dx	Observed I_n (days)
7.2.99	13	3.40	0.00100	11	0.00100	7
	13	4.65	0.00150	10	0.00150	7
	13	4.53	0.00150	9	0.00150	7
14.2.99	8	5.33	0.00100	9	0.00100	7
	8	8.04	0.00150	9	0.00150	7
	8	6.03	0.00125	8	0.00125	7
21.2.99	8	5.99	0.00125	8	0.00125	7
	8	6.59	0.00125	9	0.00125	7
	8	9.73	0.00200	8	0.00200	7
28.2.99	9	5.75	0.00150	8	0.00150	7
	8	7.11	0.00150	9	0.00150	7
	8	10.63	0.00250	8	0.00250	7
7.3.99	8	10.57	0.00150	10	0.00150	7
	8	13.67	0.00250	8	0.00250	7
	8	12.35	0.00250	7	0.00250	7
14.3.99	8	2.7	0.00050	8	0.00050	7
	8	4.78	0.00100	7	0.00100	7
	8	5.11	0.00100	8	0.00100	7
21.3.99	4	23.89	0.00200	9	0.00200	7
	4	25.43	0.00200	10	0.00200	7
	4	21.31	0.00175	9	0.00175	7
28.3.99	4	10.54	0.00125	7	0.00125	7
	4	13.96	0.00150	8	0.00150	7
	4	16.65	0.00150	9	0.00150	7

Table L- 2 Canal 2 Results computed from the equation $dy/dx=(K_3V_u^2+K_2)$ using different irrigation intervals

Date	Design I_n (days)	Design dy/dx	Model dy/dx	Model I_n (days)	Observed dy/dx	Observed I_n (days)
1.2.99	6	7.54	0.00023	9	0.00023	7
	6	7.03	0.00023	9	0.00023	7
	6	8.15	0.00023	10	0.00023	7
8.2.99	6	7.11	0.00023	10	0.00023	7
	6	5.52	0.00020	9	0.00020	7
	6	5.76	0.00020	9	0.00020	7
15.2.99	5	8.01	0.00020	9	0.00020	7
	5	6.17	0.00018	7	0.00018	7
	5	7.08	0.00018	8	0.00018	7
22.2.99	6	14.51	0.00040	10	0.00040	7
	6	13.32	0.00035	10	0.00035	7
	6	21.63	0.00060	10	0.00060	7
1.3.99	6	7.04	0.00018	9	0.00018	7
	6	4.83	0.00015	8	0.00015	7
	6	4.13	0.00015	7	0.00015	7
8.3.99	8	7.64	0.00030	8	0.00030	7
	8	6.51	0.00020	10	0.00020	7
	8	4.57	0.00018	8	0.00018	7
15.3.99	5	10.86	0.00035	7	0.00035	7
	5	5.07	0.00018	7	0.00018	7
	5	10.42	0.00030	8	0.00030	7
22.3.99	4	15.57	0.00030	8	0.00030	7
	4	8.44	0.00018	8	0.00018	7
	4	13.52	0.00030	7	0.00030	7
29.3.99	4	16.08	0.00035	9	0.00035	7
	4	10.78	0.00030	7	0.00030	7
	4	17.66	0.00050	7	0.00050	7

Table L- 3 Canal 3 Results computed from the equation $dy/dx=(K_3V_u^2+K_2)$ using different irrigation intervals

Date	Design I_n (days)	Design dy/dx	Model dy/dx	Model I_n (days)	Observed dy/dx	Observed I_n (days)
2.2.99	6	28.0	0.00100	9	0.00100	7
	6	26.7	0.00150	7	0.00150	7
	6	24.0	0.00125	6	0.00125	7
9.2.99	6	19.5	0.00040	7	0.00040	7
	6	19.0	0.00045	8	0.00045	7
	6	23.6	0.00060	6	0.00060	7
16.2.99	5	18.0	0.00045	9	0.00045	7
	5	20.5	0.00045	8	0.00045	7
	5	25.6	0.00045	6	0.00045	7
23.2.99	6	21.0	0.00110	7	0.00110	7
	6	22.0	0.00125	6	0.00125	7
	6	41.0	0.00095	5	0.00095	7
2.3.99	6	21.0	0.00095	7	0.00095	7
	6	32.8	0.00075	7	0.00075	7
	6	39.5	0.00075	6	0.00075	7
9.3.99	8	29.3	0.00400	7	0.00400	7
	8	27.0	0.00410	6	0.00410	7
	8	32.8	0.00375	5	0.00375	7
16.3.99	5	52.0	0.00533	7	0.00533	7
	5	55.4	0.00533	7	0.00533	7
	5	52.0	0.00567	5	0.00567	7
23.3.99	4	29.7	0.00167	7	0.00167	7
	4	23.8	0.00167	6	0.00167	7
	4	20.5	0.00167	5	0.00167	7
30.3.99	4	14.9	0.00100	6	0.00100	7
	4	12.5	0.00100	6	0.00100	7
	4	13.3	0.00100	5	0.00100	7

Table L- 4 Canal 4 Results computed from the equation $dy/dx=(K_3V_u^2+K_2)$ using different irrigation intervals

Date	Design I_n (days)	Design dy/dx	Model dy/dx	Model I_n (days)	Observed dy/dx	Observed I_n (days)
3.2.99	6	10.84	0.00200	6	0.00200	7
	6	6.17	0.00150	5	0.00150	7
	6	6.14	0.00150	5	0.00150	7
10.2.99	6	7.66	0.00150	6	0.00150	7
	6	6.2	0.00150	5	0.00150	7
	6	4.68	0.00150	3	0.00150	7
17.2.99	5	8.63	0.00150	5	0.00150	7
	5	4.72	0.00100	4	0.00100	7
	5	4.11	0.00075	5	0.00075	7
24.2.99	6	6.72	0.00175	4	0.00175	7
	6	4.18	0.00175	3	0.00175	7
	6	5.61	0.00175	4	0.00175	7
3.3.99	6	6.99	0.00175	4	0.00175	7
	6	5.64	0.00175	3	0.00175	7
	6	5.7	0.00175	3	0.00175	7
10.3.99	8	9.29	0.00175	8	0.00175	7
	8	4.49	0.00175	4	0.00175	7
	8	8.68	0.00200	7	0.00200	7
17.3.99	5	10.74	0.00200	5	0.00200	7
	5	9.65	0.00200	5	0.00200	7
	5	6.58	0.00175	4	0.00175	7
24.3.99	4	18.17	0.00175	8	0.00175	7
	4	13.91	0.00175	6	0.00175	7
	4	9.23	0.00175	4	0.00175	7
31.3.99	4	13.74	0.00175	6	0.00175	7
	4	14.47	0.00175	7	0.00175	7
	4	10.79	0.00175	5	0.00175	7

CANAL 1 LOCATION: Upper

Date	Farm No.	Area (A_n) (m^2)	Water In (l/s)	Average Q (l/s)	Duration (min)	Volume (m^3)	Depth (mm)	Avrge Q (m^3/s)	Manning's n	X-Area A (m^2)	Canal Slope%(S)	Hyd. R (m) $((Qn/AS))^{1.5}$	Top width	($R^{4/3}$)	($A^2 R^{4/3}$)	$n^2Q^2/A^2 R^{4/3}$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
						(4*6)*0.06	(7/3)*1000	(5/1000)	(Constant)	Measured	Measured	9*10/11*12	Measured			
7.2.99	1U	260.36	7.0	6.92	50	21.00	80.66	0.00700	0.04	0.100	2.0	0.00279	0.9	0.00039	0.0000	0.0200
14.2.99	1U	260.36	6.0	6.08	55	19.80	76.05	0.00608	0.04	0.100	2.0	0.00226	0.9	0.00030	0.0000	0.0200
21.2.99	1U	260.36	6.5	6.07	45	17.55	67.41	0.00607	0.04	0.100	2.0	0.00225	0.9	0.00029	0.0000	0.0200
28.2.99	1U	260.36	7.0	6.67	40	16.80	64.53	0.00667	0.04	0.100	2.0	0.00259	0.9	0.00036	0.0000	0.0200
7.3.99	1U	260.36	5.5	5.33	30	9.90	38.02	0.00533	0.04	0.100	2.0	0.00185	0.9	0.00023	0.0000	0.0200
14.3.99	1U	260.36	6.0	5.50	30	10.80	41.48	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
21.3.99	1U	260.36	6.0	5.50	40	14.40	55.31	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
28.3.99	1U	260.36	6.5	6.17	40	15.60	59.92	0.00617	0.04	0.100	2.0	0.00231	0.9	0.00030	0.0000	0.0200
7.2.99	2M	120.51	7.0	6.92	30	12.60	104.56	0.00700	0.04	0.100	2.0	0.00279	0.9	0.00039	0.0000	0.0200
14.2.99	2M	120.51	6.0	6.08	36	12.96	107.54	0.00608	0.04	0.100	2.0	0.00226	0.9	0.00030	0.0000	0.0200
21.2.99	2M	120.51	5.2	6.07	34	10.61	88.03	0.00607	0.04	0.100	2.0	0.00225	0.9	0.00029	0.0000	0.0200
28.2.99	2M	120.51	7.0	6.67	20	8.40	69.70	0.00667	0.04	0.100	2.0	0.00259	0.9	0.00036	0.0000	0.0200
7.3.99	2M	120.51	5.5	5.33	26	8.58	71.20	0.00533	0.04	0.100	2.0	0.00185	0.9	0.00023	0.0000	0.0200
14.3.99	2M	120.51	5.5	5.50	25	8.25	68.46	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
21.3.99	2M	120.51	5.5	5.50	30	9.90	82.15	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
28.3.99	2M	120.51	6.0	6.17	27	9.72	80.66	0.00617	0.04	0.100	2.0	0.00231	0.9	0.00030	0.0000	0.0200
7.2.99	3E	115.15	6.8	6.92	30	12.15	105.51	0.00692	0.04	0.100	2.0	0.00274	0.9	0.00038	0.0000	0.0200
14.2.99	3E	115.15	6.3	6.08	25	9.38	81.42	0.00608	0.04	0.100	2.0	0.00226	0.9	0.00030	0.0000	0.0200
21.2.99	3E	115.15	6.5	6.07	30	11.70	101.61	0.00607	0.04	0.100	2.0	0.00225	0.9	0.00029	0.0000	0.0200
28.2.99	3E	115.15	6.0	6.67	36	12.96	112.55	0.00667	0.04	0.100	2.0	0.00259	0.9	0.00036	0.0000	0.0200
7.3.99	3E	115.15	5.0	5.33	27	8.10	70.34	0.00533	0.04	0.100	2.0	0.00185	0.9	0.00023	0.0000	0.0200
14.3.99	3E	115.15	5.0	5.50	30	9.00	78.16	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
21.3.99	3E	115.15	5.0	5.50	26	7.80	67.74	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
28.3.99	3E	115.15	6.0	6.17	30	10.80	93.79	0.00617	0.04	0.100	2.0	0.00230	0.9	0.00030	0.0000	0.0200

CANAL 1 LOCATION: Upper

Date	Farm No.	Area (A_n) (m^2)	Water in (l/s)	Average Q (l/s)	Duration (min)	Volume (m^3)	Depth (mm)	Avrge Q (m^3/s)	Manning's n	X-Area A (m^2)	Canal Slope%(S)	Hyd. R (m) $((Qn/AS))^{1.5}$	Top width	($R^{4/3}$)	($A^2 R^{4/3}$)	$n^2Q^2/A^2 R^{4/3}$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
						(4*6)*0.06	(7/3)*1000	(5/1000)	(Constant)	Measured	Measured	9*10/11*12	Measured			
7.2.99	1U	260.36	7.0	6.92	50	21.00	80.66	0.00700	0.04	0.100	2.0	0.00279	0.9	0.00039	0.0000	0.0200
14.2.99	1U	260.36	6.0	6.08	55	19.80	76.05	0.00608	0.04	0.100	2.0	0.00226	0.9	0.00030	0.0000	0.0200
21.2.99	1U	260.36	6.5	6.07	45	17.55	67.41	0.00607	0.04	0.100	2.0	0.00225	0.9	0.00029	0.0000	0.0200
28.2.99	1U	260.36	7.0	6.67	40	16.80	64.53	0.00667	0.04	0.100	2.0	0.00259	0.9	0.00036	0.0000	0.0200
7.3.99	1U	260.36	5.5	5.33	30	9.90	38.02	0.00533	0.04	0.100	2.0	0.00185	0.9	0.00023	0.0000	0.0200
14.3.99	1U	260.36	6.0	5.50	30	10.80	41.48	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
21.3.99	1U	260.36	6.0	5.50	40	14.40	55.31	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
28.3.99	1U	260.36	6.5	6.17	40	15.60	59.92	0.00617	0.04	0.100	2.0	0.00231	0.9	0.00030	0.0000	0.0200
7.2.99	2M	120.51	7.0	6.92	30	12.60	104.56	0.00700	0.04	0.100	2.0	0.00279	0.9	0.00039	0.0000	0.0200
14.2.99	2M	120.51	6.0	6.08	36	12.96	107.54	0.00608	0.04	0.100	2.0	0.00226	0.9	0.00030	0.0000	0.0200
21.2.99	2M	120.51	5.2	6.07	34	10.61	88.03	0.00607	0.04	0.100	2.0	0.00225	0.9	0.00029	0.0000	0.0200
28.2.99	2M	120.51	7.0	6.67	20	8.40	69.70	0.00667	0.04	0.100	2.0	0.00259	0.9	0.00036	0.0000	0.0200
7.3.99	2M	120.51	5.5	5.33	26	8.58	71.20	0.00533	0.04	0.100	2.0	0.00185	0.9	0.00023	0.0000	0.0200
14.3.99	2M	120.51	5.5	5.50	25	8.25	68.46	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
21.3.99	2M	120.51	5.5	5.50	30	9.90	82.15	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
28.3.99	2M	120.51	6.0	6.17	27	9.72	80.66	0.00617	0.04	0.100	2.0	0.00231	0.9	0.00030	0.0000	0.0200
7.2.99	3E	115.15	6.8	6.92	30	12.15	105.51	0.00692	0.04	0.100	2.0	0.00274	0.9	0.00038	0.0000	0.0200
14.2.99	3E	115.15	6.3	6.08	25	9.38	81.42	0.00608	0.04	0.100	2.0	0.00226	0.9	0.00030	0.0000	0.0200
21.2.99	3E	115.15	6.5	6.07	30	11.70	101.61	0.00607	0.04	0.100	2.0	0.00225	0.9	0.00029	0.0000	0.0200
28.2.99	3E	115.15	6.0	6.67	36	12.96	112.55	0.00667	0.04	0.100	2.0	0.00259	0.9	0.00036	0.0000	0.0200
7.3.99	3E	115.15	5.0	5.33	27	8.10	70.34	0.00533	0.04	0.100	2.0	0.00185	0.9	0.00023	0.0000	0.0200
14.3.99	3E	115.15	5.0	5.50	30	9.00	78.16	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
21.3.99	3E	115.15	5.0	5.50	26	7.80	67.74	0.00550	0.04	0.100	2.0	0.00194	0.9	0.00024	0.0000	0.0200
28.3.99	3E	115.15	6.0	6.17	30	10.80	93.79	0.00617	0.04	0.100	2.0	0.00230	0.9	0.00030	0.0000	0.0200

1/C	dy(m)	dx(m)	dy/dx	(1/C)*dy/dx	CanalS&P q_s (m^3/s/m)	(1/C)*dy/dx minus q_s	Reciprocal	Model I_n (Days)	K_1	K_2	I_n*TI*ETc	Afi/I_nTIET$_c$	K_3	Model $K_1/I_n + K_2$ eq. 24	Model V_u^2	Model $K_3V_u^2$
35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
-6.97564286	0.014	20	0.00068	0.00697564	0.000125	0.00685064	145.9717	11	-0.01060824	-0.0179195	3.30535199	78.7692206	-11.292	-0.019	5218.264	-0.059
-8.04007421	0.020	20	0 00100	0.00804007	0.000125	0.00791507	126.341	9	-0.00886734	-0.01554712	2.57611083	101.06708	-12.570	-0.017	4698.903	-0.059
-8.05340988	0.025	20	0.00125	0.01006676	0.000125	0.00994176	100.586	8	-0.00995108	-0.01552138	1.60695264	162.020954	-20.118	-0.017	3681.658	-0.074
-7.32380809	0.030	20	0.00150	0 01098571	0.000125	0.01086071	92.07499	8	-0.01181028	-0.01706762	1.34434631	193.670335	-26.444	-0.019	3364.701	-0.089
-9.17864164	0.023	20	0.00113	0.01376796	0.000125	0.01364296	73.29786	10	-0.01537463	-0.01361857	1.13263145	229.871773	-25.044	-0.015	3561.019	-0.089
-8.89343182	0.023	20	0.00113	0.00444672	0.000125	0 00432172	231.390	8	-0.00407011	-0.01405532	1.191020	218.602587	-24.580	-0.015	1186.184	-0.029
-8.89343182	0.028	20	0.00138	0.01778686	0 000125	0 01766186	56.61917	9	-0.01792118	-0.01405532	1.80480199	144.259592	-16.221	-0.016	7345.867	-0.119
-7.92199189	0.029	20	0.00147	0.00990249	0.000125	0.00977749	102.27574	7	-0.0088846	-0.01577886	1.25830681	206.912971	-26.119	-0.017	2835.247	-0.074
-6.97564286	0.012	20	0.00058	0.01046346	0.000125	0.01033846	96.72616	10	-0.01449385	-0.0179195	1.7954968	67.1179142	-9.622	-0.019	9242.061	-0.089
-8.04007421	0.030	20	0.00150	0.01206011	0.000125	0.01193511	83.78640	9	-0.01335607	-0.01554712	1.68429545	71.5492047	-8.899	-0.017	10008.590	-0.089
-8.05340988	0.025	20	0.00125	0.01006676	0.000125	0.00994176	100.58579	9	-0.01094326	-0.01552138	1 33519789	90.2562838	-11.207	-0.017	6609.022	-0.074
-7.32380809	0.030	20	0.00150	0.01098571	0.000125	0.01086071	92 07499	9	-0.01297189	-0.01706762	0.73828569	163.229493	-22.288	-0.019	3992.187	-0.089
-9.17864164	0.045	20	0.00227	0.0229466	0 000125	0.0228216	43.81813	8	-0.01987773	-0.01361857	0.75869158	158.839248	-17.305	-0.016	8620.642	-0.149
-8.89343182	0.046	20	0.00230	0.00889343	0.000125	0.00876843	114 04548	7	-0.00718936	-0.01405532	0.86408424	139.465569	-15.682	-0.015	3772.300	-0.059
-8.89343182	0.040	20	0.00200	0.01778686	0 000125	0.01766186	56.61917	10	-0.01907255	-0.01405532	1.44056525	83 6546624	-9.406	-0.016	12667.696	-0.119
-7.92199189	0.033	20	0.00165	0.01188299	0.000125	0.01175799	85.04857	8	-0.01176266	-0 01577886	0.93508716	128.875687	-16.268	-0.017	5474.107	-0.089
-7.06044127	0.030	20	0 00150	0.01059066	0.000125	0.01046566	95.55057	9	-0.01395719	-0.01770	1.72876382	66.608289	-9.434	-0.019	9427.351	-0.089
-8.0356387	0.029	20	0.00146	0.01004455	0.000125	0.00991955	100.81104	8	-0.01003738	-0.0155557	1.05704228	108.93604	-13.557	-0.017	5463.508	-0.074
-8.05786484	0.040	20	0.00200	0.01611573	0.000125	0.01599073	62.53623	8	-0.01613192	-0.01551279	1.08034542	106.58628	-13.228	-0.017	9001.569	-0.119
-7.3275	0.050	20	0.00250	0.01831875	0.000125	0.01819375	54.96393	8	-0.01938162	-0.01705902	1.18587405	97.1013743	-13.252	-0.020	11242.117	-0.149
-9.172875	0.056	20	0.00281	0.02293219	0.000125	0.02280719	43 84583	7	-0.01796637	-0.01362713	0.71211612	161.701157	-17.628	-0.016	8462.718	-0.149
-8.89343182	0.036	20	0.00180	0.00889343	0.000125	0.00876843	114.04548	8	-0.00767563	-0.01405532	1.10703438	104.016644	-11.696	-0.015	5057.901	-0.059
-8.89343182	0 035	20	0.00175	0.01556351	0.000125	0.01543851	64.77311	9	-0.01598719	-0.01405532	1.1972352	96.1799321	-10.815	-0.016	9631.015	-0.104
-7.92630	0.020	20	0.00098	0.01188946	0.000125	0.01176446	85.00180	9	-0.01401787	-0.01577028	1.238180	92 9994357	-11.733	-0.017	7590.018	-0.089

Model	Observed	Observed	Observed	Design	Design	Design	Design	Design	Design
$K_3V_u^2+K_2$ eq. 25	K_1/I_n+K_2 I_n=7days	K_3 I_n=7days	$K_3V_u^2+K_2$ I_n=7days	Design I_n Intervals	Design K_3	$K_3V_u^2+K_2$	K_1/I_n+K_2	$K_3V_u^2+K_2$	K_1/I_n+K_2
52	53	54	55	56	57	58	59	60	61
-0.077	-0.019	121.550	6.32	13	65 45	3.40	-0.01873551	3.40	-0.01962731
-0.075	-0.017	130.050	6.10	8	113.79	5.33	-0.01665554	5.33	-0.01665554
-0.090	-0.017	186.578	6.85	8	163.26	5.99	-0.01676526	5.99	-0.01676526
-0.106	-0.019	220.345	7.40	9	171.38	5.75	-0.01837988	5.75	-0.01837988
-0.103	-0.016	339.674	12.08	8	297.21	10.57	-0.0155404	10.57	-0.0155404
-0.043	-0.015	261.563	3.09	8	228.87	2.70	-0.01456408	2.70	-0.01456408
-0.133	-0.017	185.971	13.65	4	325.45	23.89	-0.01853561		
-0.090	-0.017	212.782	6.02	4	372.37	10.54	-0.01800001	10.54	-0.01800001
-0.107	-0.020	93.768	8.65	13	50.49	4.65	-0.01903441	4.65	-0.01994043
-0 105	-0.017	91.964	9.19	8	80.47	8.04	-0.01721663	8.04	-0.01721663
-0.090	-0.017	114.299	7.54	8	100.01	6.59	-0.01688928	6.59	-0.01688928
-0.106	-0.019	203.978	8.13	8	178.48	7.11	-0.01868911	7.11	-0.01868911
-0.163	-0.016	181.409	15.63	8	158.73	13.67	-0.01610329	13.67	-0.01610329
-0.073	-0.015	145.280	5.47	8	127.12	4.78	-0 01495399	4.78	-0.01495399
-0.133	-0.017	114.771	14.52	4	200.85	25.43	-0.01882345	25.43	-0.01882345
-0.105	-0.017	145.908	7.97	4	255.34	13.96	-0.01871952	13.96	-0.01871952
-0.107	-0.020	89.597	8.43	13	48.24	4.53	-0.01877791	4.53	-0.01877791
-0.090	-0.017	126.538	6.90	8	110.72	6.03	-0.01681037	6.03	-0.01681037
-0.135	-0.018	123.777	11.13	8	108.31	9.73	-0.01752928	9.73	-0.01752928
-0.166	-0.020	108.281	12 16	8	94.75	10.63	-0.01948173	10.63	-0.01948173
-0.163	-0.016	166.920	14.11	8	146.06	12.35	-0.01587293	12.35	-0.01587293
-0.073	-0 015	115.682	5.84	8	101.22	5.11	-0.01501477	5.11	-0.01501477
-0.118	-0.016	126.538	12.17	4	221.44	21.31	-0.01805211	21.31	-0.01805211
-0.105	-0.018	125.477	9.51	4	219.58	16.65	-0.01927474	16.65	-0.01927474

2 LOCATION:Middle

Rashid Danan

Date	Farm No.	Area (A_n) (m^2)	Water In (l/s)	Average Q (l/s)	Duration (min)	Volume (m^3)	Depth (mm)	Avrge Q (m^3/s)	Manning's n	X-Area A (m^2)	Canal Slope%(S)	Hyd. R (m) $((Qn/AS))^{1.5}$	Top width	($R^{4/3}$)	($A^2R^{4/3}$)	$n^2Q^2/A^2R^{4/3}$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
						(4*6)*0.06	(7/3)*1000	(5/1000)	(Constant)	Measured	Measured	9*10/11*12	Measured			
1.2.99	1U	105.47	6.50	6.00	20	7.80	73.95	0.00600	0.04	0.214	1.2	0.00104	0.95	0.00010	0.0000	0.0120
8.2.99	1U	105.47	7.00	6.83	20	8.40	79.64	0.00683	0.04	0.214	1.2	0.00126	0.95	0.00014	0.0000	0.0120
15.2.99	1U	105.47	6.00	5.50	23	8.28	78.51	0.00550	0.04	0.214	1.2	0.00091	0.95	0.00009	0.0000	0.0120
22.2.99	1U	105.47	6.00	5.83	20	7.20	68.27	0.00583	0.04	0.214	1.2	0.00099	0.95	0.00010	0.0000	0.0120
1.3.99	1U	105.47	5.50	5.17	25	8.25	78.22	0.00517	0.04	0.214	1.2	0.00083	0.95	0.00008	0.0000	0.0120
8.3.99	1U	105.47	5.00	5.17	30	9.00	85.33	0.00517	0.04	0.214	1.2	0.00083	0.95	0.00008	0.0000	0.0120
15.3.99	1U	105.47	6.00	6.00	20	7.20	68.27	0.00600	0.04	0.214	1.2	0.00104	0.95	0.00010	0.0000	0.0120
22.3.99	1U	105.47	5.50	5.33	20	6.60	62.58	0.00533	0.04	0.214	1.2	0.00087	0.95	0.00008	0.0000	0.0120
29.3.99	1U	105.47	7.00	6.50	20	8.40	79.64	0.00650	0.04	0.214	1.2	0.00117	0.95	0.00012	0.0000	0.0120
1.2.99	2M	96.57	6.00	6.00	20	7.20	74.56	0.00600	0.04	0.214	1.2	0.00104	0.95	0.00010	0.0000	0.0120
8.2.99	2M	96.57	7.00	6.83	15	6.30	65.24	0.00683	0.04	0.214	1.2	0.00126	0.95	0.00014	0.0000	0.0120
15.2.99	2M	96.57	5.50	5.50	20	6.60	68.34	0.00550	0.04	0.214	1.2	0.00091	0.95	0.00009	0.0000	0.0120
22.2.99	2M	96.57	5.50	5.83	20	6.60	68.34	0.00583	0.04	0.214	1.2	0.00099	0.95	0.00010	0.0000	0.0120
1.3.99	2M	96.57	5.00	5.17	20	6.00	62.13	0.00517	0.04	0.214	1.2	0.00083	0.95	0.00008	0.0000	0.0120
8.3.99	2M	96.57	5.50	5.17	20	6.60	68.34	0.00517	0.04	0.214	1.2	0.00083	0.95	0.00008	0.0000	0.0120
15.3.99	2M	96.57	6.00	6.00	10	3.60	37.28	0.00600	0.04	0.214	1.2	0.00104	0.95	0.00010	0.0000	0.0120
22.3.99	2M	96.57	5.25	5.33	12	3.78	39.14	0.00533	0.04	0.214	1.2	0.00087	0.95	0.00008	0.0000	0.0120
29.3.99	2M	96.57	6.50	6.50	15	5.85	60.58	0.00650	0.04	0.214	1.2	0.00117	0.95	0.00012	0.0000	0.0120
1.2.99	3E	109.20	5.50	6.00	30	9.90	90.66	0.00600	0.04	0.214	1.2	0.00104	0.95	0.00010	0.0000	0.0120
8.2.99	3E	109.20	6.50	6.83	20	7.80	71.43	0.00683	0.04	0.214	1.2	0.00126	0.95	0.00014	0.0000	0.0120
15.2.99	3E	109.20	5.00	5.50	30	9.00	82.42	0.00550	0.04	0.214	1.2	0.00091	0.95	0.00009	0.0000	0.0120
22.2.99	3E	109.20	6.00	5.83	30	10.80	98.90	0.00583	0.04	0.214	1.2	0.00099	0.95	0.00010	0.0000	0.0120
1.3.99	3E	109.20	5.00	5.17	20	6.00	54.95	0.00517	0.04	0.214	1.2	0.00083	0.95	0.00008	0.0000	0.0120
8.3.99	3E	109.20	5.00	5.17	20	6.00	54.95	0.00517	0.04	0.214	1.2	0.00083	0.95	0.00008	0.0000	0.0120
15.3.99	3E	109.20	6.00	6.00	20	7.20	65.93	0.00600	0.04	0.214	1.2	0.00104	0.95	0.00010	0.0000	0.0120
22.3.99	3E	109.20	5.25	5.33	20	6.30	57.69	0.00533	0.04	0.214	1.2	0.00087	0.95	0.00008	0.0000	0.0120
29.3.99	3E	109.20	6.00	6.50	30	10.80	98.90	0.00650	0.04	0.214	1.2	0.00117	0.95	0.00012	0.0000	0.0120

o Rashid Danando

CANAL NAME:Rashid Danando

2Q/gA²	Eqn.B.6 numerator	$1-(Q^2T/gA^3$ denomina	Num/Deno Eqn.B.6	Rainfall (mm)	ETc mm/day	S&P (mm/day)	Vu(mm) Vu(mm) Q_f(In mm)	Qf*Afi/1000 Qf(m³)	Q_f(m³/s) Q_f(m³/s)	Q_f*1000 Q_f(l/s)	Tc*Afi/100 (m³/day)	Q_fT_f/A_nET_c	CanalS&P q_s (l/s/m)	Qf*Vu)/100 (m⁴/s)	ETc (m\day)	(m³day/s) Qf*Vu/ETc
18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
							8+22-23-24	25*3/1000	26/6*60s							
0.0267	-0.0267	0.9996	-0.0267	0.0	5.15	2.3	28.58	3.01	0.0058	5.8452	0.5431706	13	0.345	0.000389	0.00515	0.0755
0.0304	-0.0304	0.9995	-0.0304	0.0	6.24	2.3	33.18	3.50	0.0062	6.2494	0.6581328	11	0.345	0.000444	0.00624	0.0712
0.0245	-0.0245	0.9997	-0.0245	0.0	5.69	2.3	32.59	3.44	0.0054	5.3893	0.6001243	12	0.345	0.000380	0.00569	0.0668
0.0260	-0.0260	0.9997	-0.0260	1.9	2.58	2.3	46.32	4.89	0.0057	5.7381	0.2721126	25	0.345	0.000375	0.00258	0.1452
0.0230	-0.0230	0.9997	-0.0230	0.5	5.08	2.3	33.42	3.52	0.0050	5.0162	0.5357876	14	0.345	0.000358	0.00508	0.0704
0.0230	-0.0230	0.9997	-0.0230	0.7	3.68	2.3	51.61	5.44	0.0047	4.6906	0.3881296	22	0.345	0.000375	0.00368	0.1020
0.0267	-0.0267	0.9996	-0.0267	0.5	3.81	2.3	43.69	4.61	0.0055	5.5069	0.4018407	16	0.345	0.000345	0.00381	0.0906
0.0237	-0.0237	0.9997	-0.0237	0.6	2.85	2.3	39.06	4.12	0.0051	5.1001	0.3005895	20	0.345	0.000296	0.00285	0.1038
0.0289	-0.0289	0.9996	-0.0289	0.8	4.45	2.3	35.77	3.77	0.0065	6.4770	0.4693415	17	0.345	0.000477	0.00445	0.1073
0.0267	-0.0267	0.9996	-0.0267	0.0	5.15	2.3	67.11	6.48	0.0054	5.4005	0.4973355	13	0.345	0.000362	0.00515	0.0704
0.0304	-0.0304	0.9995	-0.0304	0.0	6.24	2.3	56.70	5.48	0.0061	6.0837	0.6025968	9	0.345	0.000345	0.00624	0.0553
0.0245	-0.0245	0.9997	-0.0245	0.0	5.69	2.3	60.35	5.83	0.0049	4.8570	0.5494833	11	0.345	0.000293	0.00569	0.0515
0.0260	-0.0260	0.9997	-0.0260	1.9	2.58	2.3	65.36	6.31	0.0053	5.2602	0.2491506	25	0.345	0.000344	0.00258	0.1333
0.0230	-0.0230	0.9997	-0.0230	0.5	5.08	2.3	55.25	5.34	0.0044	4.4463	0.4905756	11	0.345	0.000246	0.00508	0.0484
0.0230	-0.0230	0.9997	-0.0230	0.7	3.68	2.3	63.06	6.09	0.0051	5.0751	0.3553776	17	0.345	0.000320	0.00368	0.0870
0.0267	-0.0267	0.9996	-0.0267	0.5	3.81	2.3	31.67	3.06	0.0051	5.0971	0.3679317	8	0.345	0.000161	0.00381	0.0424
0.0237	-0.0237	0.9997	-0.0237	0.6	2.85	2.3	34.59	3.34	0.0046	4.6397	0.2752245	12	0.345	0.000161	0.00285	0.0563
0.0289	-0.0289	0.9996	-0.0289	0.8	4.45	2.3	54.63	5.28	0.0059	5.8616	0.4297365	12	0.345	0.000320	0.00445	0.0720
0.0267	-0.0267	0.9996	-0.0267	0.0	5.15	2.3	52.34	5.72	0.0050	5.0480	0.56238	16	0.345	0.000420	0.00515	0.0816
0.0304	-0.0304	0.9995	-0.0304	0.0	6.24	2.3	53.73	5.87	0.0057	5.7229	0.681408	10	0.345	0.000360	0.00624	0.0577
0.0245	-0.0245	0.9997	-0.0245	0.0	5.69	2.3	56.11	6.13	0.0045	4.5153	0.621348	13	0.345	0.000336	0.00569	0.0591
0.0260	-0.0260	0.9997	-0.0260	1.9	2.58	2.3	50.13	5.47	0.0058	5.8192	0.281736	37	0.345	0.000558	0.00258	0.2164
0.0230	-0.0230	0.9997	-0.0230	0.5	5.08	2.3	48.07	5.25	0.0044	4.3739	0.554736	9	0.345	0.000210	0.00508	0.0414
0.0230	-0.0230	0.9997	-0.0230	0.7	3.68	2.3	49.67	5.42	0.0045	4.5195	0.401856	13	0.345	0.000224	0.00368	0.0610
0.0267	-0.0267	0.9996	-0.0267	0.5	3.81	2.3	60.32	6.59	0.0055	5.4895	0.416052	16	0.345	0.000331	0.00381	0.0669
0.0237	-0.0237	0.9997	-0.0237	0.6	2.85	2.3	53.14	5.80	0.0048	4.8360	0.31122	19	0.345	0.000257	0.00285	0.0902
0.0289	-0.0289	0.9996	-0.0289	0.8	4.45	2.3	47.16	5.15	0.0056	5.6390	0.48594	21	0.345	0.000524	0.00445	0.1178

Canal 2: Danando C

Canal 2: Danando

1/C	dy(m)	dx(m)	dy/dx	(1/C)*dy/dx	CanalS&P q_s (m^3/s/m)	(1/C)*dy/dx minus q_s	Reciprocal	(h*p) In (Days)	K_1	K_2	I_n*TI*ETc	Afi/I_nTIET$_c$	K_3	Measured $K_1/I_n + K_2$ eq. 24	V_u^2	$K_3V_u^2$
35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
-37.4249122	0.005	20	0.00024	0.00842061	0.0003759	0 00804471	124.305362	9	-0.0020169	-0.00921846	0.96643347	109.133224	-2.916	-0.009	4422.872	-0.013
-32.8734754	0.005	20	0.00023	0.00739653	0.0003759	0.00702063	142.43732	10	-0.0021662	-0.01049478	1.26585352	83.319277	-2.535	-0.011	5055.708	-0.013
-40.8294975	0.005	20	0.00025	0.0081659	0.0003759	0.00779	128.369713	9	-0.00163582	-0.00844977	1.12205037	93.9975624	-2.302	-0.009	4972.469	-0.011
-38.5169704	0.005	20	0.00027	0 01540679	0.0003759	0.01503089	66.5296681	10	-0.00376976	-0.00895709	0.49846111	211.591232	-5.493	-0.009	4262.243	-0.023
-43.4371474	0.004	20	0.00022	0.00781869	0.0003759	0.00744279	134.358281	9	-0.00162179	-0.00794251	1.20205437	87.7414555	-2.020	-0.008	5089.580	-0.010
-43.4371474	0.006	20	0.00032	0.01303114	0.0003759	0.01265524	79.0186253	8	-0.00234907	-0.00794251	0.89013327	118.487876	-2.728	-0.008	6408.374	-0.017
-37.4249122	0.007	20	0.00035	0.01309872	0.0003759	0.01272282	78.5989314	7	-0.00241983	-0.00921846	0.54239752	194.451479	-5.196	-0.010	3925.756	-0.020
-42.1325184	0.006	20	0.00030	0.01263976	0.0003759	0.01226386	81.5404258	8	-0.0024646	-0.00818845	0.48262681	218.533237	-5.187	-0.008	3367.137	-0.017
-34.5439386	0.006	20	0.00029	0.01209038	0.0003759	0.01171448	85.3644488	9	-0.00310509	-0.00998728	0.8149165	129.424304	-3.747	-0.010	5430.732	-0.020
-37.4249122	0.004	20	0.00021	0.00842061	0.0003759	0 00804471	124.305362	9	-0.00188032	-0.00921846	0.90099127	107.181949	-2.864	-0.009	4503.392	-0.013
-32.8734754	0.004	20	0.00020	0.0065747	0.0003759	0.0061988	161.321674	9	-0.00168151	-0.01049478	0.83466815	115.698676	-3.520	-0.011	3214.624	-0.011
-40.8294975	0.004	20	0.00020	0.00734931	0.0003759	0.00697341	143.401874	7	-0.0012618	-0.00844977	0.84073842	114.863313	-2.813	-0.009	3642.630	-0.010
-38.5169704	0.002	20	0.00010	0.01348094	0.0003759	0.01310504	76.3065224	10	-0.00345994	-0.00895709	0.52472605	184.03889	-4.778	-0.009	4272.479	-0.020
-43.4371474	0.004	20	0.00018	0.00651557	0.0003759	0.00613967	162.875148	8	-0.00111331	-0.00794251	0.80025355	120.674254	-2.778	-0.008	3052.684	-0.008
-43.4371474	0.003	20	0.00014	0.00868743	0.0003759	0 00831153	120.314799	10	-0.00200225	-0.00794251	0.77015103	125.39099	-2.887	-0.008	3977.094	-0.011
-37.4249122	0.004	20	0.00022	0.00673648	0.0003759	0.00636058	157.218263	7	-0.00113205	-0.00921846	0.2537776	380.530032	-10.168	-0.009	1002.904	-0.010
-42.1325184	0.005	20	0.00027	0.00758385	0.0003759	0.00720795	138.735638	8	-0.00133664	-0.00818845	0.26720538	361.407394	-8.578	-0.008	1196.647	-0.010
-34.5439386	0.005	20	0.00025	0.01036318	0.0003759	0.00998728	100.127346	7	-0.00208303	-0.00998728	0.48091842	200.803287	-5.813	-0.010	2984.199	-0.017
-37.4249122	0.003	20	0.00015	0.00842061	0.0003759	0.00804471	124 305362	10	-0.00217935	-0.00921846	1.56640988	69.7135543	-1.863	-0.009	6923.794	-0.013
-32.8574247	0.003	20	0.00017	0.00657148	0.0003759	0.00619558	161.40526	9	-0.00175536	-0.01049991	1.1618031	93.9918305	-2.861	-0.011	3954.972	-0.011
-40.8294975	0.006	20	0.00030	0.00734931	0.0003759	0.00697341	143.401874	8	-0.00144654	-0.00844977	1.44575279	75.531585	-1.850	-0.009	5539.465	-0.010
-38.4949459	0.008	20	0.00042	0.02309697	0.0003759	0.02272107	44.0120165	10	-0.00562024	-0.00896222	0.73700587	148.16707	-3.849	-0.010	9200.857	-0.035
-43.4651861	0.014	20	0.00068	0.00651978	0.0003759	0.00614388	162 763651	7	-0 00095213	-0.00793739	0.68436485	159.56401	-3.671	-0.008	2310.250	-0.008
-43.4651861	0.009	20	0.00045	0.00782373	0.0003759	0.00744783	134.267234	8	-0.00140331	-0.00793739	0.6027584	181.167115	-4.168	-0.008	2466.618	-0.010
-37.4249122	0.006	20	0.00030	0.01122747	0.0003759	0.01085157	92.1525329	8	-0.0023224	-0.00921846	0.6103232	178.921595	-4.781	-0.010	3638.993	-0.017
-42.1061707	0.009	20	0.00045	0.01263185	0 0003759	0.01225595	81.593014	7	-0.00214157	-0.00819357	0.41937755	260.385895	-6.184	-0.008	2824.105	-0.017
-34.5439386	0 013	20	0 00064	0.01727197	0.0003759	0.01689607	59.1853633	7	-0.00340979	-0.00998728	0.93066796	117.33508	-3.397	-0.010	8639.907	-0.029

nal 2: Danando | Canal 2: Dana | nal 2: Danando

Measured	Observed	Observed	Observed		Design	Design	Design	Design	Design
$K_3V_u^2+K_2$ eq. 25	K_1/I_n+K_2 I_n =7days	K_3 I_n =7days	$K_3V_u^2+K_2$ I_n =7days	Design I_n ervals	Design K_3	$K_3V_u^2+K_2$	K_1/I_n+K_2	$K_3V_u^2+K_2$	K_1/I_n+K_2
52	53	54	55	56	57	58	59	60	61
-0.022	-0.010	146.283	6.46	6	170.66	7.54	-0.00955461	7.54	-0.00955461
-0.023	-0.011	120.730	6.09	6	140.85	7.11	-0.01085582	7.11	-0.01085582
-0.020	-0.009	115.131	5.72	5	161.18	8.01	-0.00877694	8.01	-0.00877694
-0.032	-0.009	291.999	12.44	6	340.67	14.51	-0.00958538	14.51	-0.00958538
-0.018	-0.008	118.639	6.03	6	138.41	7.04	-0.00821281	7.04	-0.00821281
-0.025	-0.008	136.478	8.74	8	119.42	7.64	-0.00823614	7.64	-0.00823614
-0.030	-0.010	197.732	7.75	5	276.82	10.86	-0.00970242	10.86	-0.00970242
-0.026	-0.009	264.336	8.89	4	462.59	15.57	-0.0088046	15.57	-0.0088046
-0.030	-0.010	169.294	9.18	4	296.26	16.08	-0.01076355	16.08	-0.01076355
-0.022	-0.009	133.939	6.02	6	156.26	7.03	-0.00953185	7.03	-0.00953185
-0.022	-0.011	147.390	4.73	6	171.96	5.52	-0.01077504	5.52	-0.01077504
-0.019	-0.009	121.228	4.41	5	169.72	6.17	-0.00870213	6.17	-0.00870213
-0.029	-0.009	267.359	11.41	6	311.92	13.32	-0.00953375	13.32	-0.00953375
-0.016	-0.008	135.785	4.14	6	158.42	4.83	-0.00812806	4.83	-0.00812806
-0.019	-0.008	187.442	7.45	8	164.01	6.51	-0.00819279	6.51	-0.00819279
-0.019	-0.009	362.092	3.62	5	506.93	5.07	-0.00944487	5.07	-0.00944487
-0.018	-0.008	403.383	4.82	4	705.92	8.44	-0.00852261	8.44	-0.00852261
-0.027	-0.010	206.677	6.16	4	361.69	10.78	-0.01050804	10.78	-0.01050804
-0.022	-0.010	100.971	6.98	6	117.80	8.15	-0.00958168	8.15	-0.00958168
-0.022	-0.011	125.000	4.93	6	145.83	5.76	-0.01079247	5.76	-0.01079247
-0.019	-0.009	91.388	5.05	5	127.94	7.08	-0.00873908	7.08	-0.00873908
-0.044	-0.010	201.550	18.54	6	235.14	21.63	-0.00989892	21.63	-0.00989892
-0.016	-0.008	153.543	3.54	6	179.13	4.13	-0.00809607	4.13	-0.00809607
-0.018	-0.008	211.957	5.22	8	185.46	4.57	-0.0081128	4.57	-0.0081128
-0.027	-0.010	204.724	7.44	5	286.61	10.42	-0.00968294	10.42	-0.00968294
-0.026	-0.008	273.684	7.72	4	478.95	13.52	-0.00872897	13.52	-0.00872897
-0.039	-0.010	116.854	10.09	4	204.49	17.66	-0.01083973	17.66	-0.01083973

3 LOCATION:Middle

Date	Farm No.	Area (A_n) (m^2)	Water In (l/s)	Average Q (l/s)	Duration (min)	Volume (m^3)	Depth (mm)	Avrge Q (m^3/s)	Manning's n	X-Area A (m^2)	Canal Slope%(S)	Hyd. R (m) $((Qn/AS))^{1.5}$	Top width	($R^{4/3}$)	($A^2R^{4/3}$)	$n^2Q^2/A^2R^{4/3}$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
						(4*6)*0.06	(7/3)*1000	(5/1000)	(Constant)	Measured	Measured	9*10/11*12	Measured			
2.2.99	1U	90.1	6	5.67	20	7.20	79.91	0.00567	0.04	0.125	1.0	0.00244	0.91	0.00033	0.0000	0.0100
9.2.99	1U	90.1	5	5.00	20	6.00	66.59	0.00500	0.04	0.125	1.0	0.00202	0.91	0.00026	0.0000	0.0100
16.2.99	1U	90.1	5.5	5.42	20	6.60	73.25	0.00542	0.04	0.125	1.0	0.00228	0.91	0.00030	0.0000	0.0100
23.2.99	1U	90.1	6	5.50	30	10.80	119.87	0.00550	0.04	0.125	1.0	0.00233	0.91	0.00031	0.0000	0.0100
2.3.99	1U	90.1	5.5	5.08	30	9.90	109.88	0.00508	0.04	0.125	1.0	0.00207	0.91	0.00026	0.0000	0.0100
9.3.99	1U	90.1	5.5	5.25	25	8.25	91.56	0.00558	0.04	0.125	1.0	0.00239	0.91	0.00032	0.0000	0.0100
16.3.99	1U	90.1	5	4.67	20	6.00	66.59	0.00508	0.04	0.125	1.0	0.00207	0.91	0.00026	0.0000	0.0100
23.3.99	1U	90.1	5.5	5.00	20	6.60	73.25	0.00500	0.04	0.125	1.0	0.00202	0.91	0.00026	0.0000	0.0100
30.3.99	1U	90.1	6	5.50	20	7.20	79.91	0 00550	0.04	0.125	1.0	0.00233	0.91	0.00031	0.0000	0.0100
2.2.99	2M	107.36	5.5	5.67	30	9.90	92.21	0.00567	0.04	0.125	1.0	0.00244	0.91	0.00033	0.0000	0.0100
9.2.99	2M	107.36	5	5.00	30	9.00	83.83	0.00500	0.04	0.125	1.0	0.00202	0.91	0.00026	0.0000	0.0100
16.2.99	2M	107.36	5.25	5.42	25	7.88	73.35	0.00542	0 04	0.125	1.0	0.00228	0.91	0.00030	0.0000	0.0100
23.2.99	2M	107.36	5.5	5.50	40	13.20	122.95	0.00550	0.04	0.125	1.0	0.00233	0.91	0.00031	0.0000	0.0100
2.3.99	2M	107.36	5	5.08	35	10.50	97.80	0.00508	0.04	0.125	1.0	0.00207	0.91	0.00026	0.0000	0.0100
9.3.99	2M	107.36	5.25	5 25	30	9.45	88.02	0.00558	0.04	0.125	1.0	0.00239	0.91	0.00032	0.0000	0.0100
16.3.99	2M	107.36	4.5	4.67	30	8.10	75.45	0.00508	0.04	0.125	1.0	0.00207	0.91	0.00026	0.0000	0.0100
23.3.99	2M	107 36	5	5.00	30	9.00	83.83	0.00500	0.04	0.125	1.0	0.00202	0.91	0.00026	0.0000	0.0100
30.3.99	2M	107.36	5.5	5.50	30	9.90	92.21	0.00550	0.04	0.125	1.0	0.00233	0.91	0.00031	0.0000	0.0100
2.2.99	3E	89.18	5.5	5.67	20	6.60	74.01	0.00567	0.04	0.125	1.0	0.00244	0.91	0.00033	0.0000	0.0100
9.2.99	3E	89.18	5	5.00	25	7.50	84.10	0.00500	0.04	0.125	1.0	0.00202	0.91	0.00026	0.0000	0.0100
16.2.99	3E	89.18	5.5	5 42	15	4.95	55.51	0.00542	0.04	0.125	1.0	0.00228	0.91	0.00030	0.0000	0.0100
23.2.99	3E	89.18	5	5.50	25	7.50	84.10	0.00550	0.04	0.125	1.0	0.00233	0.91	0.00031	0.0000	0.0100
2.3.99	3E	89.18	4.75	5.08	30	8.55	95.87	0.00508	0.04	0.125	1.0	0.00207	0.91	0.00025	0.0000	0.0100
9.3.99	3E	89.18	5	5.25	20	6.00	67.28	0.00525	0.04	0.125	1.0	0.00218	0.91	0.00028	0.0000	0.0100
16.3.99	3E	89.18	4.5	4.67	20	5.40	60.55	0.00467	0.04	0.125	1.0	0.00182	0.91	0.00022	0.0000	0.0100
23.3.99	3E	89.18	4.5	5.00	25	6.75	75.69	0.00500	0.04	0.125	1.0	0.00202	0.91	0.00026	0.0000	0.0100
30.3.99	3E	89.18	5	5.50	24	7.20	80.74	0.00550	0.04	0.125	1.0	0.00233	0.91	0.00031	0.0000	0.0100

2Q/gA²	Eqn.B.6 numerator	1-(Q²T/gA³ denomina	Num/Deno Eqn.B.6	Rainfall (mm)	ETc mm/day	S&P (mm/day)	Vu(mm) Vu(mm) Q_f(in mm)	Qf*Afi/1000 Qf(m³)	Q_f(m³/s) Q_f(m³/s)	Q_f*1000 Q_f(l/s)	Tc*Afi/100 (m³/day)	$Q_fT_f/A_{fi}ET_c$	CanalS&P q_s (l/s/m)	Qf*Vu)/100 (m⁴/s)	ETc (m\day)	(m²day/s) Qf*Vu/ETc
18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
							8+22-23-24	25*3/1000	26/6*60s							
0.0740	-0.0740	0.9985	-0.0741	0.0	3.39	2.3	74.22	6.69	0.0056	5.5728	0.305439	22	0.324	0.000414	0.00339	0.1220
0.0652	-0.0652	0.9988	-0.0653	0.1	6.12	2.3	58.27	5.25	0.0044	4.3753	0.551412	10	0.324	0.000255	0.00612	0.0417
0.0707	-0.0707	0.9986	-0.0708	0.0	6.10	2.3	64.85	5.84	0.0049	4.8693	0.54981	11	0.324	0.000316	0.00610	0.0518
0.0718	-0.0718	0.9986	-0.0719	0.0	5.66	2.3	78.61	7.08	0.0056	5.8016	0.509966	20	0.324	0.000627	0.00566	0.1108
0.0663	-0.0663	0.9988	-0.0664	0.0	5.63	2.3	101.95	9.19	0.0051	5.1031	0.507263	18	0.324	0.000520	0.00563	0.0924
0.0728	-0.0728	0.9985	-0.0729	7.6	1.40	2.3	95.46	8.60	0.0057	5.7343	0.126140	68	0.324	0.000547	0.00140	0.3910
0.0663	-0.0663	0.9988	-0.0664	30.2	1.14	2.3	93.35	8.41	0.0070	7.0092	0.102714	82	0.324	0.000654	0.00114	0.5740
0.0652	-0.0652	0.9988	-0.0653	37.8	4.92	2.3	103.83	9.36	0.0078	7.7960	0.443292	21	0.324	0.000809	0.00492	0.1645
0.0718	-0.0718	0.9986	-0.0719	0.0	5.15	2.3	69.73	6.28	0.0054	5.4406	0.464015	14	0.324	0.000394	0.00515	0.0766
0.0740	-0.0740	0.9985	-0.0741	0.0	3.39	2.3	86.52	9.29	0.0052	5.1606	0.3639504	26	0.324	0.000447	0.00339	0.1317
0.0652	-0.0652	0.9988	-0.0653	0.1	6.12	2.3	75.51	8.11	0.0045	4.5038	0.6570432	12	0.324	0.000340	0.00612	0.0556
0.0707	-0.0707	0.9986	-0.0708	0 0	6.10	2.3	64.95	6.97	0.0046	4.6488	0.654896	11	0.324	0.000302	0.00610	0.0495
0.0718	-0.0718	0.9986	-0.0719	0.0	5.66	2.3	114.99	12.35	0.0051	5.1439	0.6076576	20	0.324	0.000592	0.00566	0.1045
0.0663	-0.0663	0 9988	-0.0664	0.0	5.63	2.3	89.87	9.65	0.0046	4.5946	0.6044368	16	0.324	0.000413	0.00563	0.0733
0.0728	-0.0728	0.9985	-0.0729	7.6	1.40	2.3	91.92	9.87	0.0055	5.4826	0.150304	66	0.324	0.000504	0.00140	0.3600
0.0663	-0.0663	0.9988	-0.0664	30.2	1.14	2.3	102 21	10.97	0.0061	6.0961	0.122390	90	0.324	0.000623	0.00114	0.5485
0.0652	-0.0652	0.9988	-0.0653	37.8	4.92	2.3	114.41	12.28	0.0068	6.8239	0.5282112	23	0.324	0.000781	0.00492	0.1587
0.0718	-0.0718	0.9986	-0.0719	0.0	5.15	2.3	84.76	9.10	0.0051	5.0556	0.552904	16	0.324	0.000429	0.00515	0.0832
0.0739	-0.0739	0.9985	-0.0741	0.0	3.39	2.3	68.32	6.09	0.0051	5.0771	0.3023202	20	0.324	0.000347	0.00339	0.1023
0.0652	-0.0652	0.9988	-0.0653	0.1	6.12	2.3	64.57	5.76	0.0045	4.5053	0.5457816	12	0.324	0.000341	0.00612	0.0558
0.0707	-0.0707	0.9986	-0.0708	0.0	6.10	2.3	58.32	5.20	0.0047	4.6677	0.543998	8	0.324	0.000220	0.00610	0.0360
0.0718	-0.0718	0.9986	-0.0719	0.0	5.66	2.3	76.14	6.79	0.0045	4.5268	0.5047588	13	0.324	0.000345	0.00566	0.0609
0.0663	-0.0663	0.9988	-0.0664	0.0	5.63	2.3	76.73	6.84	0.0044	4.3571	0.5020834	16	0.324	0.000383	0.00563	0.0681
0.0685	-0.0685	0.9987	-0.0686	7.6	1.40	2.3	71.18	6.35	0.0053	5.2898	0.124852	51	0.324	0.000377	0.00140	0.2689
0.0609	-0.0609	0.9990	-0.0610	30.2	1.14	2 3	87.31	7.79	0.0065	6.4887	0.1016652	77	0.324	0.000567	0.00114	0.4970
0.0652	-0.0652	0.9988	-0.0653	37.8	4.92	2.3	95.06	8.48	0.0063	6.3181	0.4387656	22	0.324	0.000671	0.00492	0.1365
0.0718	-0.0718	0.9986	-0.0719	0.0	5.15	2.3	62.07	5.54	0.0045	4.5386	0.459277	14	0.324	0.000333	0.00515	0.0646

Ramadhani Chonanga

Canal 3:Chonanga

1/C	dy(m)	dx(m)	dy/dx	(1/C)*dy/dx	CanalS&P q_s (m^2/s/m)	(1/C)*dy/dx minus q_s	Reciprocal	(h*p) In (Days)	K_1	K_2	I_n*TI*ETc	Afi/I_nTIET$_c$	K_3	Measured K_1/I_n+K_2 eq. 24	V_u^2	$K_3V_u^2$
35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
-13.4962263	0.020	20	0.00100	0.01349623	0.000324	0.013	75.9173111	9	-0.0090404	-0.02400671	0.62801558	143.467779	-10.630	-0.025	5508.788	-0.059
-15.309925	0.027	20	0.00134	0.00612397	0.000324	0.006	172.414685	7	-0.00272113	-0.02116274	0.8791798	102.481882	-6.694	-0.022	3395.705	-0.023
-14.1206079	0.009	20	0.00045	0.00635427	0.000324	0.006	165.8300	9	-0.00366612	-0.02294519	1.04732749	86.0284879	-6.092	-0.023	4205.774	-0.026
-13.9146391	0.026	20	0.00130	0.0153061	0.000324	0.015	66.74630	7	-0.00795934	-0.02328483	1.2552026	71.7812407	-5.159	-0.024	12523.135	-0.065
-15.068246	0.038	20	0.00190	0.01431483	0.000324	0.014	71.4753689	7	-0.0061325	-0.02150217	1.11554381	80.767783	-5.360	-0.022	10393.377	-0.056
-13.7145678	0.043	20	0.00213	0.05485827	0.000324	0.055	18.3370929	7	-0.02851091	-0.02362451	0.25095261	359.031925	-26.179	-0.028	9113.552	-0.239
-15.068246	0.039	15	0.00257	0.08036398	0.000324	0.080	12.4937564	7	-0.03809163	-0.02150217	0.16350089	551.067352	-36.571	-0.027	8714.722	-0.319
-15.309925	0.039	15	0.00260	0.02551654	0.000324	0.025	39 6942878	7	-0.01074651	-0.02116274	0.64263372	140.204283	-9.158	-0.023	10781.072	-0.099
-13.9146391	0.047	15	0.00314	0.01391464	0.000324	0.014	73.5800571	6	-0.00550143	-0.02328483	0.58015605	155.303044	-11.161	-0.024	5250.627	-0.059
-13.4962263	0.030	20	0.00150	0 02024434	0.000324	0.020	50.1999479	7	-0.00975938	-0.02400671	0.67244816	159.65543	-11.830	-0.025	7486.249	-0.089
-15.309925	0.009	20	0.00045	0.00688947	0.000324	0.007	152.312107	8	-0.00362957	-0.02116274	1.55394563	69.0886462	-4.513	-0.022	5701.776	-0.026
-14.1206079	0.009	20	0.00045	0.00635427	0.000324	0.006	165.8300	8	-0.00350545	-0.02294519	1.25178714	85.7653801	-6.074	-0.023	4218.677	-0.026
-13.9146391	0.025	20	0.00125	0.0173933	0.000324	0.017	58.5847145	6	-0.00751051	-0.02328483	1.38612345	77 453419	-5.566	-0.025	13222.889	-0.074
-15.068246	0.020	20	0.00098	0.01130118	0.000324	0.011	91.0980406	7	-0.00486742	-0.02150217	1.3165794	81.544645	-5.412	-0.022	8076.938	-0.044
-13.7145678	0.021	20	0.00104	0.05622973	0.000324	0.056	17.8872547	6	-0.02624793	-0.02362451	0.27043954	396.983374	-28.946	-0.028	8449.582	-0.245
-15.068246	0.021	15	0.00142	0.08036398	0.000324	0.080	12.4937564	7	-0.03627142	-0 02150217	0.23353198	459.722897	-30.509	-0.027	10446.290	-0.319
-15.309925	0.020	15	0.00135	0.02551654	0.000324	0.025	39.6942878	6	-0.01036479	-0.02116274	0.92971113	115.476729	-7.543	-0.023	13089.672	-0.099
-13.9146391	0.025	15	0.00167	0.01391464	0.000324	0.014	73.5800571	6	-0.00598005	-0.02328483	0.94594348	113.495153	-8.157	-0.024	7184.786	-0.059
-13.5041895	0.025	20	0.00125	0 016880	0.000324	0.017	60.40020	6	-0.00757676	-0 02399255	0.41900587	212.837114	-15.761	-0.025	4667.298	-0.074
-15.309925	0.011	20	0.00057	0.00918596	0.000324	0.009	112.841918	6	-0.00364381	-0 02116274	0.96314349	92.5926413	-6.048	-0.022	5742.544	-0.035
-14.1293218	0.018	20	0.00090	0.00635819	0.000324	0.006	165.722194	6	-0.00255106	-0.02293104	0.54656795	163.163611	-11.548	-0.023	2218.949	-0.026
-13.9146391	0.038	20	0.00189	0.01321891	0.000324	0.013	77.55000	5	-0.00437632	-0.02328483	[illegible]	133.459221	-9.591	-0.024	5797.235	-0.056
-15.0583409	0.015	20	0.00075	0.01129376	0.000324	0.011	91.159733	6	-0.00451978	-0.02151631	1.04791702	85.1021582	-5.651	-0.022	7734.062	-0.044
-14.5791043	0.048	20	0.00240	0 05467164	0.000324	0.054	18.4000626	5	-0.01844757	-0.02222359	0.13856302	643.606085	-44.146	-0.026	5066.544	-0.224
-16.4060	0.029	15	0.00194	0.09296736	0.000324	0.093	10.7940819	5	-0.03029168	-0.01974887	0.12230571	729.156446	-44.444	-0.025	7623.332	-0.339
-15.309925	0.031	15	0.00206	0.02551654	0.000324	0.025	39 6942878	5	-0.00891366	-0 02116274	0.66628872	133.845881	-8.742	-0.023	11293.231	-0.099
-13.9146391	0.031	15	0.00208	0.01391464	0.000324	0.014	73.5800571	5	-0.00464155	-0.02328483	0.58737239	151.828724	-10.911	-0.024	5370.778	-0.059

Measured	Observed	Observed	Observed		Design	Design	Design	Design	Design
$K_3V_u^2+K_2$	K_1/I_n+K_2	K_3	$K_3V_u^2+K_2$	Design I_n	Design K_3	$K_3V_u^2+K_2$	K_1/I_n+K_2	$K_3V_u^2+K_2$	K_1/I_n+K_2
eq. 25	I_n =7days	I_n =7days	I_n =7days	ervals					
52	53	54	55	56	57	58	59	60	61
-0.083	-0.025	189.844	10.43	6	221.48	12.18	-0.02551344	12.18	-0.02551344
-0.044	-0.022	105.159	3.55	6	122.69	4.14	-0.02161626	4.14	-0.02161626
-0.049	-0.023	105.504	4.41	5	147.70	6.19	-0.02367841	6.19	-0.02367841
-0.088	-0.024	75.803	9.47	6	88.44	11.05	-0.02461139	11.05	-0.02461139
-0.077	-0.022	76.207	7.90	6	88.91	9.22	-0.02252425	9.22	-0.02252425
-0.262	-0.028	367.755	33.49	8	321.79	29.30	-0.02718838	29.30	-0.02718838
-0.340	-0.027	564.536	49.18	5	790.35	68.86	-0.0291205	68.86	-0.0291205
-0.120	-0.023	130.807	14.08	4	228.91	24.66	-0.02384937	24.66	-0.02384937
-0.082	-0.024	124.965	6.54	4	218.69	11.46	-0.02466019	11.46	-0.02466019
-0.113	-0.025	150.808	11.27	6	175.94	13.15	-0.02563327	13.15	-0.02563327
-0.047	-0.022	83.536	4.74	6	97.46	5.54	-0.02176767	5.54	-0.02176767
-0.049	-0.023	100.571	4.22	5	140.80	5.92	-0.02364628	5.92	-0.02364628
-0.097	-0.024	67.744	8.93	6	79.03	10.43	-0.02453658	10.43	-0.02453658
-0.065	-0.022	77.834	6.27	6	90.81	7.31	-0.02231341	7.31	-0.02231341
-0.268	-0.027	365.170	30.83	8	319.52	26.97	-0.02690551	26.97	-0.02690551
-0.340	-0.027	448.454	46.83	5	627.84	65.56	-0.02875645	65.56	-0.02875645
-0.120	-0.023	103.910	13.58	4	181.84	23.78	-0.02375394	23.78	-0.02375394
-0.082	-0.024	99.270	7.11	4	173.72	12.46	-0.02477984	12 46	-0.02477984
-0.098	-0.025	187.906	8.75	6	219.22	10.21	-0.02525535	10.21	-0.02525535
-0.056	-0.022	83.268	4.76	6	97.15	5.56	-0.02177004	5.56	-0.02177004
-0.049	-0.023	139.235	3.07	5	194.93	4.30	-0.02344125	4.30	-0.02344125
-0.079	-0.024	90.035	5.20	6	105.04	6.07	-0.02401422	6.07	-0.02401422
-0.065	-0.022	75.429	5.81	6	88.00	6.78	-0.02226961	6.78	-0.02226961
-0.246	-0.025	455.000	23.03	8	398.13	20.15	-0.02452953	20.15	-0.02452953
-0.359	-0.024	558.772	42 58	5	782.28	59.62	-0.0258072	59.62	-0.0258072
-0.120	-0.022	103.577	11.68	4	181.26	20.45	-0.02339116	20.45	-0.02339116
-0.082	-0.024	103.074	5.51	4	180.38	9.66	-0.02444522	9.66	-0.02444522

4 LOCATION:End

Date	Farm No.	Area (A_n) (m^2)	Water In (l/s)	Average Q (l/s)	Duration (min)	Volume (m^3)	Depth (mm)	Avrge Q (m^3/s)	Manning's n	X-Area A (m^2)	Canal Slope%(S)	Hyd. R (m) $((Qn/AS))^{1.5}$	Top width	($R^{4/3}$)	($A^2R^{4/3}$)	$n^2Q^2/A^2R^{4/3}$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
						(4*6)*0.06	(7/3)*1000	(5/1000)	(Constant)	Measured	Measured	9*10/11*12	Measured			
3.2.99	1U	32.5	6	5.58	10	3.60	110.77	0.00558	0.04	0.098	0.675	0.00462	0.875	0.00077	0.0000	0.0068
10.2.99	1U	32.5	5.5	5.12	10	3.30	101.54	0.00512	0.04	0.098	0.675	0.00406	0.875	0.00065	0.0000	0.0067
17.2.99	1U	32.5	5.5	5.00	10	3.30	101.54	0.00500	0.04	0.098	0.675	0.00391	0.675	0.00062	0.0000	0.0068
24.2.99	1U	32.5	5.5	5.17	9	2.97	91.38	0.00517	0.04	0.098	0.675	0.00412	0.875	0.00066	0.0000	0.0067
3.3.99	1U	32.5	5.5	4.92	8	2.64	81.23	0.00492	0.04	0.098	0.675	0.00382	0.875	0.00060	0.0000	0.0067
10.3.99	1U	32.5	5.25	5.33	12	3.78	116.31	0.00558	0.04	0.098	0.675	0.00462	0.875	0.00077	0.0000	0.0068
17.3.99	1U	32.5	5.5	5.33	10	3.30	101.54	0.00533	0.04	0.098	0.675	0.00431	0.875	0.00070	0.0000	0.0067
24.3.99	1U	32.5	5	4.92	12	3.60	110.77	0.00533	0.04	0.098	0.675	0.00431	0.875	0.00070	0.0000	0.0067
31.3.99	1U	32.5	5.75	5.42	9	3.11	95.54	0.00558	0.04	0.098	0.675	0.00462	0.875	0.00077	0.0000	0.0068
3.2.99	2M	89	5.5	5.58	20	6.60	74.16	0.00558	0.04	0.098	0.675	0.00462	0.875	0.00077	0.0000	0.0068
10.2.99	2M	89	5.25	5.12	25	7.88	88.48	0.00512	0.04	0.098	0.675	0.00406	0.875	0.00065	0.0000	0.0067
17.2.99	2M	89	5	5.00	20	6.00	67.42	0.00500	0.04	0.098	0.675	0.00391	0.875	0.00062	0.0000	0.0068
24.2.99	2M	89	5	5.17	20	6.00	67.42	0.00517	0.04	0.098	0.675	0.00412	0.875	0.00066	0.0000	0.0067
3.3.99	2M	89	4.75	4.92	24	6.84	76.85	0.00492	0.04	0.098	0.675	0.00382	0.875	0.00060	0.0000	0.0067
10.3.99	2M	89	5	5.33	19	5.70	64.04	0.00558	0.04	0.098	0.675	0.00462	0.875	0.00077	0.0000	0.0068
17.3.99	2M	89	5.5	5.33	25	8.25	92.70	0.00533	0.04	0.098	0.675	0.00431	0.875	0.00070	0.0000	0.0067
24.3.99	2M	89	5	4.92	26	7.80	87.64	0.00533	0.04	0.098	0.675	0.00431	0.875	0.00070	0.0000	0.0067
31.3.99	2M	89	5.5	5.42	28	9.24	103.82	0.00658	0.04	0.098	0.675	0.00462	0.875	0.00077	0.0000	0.0068
3.2.99	3E	123.24	5.25	5.58	30	9.45	76.68	0.00558	0.04	0.098	0.675	0.00462	0.875	0.00077	0.0000	0.0068
10.2.99	3E	123.24	4.6	5.12	35	9.66	78.38	0.00512	0.04	0.098	0.675	0.00405	0.875	0.00065	0.0000	0.0068
17.2.99	3E	123.24	4.5	5.00	30	8.10	65.73	0.00500	0.04	0.098	0.675	0.00391	0.875	0.00062	0.0000	0.0068
24.2.99	3E	123.24	5	5.17	35	10.50	85.20	0.00517	0.04	0.098	0.675	0.00411	0.875	0.00066	0.0000	0.0068
3.3.99	3E	123.24	4.5	4.92	37	9.99	81.06	0.00492	0.04	0.098	0.675	0.00382	0.875	0.00060	0.0000	0.0068
10.3.99	3E	123.24	5.75	5.33	36	12.42	100.78	0.00533	0.04	0.098	0.675	0.00431	0.875	0.00070	0.0000	0.0068
17.3.99	3E	123.24	5	5.33	30	9.00	73.03	0.00533	0.04	0.098	0.675	0.00431	0.875	0.00070	0.0000	0.0068
24.3.99	3E	123.24	4.75	4.92	28	7.98	64.75	0.00492	0.04	0.098	0.675	0.00382	0.875	0.00060	0.0000	0.0068
31.3.99	3E	123.24	5	5.42	36	10.80	87.63	0.00542	0.04	0.098	0.675	0.00441	0.875	0.00072	0.0000	0.0068

2Q/gA²	Eqn.B.6 numerator	1-(Q⁴T/gA³ denomina	Num/Deno Eqn.B.6	Rainfall (mm)	ETc mm/day	S&P (mm/day)	Vu(mm) Vu(mm) Q_r(in mm)	Qf*Afi/1000 Qf(m³)	Q_r(m³/s) Q_r(m³/s)	Q_r*1000 Q_r(l/s)	Tc*Afi/100 (m³/day)	Q_rT_r/A_nET_c	CanalS&P q_s (l/s/m)	Qf*Vu)/100 (m⁴/s)	ETc (m\day)	(m³day/s) Qf*Vu/ETc
18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
							8+22-23-24	25*3/1000	26/6*60s							
0.1185	-0.1185	0.9970	-0.1188	0.0	5.31	2.3	226.24	7.35	0.0056	5.5878	0.172575	19	0.107	0.000576	0.00531	0.1086
0.1087	-0.1087	0.9975	-0.1090	0.0	6.12	2.3	158.46	5.15	0.0050	5.0439	0.1989	15	0.107	0.000470	0.00612	0.0767
0.1061	-0.1061	0.9976	-0.1064	0.0	6.47	2.3	185.08	6.01	0.0050	5.0250	0.210275	14	0.107	0.000466	0.00647	0.0720
0.1097	-0.1097	0.9975	-0.1100	0.0	6.15	2.3	175.24	5.70	0.0050	4.9914	0.199875	13	0.107	0.000414	0.00615	0.0673
0.1044	-0.1044	0.9977	-0.1047	0.0	5.25	2.3	168.31	5.47	0.0050	4.9888	0.170625	14	0.107	0.000368	0.00525	0.0700
0.1185	-0.1185	0.9970	-0.1188	1.4	4.48	2.3	203.24	6.61	0.0050	5.0072	0.1456	25	0.107	0.000555	0.00448	0.1240
0.1131	-0.1131	0.9973	-0.1135	0.0	5.33	2.3	216.99	7.05	0.0051	5.0867	0.173225	18	0.107	0.000478	0.00533	0.0896
0.1131	-0.1131	0.9973	-0.1135	0.0	4.06	2.3	165.95	5.39	0.0047	4.7129	0.13195	26	0.107	0.000492	0.00406	0.1212
0.1185	-0.1185	0.9970	-0.1188	0.0	5.10	2.3	180.45	5.86	0.0053	5.3046	0.16575	17	0.107	0.000468	0.0051	0.0917
0.1185	-0.1185	0.9970	-0.1188	0.0	5.31	2.3	77.78	6.92	0.0049	4.9356	0.47259	13	0.107	0.000328	0.00531	0.0619
0.1087	-0.1087	0.9975	-0.1090	0.0	6.12	2.3	80.06	7.13	0.0048	4.7504	0.54468	13	0.107	0.000380	0.00612	0.0621
0.1061	-0.1061	0.9976	-0.1064	0.0	6.47	2.3	58.65	5.22	0.0043	4.3496	0.57583	9	0.107	0.000255	0.00647	0.0394
0.1097	-0.1097	0.9975	-0.1100	0.0	6.15	2.3	76.04	6.77	0.0044	4.3733	0.54735	10	0.107	0.000258	0.00615	0.0419
0.1044	-0.1044	0.9977	-0.1047	0.0	5.25	2.3	69.30	6.17	0.0043	4.2834	0.46725	13	0.107	0.000297	0.00525	0.0565
0.1185	-0.1185	0.9970	-0.1188	1.4	4.48	2.3	79.68	7.09	0.0046	4.5800	0.39872	13	0.107	0.000269	0.00448	0.0600
0.1131	-0.1131	0.9973	-0.1135	0.0	5.33	2.3	86.41	7.69	0.0050	5.0473	0.47437	16	0.107	0.000429	0.00533	0.0806
0.1131	-0.1131	0.9973	-0.1135	0.0	4.06	2.3	85.21	7.58	0.0046	4.6372	0.36134	20	0.107	0.000377	0.00406	0.0928
0.1185	-0.1185	0.9970	-0.1188	0.0	5.10	2.3	96.42	8.58	0.0051	5.1080	0.4539	19	0.107	0.000493	0.0051	0.0966
0.1185	-0.1185	0.9970	-0.1189	0.0	5.31	2.3	69.07	8.51	0.0047	4.7290	0.6544044	13	0.107	0.000327	0.00531	0.0615
0.1086	-0.1086	0.9975	-0.1089	0.0	6.12	2.3	69.96	8.62	0.0041	4.1059	0.7542288	11	0.107	0.000287	0.00612	0.0469
0.1061	-0.1061	0.9976	-0.1064	0.0	6.47	2.3	53.71	6.62	0.0039	3.8995	0.7973628	9	0.107	0.000222	0.00647	0.0343
0.1097	-0.1097	0.9975	-0.1100	0.0	6.15	2.3	76.75	9.46	0.0045	4.5041	0.757926	12	0.107	0.000346	0.00615	0.0562
0.1044	-0.1044	0.9977	-0.1046	0.0	5.25	2.3	73.51	9.06	0.0041	4.0809	0.64701	14	0.107	0.000300	0.00525	0.0571
0.1132	-0.1132	0.9973	-0.1135	1.4	4.48	2.3	79.17	9.76	0.0054	5.4430	0.5521152	21	0.107	0.000519	0.00448	0.1159
0.1132	-0.1132	0.9973	-0.1135	0.0	5.33	2.3	65.40	8.06	0.0045	4.4776	0.6568692	12	0.107	0.000293	0.00533	0.0549
0.1044	-0.1044	0.9977	-0.1046	0.0	4.06	2.3	61.64	7.60	0.0043	4.2834	0.5003544	14	0.107	0.000250	0.00406	0.0616
0.1150	-0.1150	0.9972	-0.1153	0.0	5.10	2.3	80.23	9.89	0.0046	4.5778	0.628524	16	0.107	0.000367	0.0051	0.0720

Canal 4: Ng'omwa

1/C	dy(m)	dx(m)	dy/dx	(1/C)*dy/dx	CanalS&P q_s ($m^3/s/m$)	(1/C)*dy/dx minus q_s	Reciprocal	(h*p) ln (Days)	K_1	K_2	I_n*TI*ETc	Afi/I_nTIET$_c$	K_3	Measured K_1/I_n+K_2 eq. 24	V_u^2	$K_3V_u^2$
35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
-8.41731509	0.040	20	0.00200	0.01683463	0.000107	0.01673	59.7813312	6	-0.01290	-0.01271189	0.3445989	94.3125481	-11.205	-0.015	10641.827	-0.119
-9.17784989	0.040	20	0.00200	0.01376677	0.000107	0.01366	73.2076489	6	-0.00836202	-0.0116585	0.34384297	94.5198898	-10.299	-0.013	8671.048	-0.089
-9.39920257	0.039	20	0.00197	0.0140988	0.000107	0.01399	71.470413	5	-0.00766545	-0.01138394	0.3331648	97.5493208	-10.378	-0.013	8605.987	-0.089
-9.08864498	0.053	20	0.00265	0.01590513	0.000107	0.01580	63.2986361	4	-0.00740606	-0.01177293	0.235830	137.811427	-15.183	-0.014	6878.150	-0.104
-9.55275523	0.075	20	0.00375	0.01671732	0.000107	0.01661	60.2035301	4	-0.0073293	-0.01120096	0.17703632	183.578151	-19.217	-0.013	5428.856	-0.104
-8.41731509	0.023	20	0.00115	0.0147303	0.000107	0.01462	68.3840107	8	-0.0147292	-0.01271189	0.45579193	71.304465	-8.471	-0.014	12304.953	-0.104
-8.81440798	0.052	20	0.00260	0.01762882	0.000107	0.01752	57.07171	5	-0.01016766	-0.01213922	0.27262297	119.212258	-13.525	-0.014	8818.799	-0.119
-8.81440798	0.028	20	0.00140	0.01542521	0.000107	0.01532	65.2817621	8	-0.01375021	-0.01213922	0.38547993	84.3104854	-9.565	-0.014	10901.287	-0.104
-8.41731509	0.035	20	0.00175	0.0147303	0.000107	0.01462	68.3840107	6	-0.01089123	-0.01271189	0.28775151	112.944673	-13.418	-0.014	7768.388	-0.104
-8.41731509	0.030	20	0.00150	0.01262597	0.000107	0.01252	79.8787591	5	-0.00734855	-0.01271189	0.52472407	169.6130	-20.150	-0.014	4428.544	-0.089
-9.17784989	0.030	20	0.00150	0.01376677	0.000107	0.01366	73.2076489	5	-0.00677129	-0.0116585	0.69608219	127.858465	-13.931	-0.013	6410.107	-0.089
-9.39920257	0.031	20	0.00153	0.0093992	0.000107	0.00929	107.617111	4	-0.00419456	-0.01138394	0.54902597	162.105265	-17.247	-0.012	3439.322	-0.059
-9.08864498	0.035	20	0.00175	0.01590513	0.000107	0.01580	63.2986361	3	-0.00461354	-0.01177293	0.32646188	272.619888	-29.996	-0.014	3476.957	-0.104
-9.55275523	0.035	20	0.00175	0.01671732	0.000107	0.01661	60.2035301	3	-0.0059191	-0.01120096	0.42892017	207.497818	-21.721	-0.013	4803.035	-0.104
-8.41731509	0.035	20	0.00175	0.0147303	0.000107	0.01462	68.3840107	4	-0.0071251	-0.01271189	0.34910064	254.940811	-30.288	-0.014	3441.576	-0.104
-8.81440798	0.033	20	0.00165	0.01762882	0.000107	0.01752	57.07171	5	-0.00913896	-0.01213922	0.61260155	145.2820	-16.482	-0.014	7236.331	-0.119
-8.81440798	0.029	20	0.00147	0.01542521	0.000107	0.01532	65.2817621	6	-0.01053218	-0.01213922	0.63973899	139.119238	-15.783	-0.014	6606.511	-0.104
-8.41731509	0.026	20	0.00132	0.0147303	0.000107	0.01462	68.3840107	7	-0.0114729	-0.01271189	0.94303889	94.3757473	-11.212	-0.014	9296.860	-0.104
-8.41226008	0.030	20	0.00150	0.01261839	0.000107	0.01251	79.9271696	5	-0.00731217	-0.01271953	0.78319405	157.35564	-18.706	-0.014	4770.616	-0.089
-9.18385872	0.032	20	0.00160	0.01377579	0.000107	0.01367	73.1593756	3	-0.00511094	-0.01165088	0.73555515	167.546919	-18.244	-0.013	4894.911	-0.089
-9.39920257	0.027	20	0.00136	0.0070494	0.000107	0.00694	144.042366	5	-0.00365219	-0.01138394	0.95975572	128.407674	-13.662	-0.012	3243.919	-0.044
-9.09453839	0.035	20	0.00175	0.01591544	0.000107	0.01581	63.2573398	4	-0.00618058	-0.0117653	0.76535641	161.0230	-17.705	-0.014	5890.503	-0.104
-9.55926144	0.035	20	0.00175	0.01672871	0.000107	0.01662	60.1622907	3	-0.00597756	-0.01119333	0.66778018	184.551748	-19.306	-0.013	5403.918	-0.104
-8.80886923	0.026	20	0.00130	0.01761774	0.000107	0.01751	57.1078143	7	-0.01315792	-0.01214685	1.06753797	115.443201	-13.105	-0.014	9100.963	-0.119
-8.80886923	0.035	20	0.00175	0.01541552	0.000107	0.01531	65.32310	4	-0.00623683	-0.01214685	0.57385119	214.759508	-24.380	-0.014	4276.929	-0.104
-9.55926144	0.035	20	0.00175	0.01672871	0.000107	0.01662	60.1622907	4	-0.00644458	-0.01119333	0.42133458	292.499137	-30.599	-0.013	3409.591	-0.104
-8.67260984	0.032	20	0.00161	0.01517707	0.000107	0.01507	66.35670	5	-0.00830412	-0.01233769	0.87740659	140.459396	-16.196	-0.014	6437.476	-0.104

Measured	Observed	Observed	Observed		Design	Design	Design	Design	Design
$K_3V_u^2+K_2$ eq. 25	K_1/l_n+K_2 l_n =7days	K_3 l_n =7days	$K_3V_u^2+K_2$ l_n =7days	Design l_n ervals	Design K_3	$K_3V_u^2+K_2$	K_1/l_n+K_2	$K_3V_u^2+K_2$	K_1/l_n+K_2
52	53	54	55	56	57	58	59	60	61
-0.132	-0.015	87.436	9.29	6	102.01	10.84	-0.01486135	10.84	-0.01486135
-0.101	-0.013	75.864	6.57	6	88.51	7.66	-0.01305217	7.66	-0.01305217
-0.101	-0.012	71.760	6.16	5	100.46	8.63	-0.01291703	8.63	-0.01291703
-0.116	-0.013	83.882	5.76	6	97.86	6.72	-0.01300727	6.72	-0.01300727
-0.116	-0.012	110.544	5.99	6	128.97	6.99	-0.01242251	6.99	-0.01242251
-0.117	-0.015	86.363	10.61	8	75.57	9.29	-0.01455304	9.29	-0.01455304
-0.131	-0.014	87.108	7.67	5	121.95	10.74	-0.01417275	10.74	-0.01417275
-0.116	-0.014	95.297	10.38	4	166.77	18.17	-0.01557677	18.17	-0.01557677
-0.117	-0.014	101.152	7.85	4	177.02	13.74	-0.0154347	13.74	-0.0154347
-0.102	-0.014	119.720	5.29	6	139.67	6.17	-0.01393665	6.17	-0.01393665
-0.101	-0.013	83.100	5.32	6	96.95	6.20	-0.01278705	6.20	-0.01278705
-0.071	-0.012	98.256	3.37	5	137.56	4.72	-0.01222286	4.72	-0.01222286
-0.116	-0.012	103.368	3.58	6	120.60	4.18	-0.01254185	4.18	-0.01254185
-0.116	-0.012	100.907	4.84	6	117.72	5.64	-0.01218747	5.64	-0.01218747
-0.117	-0.014	149.369	5.13	8	130.70	4.49	-0.01360253	4.49	-0.01360253
-0.131	-0.013	95.417	6.89	5	133.58	9.65	-0.01396701	9.65	-0.01396701
-0.116	-0.014	120.446	7.95	4	210.78	13.91	-0.01477226	13.91	-0.01477226
-0.117	-0.014	89.036	8.26	4	155.81	14.47	-0.01558012	14.47	-0.01558012
-0.102	-0.014	110.519	5.26	6	128.94	6.14	-0.01393823	6.14	-0.01393823
-0.101	-0.012	82.193	4.01	6	95.89	4.68	-0.0125027	4.68	-0.0125027
-0.056	-0.012	90.704	2.93	5	126.99	4.11	-0.01211438	4.11	-0.01211438
-0.116	-0.013	81.792	4.81	6	95.42	5.61	-0.0127954	5.61	-0.0127954
-0.116	-0.012	90.634	4.89	6	105.74	5.70	-0.01218959	5.70	-0.01218959
-0.131	-0.014	109.162	9.92	8	95.52	8.68	-0.01379159	8.68	-0.01379159
-0.116	-0.013	110.105	4.70	5	154.15	6.58	-0.01339421	6.58	-0.01339421
-0.116	-0.012	154.871	5.27	4	271.02	9.23	-0.01280448	9.23	-0.01280448
-0.117	-0.014	95.892	6.16	4	167.81	10.79	-0.01441372	10.79	-0.01441372

APPENDIX N: Discharges for canals 1to 4

Canal 1:

Date	Farm No.	Discharge (l/s)
7.2.99	1U	7.0
14.2.99	1U	6.0
21.2.99	1U	6.5
28.2.99	1U	7.0
7.3.99	1U	5.5
14.3.99	1U	6.0
21.3.99	1U	6.0
28.3.99	1U	6.5
7.2.99	2M	7.0
14.2.99	2M	6.0
21.2.99	2M	5.2
28.2.99	2M	7.0
7.3.99	2M	5.5
14.3.99	2M	5.5
21.3.99	2M	5.5
28.3.99	2M	6.0
7.2.99	3E	6.8
14.2.99	3E	6.3
21.2.99	3E	6.5
28.2.99	3E	6.0
7.3.99	3E	5.0
14.3.99	3E	5.0
21.3.99	3E	5.0
28.3.99	3E	6.0

Canal 2

Date	Farm No.	Discharge (l/s)
1.2.99	1U	6.50
8.2.99	1U	7.00
15.2.99	1U	6.00
22.2.99	1U	6.00
1.3.99	1U	5.50
8.3.99	1U	5.00
15.3.99	1U	6.00
22.3.99	1U	5.50
29.3.99	1U	7.00
1.2.99	2M	6.00
8.2.99	2M	7.00
15.2.99	2M	5.50
22.2.99	2M	5.50
1.3.99	2M	5.00
8.3.99	2M	5.50
15.3.99	2M	6.00
22.3.99	2M	5.25
29.3.99	2M	6.50
1.2.99	3E	5.50
8.2.99	3E	6.50
15.2.99	3E	5.00
22.2.99	3E	6.00
1.3.99	3E	5.00
8.3.99	3E	5.00
15.3.99	3E	6.00
22.3.99	3E	5.25
29.3.99	3E	6.00

Canal 3:

Date	Farm No.	Discharge (l/s)
2.2.99	1U	6
9.2.99	1U	5
16.2.99	1U	5.5
23.2.99	1U	6
2.3.99	1U	5.5
9.3.99	1U	5.5
16.3.99	1U	5
23.3.99	1U	5.5
30.3.99	1U	6
2.2.99	2M	5.5
9.2.99	2M	5
16.2.99	2M	5.25
23.2.99	2M	5.5
2.3.99	2M	5
9.3.99	2M	5.25
16.3.99	2M	4.5
23.3.99	2M	5
30.3.99	2M	5.5
2.2.99	3E	5.5
9.2.99	3E	5
16.2.99	3E	5.5
23.2.99	3E	5
2.3.99	3E	4.75
9.3.99	3E	5
16.3.99	3E	4.5
23.3.99	3E	4.5
30.3.99	3E	5

Canal 4:

Date	Farm No.	Discharge (l/s)
3.2.99	1U	6
10.2.99	1U	5.5
17.2.99	1U	5.5
24.2.99	1U	5.5
3.3.99	1U	5.5
10.3.99	1U	5.25
17.3.99	1U	5.5
24.3.99	1U	5
31.3.99	1U	5.75
3.2.99	2M	5.5
10.2.99	2M	5.25
17.2.99	2M	5
24.2.99	2M	5
3.3.99	2M	4.75
10.3.99	2M	5
17.3.99	2M	5.5
24.3.99	2M	5
31.3.99	2M	5.5
3.2.99	3E	5.25
10.2.99	3E	4.6
17.2.99	3E	4.5
24.2.99	3E	5
3.3.99	3E	4.5
10.3.99	3E	5.75
17.3.99	3E	5
24.3.99	3E	4.75
31.3.99	3E	5