MODELING OF "FIELD-TO-FIELD" IRRIGATION METHOD IN PADDY BASINS FOR EFFICIENT WATER MANAGEMENT

BY

OSCAR S. NKHOMA

A DISSERTATION SUBMITED IN PARTIAL FULFILMENT FOR THE
DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL
ENGINEERING OF SOKOINE UNIVERSITY OF AGRICULTURE

1998

ABSTRACT

In rice fields the most common traditional irrigation method is field-to-field irrigation method, i.e. conveyance of water across a paddy basin bund through a simple weir or circular pipe to irrigate the next basin. In using the method, there is uncertainty as to when the nth basin, in a cascade, will receive the water after the preceding basins have attained the required depths. The method has been recognized and is practiced in some schemes in the sub-Saharan Africa. The method is commonly practiced by rice farmers in water scarce conditions. A farmer is tempted to tap water available in the neighbouring basin which has received water when there is low flow in the canal.

The study to model field-to-field irrigation method in paddy basins was conducted at Kasitu Self-help irrigation scheme in Malawi. This system of irrigation is practiced at this scheme.

Reservoir routing equation was adopted and used to develop irrigation water routing model for paddy basins in field-to-field irrigation method by incorporating the factors associated with paddy basins. The model was tested with data obtained from Kasitu Self-help irrigation scheme. The model showed high precision in predicting paddy basin water storage with given inflows and outflows in a specified time, hence it was able to predict closely the time of fill of a given depth in a paddy basin.

The results from the statistical analysis of the observed and calculated changes in water storage (in depth units) using the method of analysis of variance (ANOVA) at 5% significant level showed no significant difference in 11 sets of data out of 15 sets of data.

The study revealed that the factors which affect water storage in a paddy basin and hence time of fill includes the initial soil water content, surface water inflow, surface water outflow, vertical seepage and percolation through the basin base, horizontal seepage across the bunds with water loss through cracks and fissures, evapotranspiration, and rainfall.

The time of fill of *n* basins in a cascade of paddy basins was obtained as the summation of the times of fill of each of the *n* basins. The distance of travel of the stream flow was taken as the summation of the longitudinal distances of each basin in the direction of flow to the water front. Basin storage, time of fill, and distance travelled by the water front are all dependent on stream size (inflow and outflow), basin size and the associated water losses. The study proved that water travel time and time of fill of a paddy basin is predictable by using the factors which affect water storage in paddy basins.

The computer program developed reduces the many calculations involved in the process to simply entering the raw data or some processed data on choice, hence serve time. It also helps to eliminate some simple errors which may occur in the calculation process. It is recommended that the method be adopted in the design process of paddy basin irrigation systems. The weirs used in the method are recommended that they should also serve as measuring devices for irrigation water.

DECLARATION

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

Signature...

Date......19/05/98..

COPYRIGHT

ACKNOWLEDGEMENT

The author extends many thanks to Dr A. K. P. R. Tarimo of Sokoine University of Agriculture (Tanzania) and Prof. Z. M. Kasomekera of Bunda College of Agriculture (Malawi) for their contribution in supervising this work. Further, thanks go to SACCAR/GTZ for the financial support rendered to this study.

Grateful acknowledgement is also due to the staff of Ministry of Irrigation and Water Development (Malawi). Special thanks go to Mr J. K. Chisenga and Mr R. H. Padambo for their contribution towards this study.

Finally but not least, the deepest thanks and heartfelt appreciation go to the family of Mr and Mrs J. Kapala for their continuous support, financially, materially, morally and their encouragement in academics. The contribution of Mr I. I. Majamanda academically, can not go without due thanks.

DEDICATION

This dissertation is dedicated to The Almighty God, The Creator of the Universe:

" When he uttereth his voice, there is a multitude of waters in the heavens, and causeth the vapours to ascend from the ends of the earth; he maketh lightenings with rain, and brings forth the wind out of his treasures. "

(Jeremiah 10 : 13 ~ KJV)

TABLE OF CONTENTS

	Page
Abstruct	(ii)
Declaration	(v)
Copyright	(vi)
Acknowledgement	(vii)
Dedication	(viii)
Table of contents	(ix)
List of tables	(xiii)
List of figures	(xiv)
List of appendices	(xv)
Abreviations and symbols	(xvi)

CHAPTER ONE

1.0 INTRODUCTION	1
1.1 Background of the study	1
1.2 Paddy Irrigation	2
1.3 The Situation in Malawi	3
1.4 Irrigation Development	7
1.5 Objectives	11
1.6 Hypothesis	12
1.7 Definition of terms	12

CHAPTER TWO

2.0 LITERATURE REVIEW 14

2.1 Introduction 14

2.2 Research into African traditional agriculture 14

2.3 Local technology in irrigation 15

2.4 Basin irrigation 16

2.5 Field-to-field irrigation system 17

2.6 Reservoir model 19

2.6.1 Irrigation water requirement in paddy fields 19

2.6.2 Water storage in a paddy basin 21

2.6.3 Reservoir routing 23

2.6.4 Volume balance equation (water balance) 25

2.7 Evapotranspiration 31

2.8 Intake characteristics of soils (infiltration) 32

2.9 Infiltration and soil water movement during irrigation (percolation) 35

2.10 Seepage across a bund 38

2.11 Discharge over spillway 42

2.12 Characteristics of water flows in paddy fields 42

2.13 Summary 43

CHAPTER THREE

3.0 MATERIALS AND METHOD 44

3.1 Introduction 44

3.2 The Model 44

3.3 The Study Area 49

3.4 Methodology 52

3.5 Soil characteristics 53

3.6 Infiltration 53

3.7 Seepage across bunds 56

3.8 Evapotranspiration 58

3.9 Water measurements 59

3.10 Rainfall 62

3.11 The Computer Program 63

3.11.1 Input 63

3.11.2 Main areas of computations 65

3.11.3 Output 65

3.11.4 Simplified diagram of the program 66

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION 67

4.1 Soil characteristics 67

4.2 Infiltration 68

4.3 Seepage across bunds 70

4.4 Crop evapotranspiration 70

4.5 Surface flows 70

4.6 Paddy basin water storage 71

4.7 Time taken to fill a specified depth 74

4.8 Yield 78

4.9 Computer program testing 80

CHAPTER FIVE

5.0 CONCLUSION AND RECOMENDATIONS 81

5.1 Conclusion 81

5.2 Recommendations 82

6.0 REFERENCES 84

7.0 APPENDICES 88

LIST OF TABLES

Table Page

2.1 Suggested basin sizes 17

2.2 Representative physical properties of soils 34

4.1 Soil characteristics 68

4.2 Statistical Analysis on observed and calculated basin storage 73

4.3 Time of fill for a paddy basin 76

4.4 Observed and simulated time of fill for a paddy basin 77

4.5 Basin areas and yield 80

LIST OF FIGURES

Figure		Page
2.1	Typical infiltration rates for various soils	37
2.2	Horizontal water flow between two water bodies	39
3.1	Kasitu Self-Help Irrigation Scheme	50
3.2	Location of Kasitu Self-Help Irrigation Scheme	51
3.3	A typical cross-section of Paddy-to-Paddy water movement	53
3.4	A cross-section of a paddy bund	56
3.5	Sketch of a wooden weir	60
3.6	Water flowing across a bund through a wooden weir	60
4.1	Cumulative infiltration against the square root of time elapsed	69

LIST OF APPENDICES

Appendix		Page
A	Water measurement data	89
B	Processed and observed basin water storage	95
C	Processed basin inflows and outflows	101
D	Statistical Analysis	107
E	Graphical comparison of observed and calculated basin water storage	113
F	Computer program testing input data and output	124

ABBREVIATIONS, SYMBOLS AND SHORT FORMS

The following abbreviations, symbols and short forms are used in this dissertation, of which some are particular to this dissertation while some are standard notations:

ADD	Agricultural Development Division
SLADD	Salima Agricultural Development Division
IT	Intermediate Technology
AT	Appropriate Technology
RH	Relative Humidity
Calc.	Calculated
Cum.	Cumulative
Coef.	Coefficient
No.	Number
Adj.	Adjacent
D_t	Maintenance water requirement
D_s	Land-soaking and standing water application
D_d	Ditch depth
D_{ss}	Land-soaking water application
D_{st}, H	Flooding or standing water depth
n	Soil porosity; total pore space; constant
D_{sat}	Soil depth to be saturated
D	Water depth
Δt	Time period; change in time
P_v	Soil moisture content on volume basis

D_R	Total water requirement in depth units
ET_c, Et	Crop evapotranspiration
ET	Evapotranspiration
$S\&P$	Seepage and percolation
S	Soil sorptivity; Seepage; Water storage
ΔS	Change in water storage
ΔS_1	Average dead storage
ΔS_2	Temporary water storage
Δz_0	Height of weir crest above the soil surface
y	Height of weir crest above the soil surface
y_{01}	Water depth
RI	Rotational interval
F	Allowable submergence depth at the design storm period
$I(t)$	Time varying rate of surface inflow to storage element
$O(t, S)$	Time varying rate of surface outflow from storage element
I_1, I_2	Surface inflow at time point 1 and 2, respectively
O_1, O_2	Surface outflow at time point 1 and 2, respectively
Q_1, Q_2	Amount of surface inflow and outflow, respectively
G_1, G_2	Amount of subsurface inflow and outflow, respectively
P_1, P_2	Amount of percolation at time point 1 and 2, respectively
k	Time parameter; hydraulic conductivity
k_{sat}	Saturated hydraulic conductivity
k_h , k_v	Horizontal and vertical hydraulic conductivity, respectively

a	Discharge coefficient; constant
b	Discharge exponent; constant
A	Area
$A\ (h)$	Plan area of the water surface at elevation h
h	Water level in a reservoir
Q	Inflow rate
Q_u	Stream size per unit width
t	Time
T	Time
t_l	Stream advance time to a distance l from the inlet
t_x	Stream advance time to a distance x from the inlet
t_{op}	Intake opportunity time
$(t_{m,n})_k$	Time of current calculation at the time point k
$(t_{m,n})_{k-1}$	Time of last calculation at the time point k-1
R	Rainfall
Rf_j	Effective rainfall in a given period
W	Basin width; Water depth
$W_j,\ W_{j-1}$	Water depth at a given period
L	Basin length; Paddy bund length
l_b	Bund length
C_s	Surface storage
$f_z,\ (t)$	Cumulative infiltration function
I	Cumulative infiltration; Depth of irrigation; Infiltration intake rate

Ir_j,	Depth of irrigation
I_f	Final infiltration intake rate
Dr_i	Surface drainage
DR	Drainage runoff
W_{max}, W_{min}	Maximum and minimum depth of water, respectively
W_{opt}	Optimum water depth
VS	Vertical seepage
VS_v	Vertical seepage flow
HS	Horizontal seepage
HS_v	Horizontal seepage flow
ΔH, Δh	Vertical change in length
ΔZ	Horizontal change in length
L_t	Total ditch length
L_w	Bund width
h_l	Water depth in the ditch
V_y	Rate of percolation
s	Change in degree of saturation
H, h, h_f, h_x	Vertical length
x	Horizontal distance
q, q_b	Water flow
V_1, v_1, v	Velocity
C_d	Coefficient of discharge
B_o	Spillway length perpendicular to flow direction

g	Gravitational constant (acceleration due to gravity)
E	Approach energy
A_s	Seepage area
ΔQ_n	Change in net volume
u	Outflow
D, D_b, D_{out}	Depth
D_{in}, d	Depth
E_p	Pan evaporation
k_c, k_p	Crop and pan coefficients

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

In the wake of insufficient and unreliable rainfall in the sub-Saharan Africa, irrigation is the best alternative for crop production. In irrigated agriculture, there is a growing need to increase food production, but simultaneously, the availability of water for irrigation and the availability of capital for agricultural investment is decreasing. Resources such as capital investment and trained personnel are generally limited. Hence, designs of irrigation systems that are economic and simple to manage are exceedingly important (USAID, 1973). Therefore, in irrigation sector there is a great need to improve and modernise the existing conventional and traditional irrigation methods for efficient operation and management.

Farmers before modern scientific knowledge, practised irrigated agriculture using locally available technology and resources. Such agricultural practices are handed down from father to son and are usually finely 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). Even though, a farmer takes into account the possibility that the new techniques will not yield as much on his own field as they do on experimental plots. He knows what his past practices have yielded, but he is not sure of the new. He knows how to apply established methods, but he may not be confident of his ability to handle the new. 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 Paddy irrigation

This study is on "field-to-field" irrigation method (Bredero, 1991) in paddy fields. In other circles the method is termed "paddy-to-paddy" (ADC, 1978), "basin-to-basin" (Kay, 1986), "plot-to-plot" (Nippon Koel, 1993), or "traditional check" (Bredero, 1993). The method originates from traditional methods of irrigation, hence the term "traditional check". Traditional irrigation can be defined as application of water to crop land by using indigenous water harvesting techniques (simple diversions, bunding, e.t.c.) which are not based on scientific understanding but are locally handed down from father to son. Field-to-field irrigation method is very common in farmer-managed rice schemes or paddy fields in the Sub-Saharan Africa but lacks scientifically supported design and water management techniques; so that instead of being hazardous to irrigation water efficiency (IIMI, 1992), it can be accommodated in the design process as a beneficial method of water conveyance. The number and size of fields crossed by the water flow and time of travel from inlet to the tail-end field is based on local experience (or guess work) rather than on scientifically supported design.

Irrigation in paddy fields is principally associated with extraction of water from irrigation canals to flood each paddy basin. This method is maintained in government managed schemes and self-help schemes before turn-over (i.e. change of irrigation management from government institution to farmers) is done. After handing over responsibility of an irrigation scheme to farmers, farmers resort to their traditional method of extracting water from adjacent paddy basin by constructing simple weirs in the separating bunds or dikes. The weir is constructed by simply cutting a bund without using standard design. Water moves to adjacent plot through the weir within a strip of paddy plots. This defeats the design requirement leading to low irrigation efficiency (IIMI, 1992).

1.3 The situation in Malawi

Malawi has an estimated overall irrigation potential of 161,900 ha (FAO, 1995). Irrigated land in Malawi consists of sugar estates (16,500 ha), other commercial estates (3,000 ha), government managed (3,600 ha) and smallholder self-help schemes (3,000 ha) (CODA and Partners, 1994). According to FAO (1995), by 1994, Malawi had 28,000 ha which are full or partial control irrigation. Almost all irrigation is from surface water either through gravity method or by pumping from rivers. There are some very small areas (15 to 20 ha) along the lake shore areas of Lake Malawi which are irrigated by ground water.

Reliable yields under irrigation are only achievable in the alluvial basins along the western shore area of Lake Malawi, Lake Chilwa and in Lower Shire Valley (FAO, 1995). There are some 61,900 ha of *dambo*[1] (wetland) areas under rice cultivation. Simple diversions and bunding are applied, and farmers often cooperate in small groups to manage water. Studies are being undertaken to estimate areas, uses and potential for drainage using low-cost structures (FAO, 1995).

There are three basic categories of farming in the full or partial control irrigation sub-sector (FAO, 1995):

- Private estates,
- Government-run smallholder schemes, and
- Self-help Smallholder schemes.

The government run schemes are located mostly on the lakeshore plains of Lake Malawi, Lake Chilwa, and in the Lower Shire Valley. The schemes are managed, operated, and maintained by government staff and funds. Farmers are allocated plot licenses renewable every 5 years. Cropping patterns and regimes are strictly controlled by government. The government of Malawi is in the process of handing over the scheme management, operation and maintenance to the farmers at each scheme (CODA and Partners, 1994).

Self-help Irrigation Schemes in Malawi were constructed by the government with full support and participation of farmers at each stage of development, including identification and planning. Farmers contribute their labour during construction, and when completed, farmers manage and maintain their schemes with minimum government support. Irrigation under self-help smallholder schemes implies that farmers contribute towards the planning, designing, and implementation as well as the management operations and maintenance of the scheme. This is facilitated by the formation of committees and associations. Most of the self-help schemes in Malawi use gravity-fed water from rivers or streams, employing simple diversion technologies. In these self-help schemes, the main

---

[1] **Dambo, is a low lying area which is usually wet most of the times (wetland)**

crops grown include rice, maize, potatoes and vegetables. It is worth noting that the formal self-help irrigation schemes have been developed in areas where traditional irrigation was being practised and is still practised. Apart from the formal irrigation schemes, there are numerous areas of *dambos* in Malawi where farmers have been using simple water harvesting techniques (simple diversions, bunding, e.t.c.) to irrigate vegetables and rice.

Self-help irrigation has gained prominence as a strategy for irrigation development. It is in its adaptability to the smallscale situation that self-help irrigation has favour over largescale irrigation in Malawi. The methods used in self-help irrigation systems allow the farmers to gradually improve their skill levels while at the same time not putting much of a financial burden on them.

It is generally accepted that management on the rice schemes is of a reasonable standard in the schemes. The main problem at present is the management of water by the farmers and government staff (CODA and Partners, 1994). The problems that exist in the schemes can be solved by improved management or by improved engineering works.

Lack of farmers' activity on maintenance is clearly visible on all the existing schemes. Though responsibility of scheme management, operation and maintenance is being handed over to the farmers, there is still lack of sense of ownership. The farmers still believe that the schemes belong to the government and hence lack of maintenance of such schemes.

Of the existing government managed irrigation scheme, very few can claim to have any means of knowing how much water is being applied into the schemes because of lack of calibrated measuring devices (CODA and Partners, 1994).

The irrigation policy in Malawi can be broadly be summarised as follows: to expand and increase crop production under irrigation to enhance local and national food security, and to increase cropping opportunities for farming families where appropriate and applicable (CODA and Partners, 1994).

For this policy to be put into operation, the strategy to be used by the government of Malawi among other things include, encouragement of the rural community to contribute to agricultural development through the development of small scale irrigation schemes (CODA and Partners, 1994). The emphasis is on small scale irrigation and smallholder participation.

Among the 23 point irrigation development strategy plan for poverty alleviation set by the Ministry of Irrigation and Water Development, one of the main features include (FAO, 1995):

- to increase development of self-help farmer schemes, and hand over operation and management of existing government-run schemes to the farmers after completion of rehabilitation.

1.4 Irrigation development

In 1991, FAO/World Bank Co-operative Program concluded that possible irrigation strategies for irrigation development should involve two basic but inter-related choices, namely, choice of technology and scale of development. The strategy in choice of technology states that a decision has to be made as to whether to use low cost as opposed to "high tech" technology which is associated with high cost (CODA and Partners, 1994). The concept of "appropriate technology" is relevant in this case. Some policy makers believe that low cost traditional technologies are appropriate for smallholder irrigation and that farmers are not ready for high technology systems such as sprinklers and drip. Other schools of thought contend that it is better to introduce these technologies in farmer-managed schemes now to evolve and build up a tradition.

There are thirteen different types of irrigation technologies which have been identified by FAO/WB (1991) in Malawi as cited by CODA and Partners (1994). The technology required for large scale irrigation are not economical when used on crops of low cash value. The irrigation strategy must be based on simple technologies suitable only for smallscale irrigation schemes. This consideration is reinforced by recurrent management cost considerations (CODA and Partners, 1994).

Better scheme designs and equipment would allow irrigation to be adapted to the African farmer, rather than vice versa. If more of the operation and management of major government projects is to be left to the farmers as owners, it will be necessary to involve farmers from the beginning and adapt irrigation system designs to be manageable by farmers. Designs are required which can be maintained by relatively unskilled local contractors hired by the farmers with instructions from the farmers, or by the farmers themselves, and which can if necessary continue to operate reasonably well even under sub-optimal maintenance (FAO, 1986).

Studying existing local systems and skilfully drawing upon farmers' past irrigation experience are valuable complements to modern engineering science in developing and improving irrigation systems (Velde, 1989). Field-to-field irrigation method is a traditional irrigation method. Farmers owning paddy fields resort to this method once responsibility of the scheme has been handed over to them. This is evident at Kasitu Self-help Irrigation scheme (Figure 3.1) in Malawi. Farmers break bunds at three to four points to collect water from adjacent paddy basin and from any adjacent canal. Rectangular, V-shaped, and circular cuts are seen along the bunds and canal sides. In some cases short hollow bamboo pieces or circular PVC pipes, asbestosis pipes and steel pipes are used to channel water across a bund in a mole type of drain. The use of the method is further strengthened in times of water scarcity and low flows. A farmer is tempted to extract water available in the neighbouring basin across a bund when there is low flow in the canal.

There is a great need through on-farm research to determine the optimum density of field channels in paddy irrigation systems and the optimum flow/field size ratio. In addition, there is a need to determine the distance from the water course or number of fields crossed by the water flow in the field (Bredero, 1991).

German Association for Water Resources and Land Improvement (1985) records that irrigation planners should try to find the best-fitting technical solution into traditional agricultural systems for the local people instead of parachuting the technically-best solution in the rash hope that farmers and management staff will use it properly.

Imaginative methods are needed to improve irrigation water distribution systems, irrigation methods, drainage, cultural practices for improved natural water use efficiency (ASAE, 1982).

In the wake of "turn over" i.e. change of irrigation management from government institution to farmers, the likelihood of farmers modifying the systems to traditional methods for their easy management is high. Farmers need technology they can understand and manage. For example, farmers may not be able to manage an automatic irrigation system or a system which require alteration of water depth into a canal according to crop water need. What farmers need is a system which simply requires them to open and close according to demand. Field-to-field irrigation method is a simple and locally practised technology, hence can be easily managed by farmers.

Lack of maintenance has caused many systems to fall into disrepair, further inhibiting performance (CODA and Partners, 1994). Bua Irrigation scheme in Malawi (Figure 3.3) is one example. Over time, distribution channels fill up with silt, increasing the likelihood of breaking, damaging outlets and leading to salt build-up in the soil. Field-to-field irrigation method results in fewer irrigation channels hence little and simpler maintenance work is required compared to individual field channel method.

The aim of this research work is to model "field-to-field" irrigation method in paddy basins for efficient water management, such that field-to-field irrigation should be adopted in the design rather than considering only the normal standard design in new or upgraded systems.

1.5 Objectives

The main objective of this study is to model “field-to-field” irrigation method in paddy basins for efficient water management.

To achieve this objective the following specific objectives are considered:

- Adapt and modify a reservoir routing equation for paddy basins;
- Develop irrigation water routing model for paddy basins (IWRMPB) in field-to-field irrigation method which determines paddy basin water storage and hence time of fill of a paddy basin as a function of basin water storage and net inflow;
- Validate the model using data obtained from the field conditions.
- Develop a computer program for the model.

1.6 Hypothesis

The hypothesis is that for newly or upgraded farmer-managed irrigation systems in paddy fields, water users will resort to using traditional methods of irrigation, one of which is field-to-field irrigation method in paddy fields.

1.7 Definition of terms

The following terms are used in this dissertation:

"high tech"	High technology
Paddy	Used interchangeably to mean rice-field and rice
ANOVA	Analysis of variance
Traditional Irrigation	Application of water to a crop land by using indigenous water harvesting techniques (simple diversions, bunding, etc.) which are not based on scientific understanding but are locally handed down from father to son.
Reservoir routing	Channelling of water across a reservoir
Dead storage	Paddy water storage below the spillway sill
Temporary storage	Paddy water storage above the spillway sill
Intermediate Technology (IT)	A technical change which meets a specific need in a specific situation, sometimes known as Appropriate Technology (AT)
Traditional Check	Localised term for "Field-to-field" irrigation method

Dambo	Low lying area which is usually wet most of the time (wet land)
Self-help	Farmer participation (in scheme design, operation and management)
Basin Irrigation	Running water into a level area surrounded by a bank or bunds
"Field-to-field"	Used interchangeably with "Paddy-to-paddy", "Basin-to-basin" and "Plot-to-plot" to mean water conveyance from one field, paddy, basin or plot to the other
Turn-over	Change of irrigation management from government institution to farmers
Horizontal seepage	Water moving across paddy basin bunds
Vertical seepage	Water moving through paddy basin base

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This section reviews some work done by scientists in modelling water movement and water storage in reservoirs and paddy fields. It also covers calls and views of some scientists towards simple and traditional irrigation methods and shades some light on basin (paddy) irrigation and factors associated with paddy irrigation and soils.

2.2 Research into African traditional agriculture

Scientific researchers opportunistically attempt to discover and appreciate some "scientific truth" in African "traditional" agricultural systems only to the extent that those truths can be explained and understood by "modern science". It is often mentioned in scientific reports on traditional agriculture that with the help of modern science, the wisdom of indigenous African agriculture must be re-evaluated and improved (Sakamoto, 1988).

Shigeta (1988) as cited by Sakamoto (1988) emphasizes that in contemporary African agriculture, there are "indigenous sciences" according to Paul Richards (1985); or "folk knowledge system" as termed by Fukui (1987); or the "indigenous knowledge system" of Brokensha *et. al.* (1980) which we can not neglect to appreciate. Of course these "sciences" are not available in written form such as text books, nor as a given entity of inherent nature. In many cases, they appear as analytical models of researchers. What we can observe in a tangible form and should comprehend is an on going process of their application and modification in agricultural activities based on the farmer's judgements. We may even say that farmers themselves are incessantly conducting on-farm experiments as they go about their daily agricultural activities. Shigeta (1988) as cited by Sakamoto (1988) suggests that what scientific researchers should do is not to find out "scientific truths" in African "traditional" agriculture, but try instead to interpret the whole system of indigenous agricultural science existing within contemporary African agriculture.

2.3 Local technology in irrigation

Before modern scientific knowledge, farmers practised irrigated agriculture using locally available technology and resources. Sustained irrigated-agriculture development can be achieved by using a participatory strategy that draws upon local knowledge and experience yielding greatest long-run significance. Velde (1989) records that the general farmer satisfaction with and apparent absence of failure in the Aga Khan Rural Support Programme-assisted system, is firm evidence that studying existing local systems and skilfully drawing upon farmers' past irrigation experience are valuable complements to modern engineering science in developing new irrigation systems.

Intermediate Technology (IT), sometimes called Appropriate Technology (AT), defined as a technical change which meets a specific need in a specific situation, is a stepping stone between indigenous methods and the modern technology. Local folklore should be treated with respect and built upon where it can play a role in the modernisation (Adams, 1982).

2.4 Basin irrigation

Basin Irrigation involves dividing the field into small units so that each has a nearly level surface. Levees (ridges, bunds or dikes) are constructed around the areas forming basins (plots or paddies) within which the irrigation water can be controlled. The basins are filled to the desired depth and the water is retained until it infiltrates into the soil, or the excess drained off (Doneen and Westcot, 1988). The basin method is best adapted to soils having low to moderate infiltration (intake) rates and moderate to high available water holding capacity soils (Doneen, 1988; Kay, 1986; Booher, 1974; FAO/UNESCO, 1973). Smooth, gentle, uniform land slopes are best adapted and result in the best field layouts for basins. Basin irrigation can be adopted where the land has a gentle slope and levelling is not costly (Doneen, 1988; FAO/UNESCO, 1973).

Basin sizes depends on the soil infiltration characteristics, the stream size available and the crop needs (Kay, 1986). The sizes may vary from 1m^2, used for growing vegetables and other intensive crops, to as much as 7.5 ha for production of rice and other grain crops on basin-type clay soils (Booher, 1974). Kay (1986) suggested basin sizes from type of soil and stream size as shown in Table 2.1.

Table 2.1 Suggested basin sizes

Stream Size (l/s)	Sand	Sandy loam	Clay loam	Clay
	Basin size (ha)			
15	0.01	0.03	0.06	0.1
30	0.02	0.06	0.12	0.2
60	0.04	0.12	0.24	0.4
90	0.06	0.18	0.36	0.6
120	0.08	0.24	0.48	0.8
150	0.10	0.30	0.60	1.0
180	0.12	0.36	0.72	1.2
210	0.14	0.42	0.84	1.4
240	0.16	0.48	0.96	1.6

Source: Kay, 1986

Basin irrigation for crops other than rice is, in general, a relatively inefficient system of field application unless handled in small basins which are easy to level (Bredero, 1991). On the other hand, basin irrigation conveyance systems used in rice-based projects tend to be very efficient because a lot of percolation and runoff water is picked up downstream in lower fields and used again (Bredero, 1991).

2.5 Field-to-Field irrigation system

Field-to-field irrigation system is a system of irrigating rice and is the most common traditional innovation in rice crop lands (Bredero, 1991). The number and size of fields crossed by water flow is based on local experience (or guess work) rather than on scientifically supported design. The seepage and percolation, and runoff losses inherent in this irrigation method usually reappear somewhere downstream as drainage losses or rising ground water table (Bredero, 1991).

There is a great need through on-farm research to determine the optimum density of field channels in paddy irrigation systems and optimum flow/field size ratio. In addition, there is a need to determine the distance from the water course or number of fields crossed by the water flow in the field (Bredero, 1991).

Advantages of field-to-field irrigation method include lower on-farm construction costs and bigger utilised land area compared to individual field channel method; percolation and runoff water is picked up down stream of the field and used again; the method is easily accepted by farmers because it conforms with their traditional practices; the method encourages farmers not adjacent to the head canal to participate in the maintenance of the head canal; the method serves as a way of disposing excess water hence act in place of drainage canals; the method serves as an alternative when not all fields can be reached by canals economically; the method supplies the soil with oxygen and dilutes hydrogen sulphide and other harmful substances that accumulate due to poor drainage; the method provides a limited adjustment of soil temperature and a saving of water management labour. The disadvantages of this method include loss of soil nutrients carried away by the flowing water in the long run in using this method, it can lead to considerable delay in water reaching the tail-end fields (Bredero, 1991; Wang and Hagan, 1981). Therefore, there is a need to determine the time water will take to reach the tail-end field.

2.6 Reservoir models

This section looks at some models done by researchers to relate water storage and movement in reservoirs or paddy basins. A paddy basin is simply a water reservoir on unlined soil surface. Unlike lined water reservoirs, a paddy basin faces water outflows through horizontal seepage across bunds, vertical seepage through basin base (seepage and percolation), evapotranspiration and surface outflow. Water outflow from a lined reservoir is principally through surface outflow and evaporation.

Modelling in basin irrigation is based on volume balance equation obtained from the mathematical modelling of the rate of inflow and outflow as cited by FAO (1994), CBIP (1989) and IRRI (1989); hydrodynamic equation using flow resistance relationship as cited by ASAE (1993, 1986) and Walker and Skogerboe (1987); reservoir routing model as cited by Linsley *et al.* (1988) and Boyd *et al.* (1979). This study is based on reservoir routing model and volume balance model.

2.6.1 Irrigation water requirement in paddy fields

Water requirements for crops have been determined by various methods at different research institutes and agricultural universities (Bredero, 1991; Pruit and Doorenbos, 1977). However, some of the aspects like depth, growth stage, depletion of available soil moisture, etc., have produced results which are location specific because of their dependence on variations in local climate, moisture characteristics of the soil type, effective rooting depth and ramification, irrigation method used, rainfall pattern, variation in crop coefficient (k_c), extent of capillary contribution or deep percolation, initial soil moisture reserve carried forward from previous season, etc.

Wang and Hagan (1981) has the following divisions of Irrigation water requirement in paddy fields:

- Maintenance water to meet evapotranspiration requirements, field seepage and percolation losses, D_t (m/day);
- Pretillage soil conditioning (soaking water), D_{ss}(m). D_{ss} is determined by soil type, its structure at the time of the initial water application, and the desired depth of saturation; and
- Flooding or standing water, D_{st} (m).

Land soaking and standing water is obtained by using the relationship (Wang and Hagan, 1981):

$$\begin{aligned} D_s &= D_{ss} + D_{st} \\ &= \frac{(n - P_v)D_{sat}}{100} + H \qquad (2.1) \end{aligned}$$

where,

D_s = land-soaking and standing-water application (mm),

P_v = soil moisture content on volume basis (%),

n = soil porosity (%),

D_{sat} = soil depth to be saturated (mm),

H = depth of standing water (mm).

Therefore, total water requirement in terms of depth in a paddy plot will be given by:

$$D_R = D_{ss} + D_{st} + D_t$$

$$= \frac{(n - P_v)D_{sat}}{100} + H + (ET_c + S\&P)\Delta t \qquad (2.2)$$

where,

D_t = daily maintenance water requirement (mm/day),

ET_c = crop evapotranspiration (mm/day),

$S\&P$ = seepage and percolation (mm/day),

Δt = time period (days).

The term $\frac{(n - P_v)D_{sat}}{100}$ in Equation 2.2 is applicable in unsaturated soil conditions because when the soil is saturated $n = P_v$ which reduces the term to zero (Wang and Hagan, 1981). As for paddy fields such a condition occurs at first irrigation before transplanting. The rice crop does not require unsaturated conditions. Maintenance water requirement is water required for consumptive use and field water losses to maintain a specified water level in a continuous water application system.

2.6.2 Water storage in a paddy basin

Water storage in a paddy basin is in two parts:

- Dead storage below the spillway sill, and
- Temporary storage above the spillway sill.

Average storage in a paddy is given by the relationship (Wang and Hagan, 1981):

$$\Delta S = \Delta S_1 + \Delta S_2 \qquad (2.3)$$

where,

ΔS = average depth of available paddy water storage (m),

ΔS_1 = average dead storage,

ΔS_2 = temporary storage.

Dead storage is the water retained by the paddy basin excluding the water which is depleted by the plant. In Equation 2.3, the average dead storage (ΔS_1) over an area of a paddy field under rotational irrigation is given by (Wang and Hagan, 1981):

$$\Delta S_1 = y - RI \times \frac{D_t}{2} \qquad (2.4)$$

where,

y = height of weir crest above the soil surface (m),

RI = rotational interval (days),

Equation 2.4 assumes half of maintenance water application is consumed on each day of irrigation water application (Wang and Hagan, 1981). The temporary storage (ΔS_2) is given by:

$$\Delta S_2 = F - y \qquad (2.5)$$

where, F = allowable submergence depth at the design storm period (m).

2.6.3 Reservoir routing

The reservoir routing model is derived from the continuity equation and storage-discharge equation i.e.

Continuity equation (Fenton, 1992):

$$I(t) - O(t,s) = \frac{dS}{dt} \tag{2.6}$$

Storage-discharge equation (Boyd *et al.*, 1979):

$$S = kO(t,s) \tag{2.7}$$

where,

$I(t)$ = time varying rate of surface inflow to storage element,

$O(t,s)$ = time varying rate of surface outflow from storage element,

S = volume of water stored in the element at time t,

k = time parameter.

The time parameter, k is constant for linear response and variable for non-linear response.

For linear response (Boyd *et al.*, 1979),

$$I - O = k\frac{dO}{dt} \tag{2.8}$$

For non-linear response (Boyd *et al*, 1979),

$$k = aO^{b} \tag{2.9}$$

Substituting k in Equation 2.7,

$$S = aO^{b+1} \tag{2.10}$$

Substituting *S* in Equation 2.6 and simplifying it,

$$I - O = a(b + 1)O^b . \frac{dO}{dt} \qquad (2.11)$$

where,

a = discharge coefficient,

b = discharge exponent.

If the reservoir surface elevation (h) changes by an amount dh, in the limit as $dh \rightarrow 0$ the change in storage, dS, is given by (Chow *et al.*,1988):

$$dS = A(h)dh \qquad (2.12)$$

where,

$A(h)$ = plan area of the water surface at elevation h,

h = water level in reservoir.

Substituting Equation 2.12 into Equation 2.6, and writing the surface outflow (O) as a function of both t (in the case of controlled discharges) and of h (usually a simple mathematical function like $(h\text{-}y_{crest})^{3/2}$, where y_{crest} is the elevation of the spillway crest), an equivalent form of the storage equation is obtained (Chow *et al.*,1988; Roberson *et al.*,1988):

$$\frac{dh}{dt} = \frac{I(t) - O(t,h)}{A(h)} \qquad (2.13)$$

which is the differential equation for the surface elevation itself. If the form of Equation 2.6 is used then the storage volume, *S*, has to be obtained as a function of *h* from the integral:

$$S(h) = \int^{h} A(y)dy \tag{2.14}$$

It is important to note that at $h \leq y_{crest}$; surface outflow $(O) = 0$

2.6.4 Volume balance equation (water balance)

Water balance for a paddy basin is a mathematical relationship of contributing flows into the basin, out of the basin, and the amount stored in the basin. Different researchers, such as Iwata *et. al.*, (1985) as cited by Juo and Lowe (1986), Murty and Sriramany (1993) as cited by FAO (1994), Pereira and Texeiera (1993) as cited by FAO (1994); have produced equations to relate water balance in paddy basins.

IRRI (1989) has the following equation as the governing equation:

$$Q_u t_l = C_s \cdot L + \int_0^l f_z(t_{op})dx \tag{2.15}$$

where,

$$Q_u = \frac{Q}{W}$$

Q = inflow rate (m^3/s),

Q_u = stream size per unit width (m^3/s/m),

t_l = stream advance time to reach a distance l from the inlet (s),

W = basin width (m),

L = basin length (m),

C_s = surface storage (m),

$f_z(t)$ = cumulative infiltration function (m),

t_{op} = intake opportunity time (s),

= t_l - t_x ,

t_x = advance time to distance x from the inlet.

C_x represents the average depth of water at the soil surface and is computed as (IRRI, 1989):

$$C_x = 0.9 * n^{3/8} Q_u^{9/16} \left[\left(t_{m,l} \right)_k^{3/16} + \left(t_{m,l} \right)_{k-1}^{3/16} \right] \qquad (2.16)$$

where,

n = Manning's roughness coefficient;

$(t_{m,l})_k$ = time of current calculation at the time point k (min);

$(t_{m,l})_{k-1}$ = time of last calculation (min).

For $k = 1$, $k-1 = 0$, $(t_{m,l})_0 = (t_{m,l})_1$. Once the advance water front reaches L, Equation 2.15 is no longer valid, and infiltration volume is given by the equation:

$$I = \int_0^L f_z \left(t - t_L \right) dl, \qquad t \geq t_L \qquad (2.17)$$

I has to be evaluated numerically using the data point number corresponding to the end of the field.

Philip (1957) as cited by British Society of Soil Science (1997), produced the following relationship for approximating cumulative infiltration, I, as a function of time, t, after ponding:

$$I = St^{1/2} + kt \qquad (2.18)$$

where,

I = cumulative infiltration,

S = sorptivity,

$k \cong k_{sat}$, the saturated hydraulic conductivity in the transmission zone, when t is large,

t = time.

The first term of Equation 2.18 is dominant for short infiltration times. The influence of potential gradients due to gravity is initially negligible. Infiltration is controlled by gravity at long infiltration times. S and k_{sat} can be estimated from simple ponded infiltration experiments using Equation 2.18. Sorptivity can be obtained by plotting cumulative infiltration against the square root of time, and k can be obtained from the infiltration rate at longer times (British Society of Soil Science, 1997).

In river basins, subsurface water inflow into the basin and subsurface water outflow from the basin are small and negligible, hence subsurface water exchange with neighbouring basins is assumed to be zero (CBIP, 1989).

Iwata *et. al.*, (1985) as cited by Juo and Lowe (1986), states that the water balance equation for a given time period in a paddy basin after ponding is given by the relationship:

$$RA + Q_1 + G_1 = Q_2 + G_2 + A(ET) + \Delta S \tag{2.19}$$

where,

R = rainfall (m),

A = area of the field (m^2),

Q_1, Q_2 = amount of surface inflow and outflow water respectively (m^3),

G_1, G_2 = amount of subsurface inflow and outflow water respectively (m^3),

ET = evapotranspiration (m),

ΔS = change in the amount of water stored in and on the soil (m^3).

If water depth is kept constant, ΔS can be considered to be negligible. At low elevations, G_1 and G_2 are also negligible because the impermeable soil layer, on which groundwater is stored, is usually flat. The resulting water balance equation in a paddy field is:

$$Q_1 + RA = Q_2 + P_1 + P_2 + (ET)A + \Delta S \tag{2.20}$$

where,

$P1, P2$ = amounts of seepage and percolated through the base and through the levee, respectively.

Murty and Sriramany (1993) as cited by FAO (1994) states that the generalised water balance equation for a given period in a paddy field is given by:

$$W_j = W_{j-1} + Rf_j - Et_j - S_j + Ir_j - Dr_j \tag{2.21}$$

where,

W_j = water depth in the field at the end of the given period,

W_{j-1} = water depth in the field at the beginning of the given period,

Rf_j = effective rainfall during the period,

Et_j = crop evapotranspiration,

S_j = seepage and percolation for the period,

Ir_j = depth of irrigation,

Dr_j = surface drainage.

If W_{max} is the maximum depth of water possible in the paddy field, W_{opt} the optimum depth and W_{min} the minimum depth at which irrigation is to be given, the water balance equation can be used for determining the irrigation schedules and the depth of water to be applied in each irrigation. The values of Et_j and S_j are estimated for each day. Rainfall occurring on the day will add to the water balance equation to the extent that the field is capable of retaining the rainfall based on the initial depth of water on the day. Excess rainfall will go as drainage.

Pereira and Texeiera (1993) as cited by FAO (1994) states that the water balance for a rice basin for a period of duration t is given by:

$$R + I = ET_c + VS + HS + DR + \Delta S \qquad (2.22)$$

where,

R = rainfall (mm),

I = irrigation (mm),

ET_c = rice crop evapotranspiration (mm),

VS = vertical seepage through the soil profile (mm),

HS = horizontal seepage through the basin bunds to the drainage ditches or to/from the neighbouring rice fields (mm),

DR = drainage runoff (mm),

ΔS = changes in storage in the basin during the period Δt (mm),

The terms R and ET_c are obtained from meteorological observations. The vertical and horizontal seepage are computed assuming saturated flow conditions. VS is estimated assuming Darcy flow conditions for vertical flow. The horizontal seepage (HS) for a ditch of depth D_d is obtained using Dupuit approach (Pereira, Alves and Pereira, 1987) as cited by FAO (1994), i.e.

$$VS_v = \sum - k_V \times A \times \frac{\Delta H}{\Delta Z} \tag{2.23}$$

$$HS_v = \sum - L_l \frac{k_H}{2L_w}\left\{(W + D_d)^2 - h_l^2\right\} \tag{2.24}$$

where,

k_V, k_H = vertical and horizontal hydraulic conductivity,

A = basin area,

$\frac{\Delta H}{\Delta Z}$ = hydraulic gradient,

L_t = total ditch length,

L_w = bund width,

W = water depth,

D_d = ditch depth,

h_t = water depth in the drainage ditch,

VS_v = Vertical seapage flow,

HS_v = Horizontal seapage flow.

Change in water storage in the basin on volume basis can be expressed as (FAO, 1994):

$$\Delta S = \left(W_{i+1} - W_i\right)A, \tag{2.25}$$

where,

W_{i+1} = current water depth (m),

W_i = initial water depth (m),

A = basin area (m^2).

2.7 Evapotranspiration

Evapotranspiration is influenced by many factors:

- climatic conditions such as humidity of the air, temperature, wind velocity, and amount of sunshine;
- water supply to the leaves, which depends on soil conditions and weather conditions on previous days and weeks; and
- plant food supply to the roots (Mohr, 1972), as cited by Wang and Hagan (1981).

For most cereals, the age of the plant can also influence the evapotranspiration rate (Wang and Hagan, 1981).

2.8 Intake characteristics of soils (infiltration)

Intake rate varies with many factors, including depth of water on the surface, temperature of water and soil, soil structure and texture, and moisture and salinity content of the soil (Hansen *et al.*, 1980). Hence, intake rate varies from place to place on a field and it also varies with time. Sandy soils may have rates in excess of 250 mm per hour, whereas clay soils may have rates approaching zero when soil structure has been practically destroyed by poor management. Usually the intake rate plotted against time on a logarithmic scale will show as a straight line, and therefore can be represented by the following equation (Hansen *et al.*, 1980):

$$I = aT^n \tag{2.26}$$

where,

I = intake rate,

a = a constant and is the value on the ordinate when time T on the abscissa has a value of 1.

n = a constant and is the slope of the line.

When the observation of intake extends over long periods, a better representation of the data can usually be obtained by using the equation (Hansen *et al.*, 1980):

$$I = aT^n + b \tag{2.27}$$

Since n is negative, I decreases with an increase in T. The intake rate I will approach a constant value b as time increases. The constant intake rate is referred to as final intake rate. How intake rate varies with soil texture is shown in Table 2.2.

By the time the infiltration rate has become constant, a pronounced transition zone has established with nearly uniform moisture content close to saturation. Pressure differences in the zone are small and the water movement is dominated by the gravity force. The final infiltration rate thus becomes approximately equal to the saturated hydraulic conductivity, k_{sat} , of the soil (Smedema and Rycroft, 1983).

Table 2.2 Representative Physical Properties of Soils

Soil Texture	Infiltration[a] and Permeability, (cm/hr) I_f	Total Pore Space (%) N	Apparent Specific Gravity A_s	Field Capacity (%) FC	Permanent Wilting (%) PW	Total Available Moisture[b]: Dry Weight (%) $P_w = FC - PW$	Total Available Moisture[b]: Volume (%) $P_v = P_w A_s$	Total Available Moisture[b]: cm/m $d = \frac{P_w}{100} A_s D$
Sandy	5	38	1.65	6	4	5	8	8
	(2.5–25)	(32–42)	(1.55–1.80)	(6–12)	(2–6)	(4–6)	(6–10)	(7–10)
Sandy loam	2.5	43	1.50	14	6	8	12	12
	(1.3–7.6)	(40–47)	(1.40–1.60)	(10–18)	(4–8)	(6–10)	(9–15)	(9–15)
Loam	1.3	47	1.40	22	10	12	17	17
	(0.8–2.0)	(43–49)	(1.35–1.50)	(18–26)	(8–12)	(10–14)	(14–20)	(14–19)
Clay loam	0.8	49	1.35	27	13	14	19	19
	(0.25–1.5)	(47–51)	(1.30–1.40)	(23–31)	(11–15)	(12–16)	(16–22)	(17–22)
Silty clay	.25	51	1.30	31	15	16	21	21
	(.03–0.5)	(49–53)	(1.30–1.40)	(27–35)	(13–17)	(14–18)	(18–23)	(18–23)
Clay	0.5	53	1.25	35	17	18	23	23
	(.01–0.1)	(51–55)	(1.20–1.30)	(31–39)	(15–19)	(16–20)	(20–25)	(20–25)

Note: Normal ranges are shown in parentheses.

[a] Intake rates vary greatly with soil structure and structural stability, even beyond the normal ranges shown above.

[b] Readily available moisture is approximately 75% of the total available moisture.

Source: Hansen *et al.*, 1980

When light, frequent irrigation are applied, the irrigation may be completed before the final intake rate is reached. Since initial rates are considerably in excess of final rates, the amount of water entering the soil can best be represented by the accumulated depth of water that has entered the soil. This quantity is represented by the integral of Equation 2.26 as (Hansen *et. al.*, 1980):

$$D = \frac{a}{n+1} T^{n+1} \tag{2.28}$$

or, integrating Equation 2.27 when this equation represents more accurately the intake function, the accumulated depth of water applied becomes (Hansen *et. al.*, 1980):

$$D = \frac{a}{n+1} T^{n+1} + bT \tag{2.29}$$

Dividing the depth Equation 2.28 by time, yields the average intake as (Hansen *et. al.*, 1980):

$$I_{ave} = \frac{a}{n+1} T^{n} \tag{2.30}$$

and Equation. 2.29 becomes

$$I_{ave} = \frac{a}{n+1} T^{n} + b \tag{2.31}$$

2.9 Infiltration and soil water movement during irrigation (percolation)

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 conductivities 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, 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 the infiltration rate has become constant, the final infiltration rate becomes approximately equal to the k_{sat} of the soil. 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 shows typical infiltration rates for various soils.

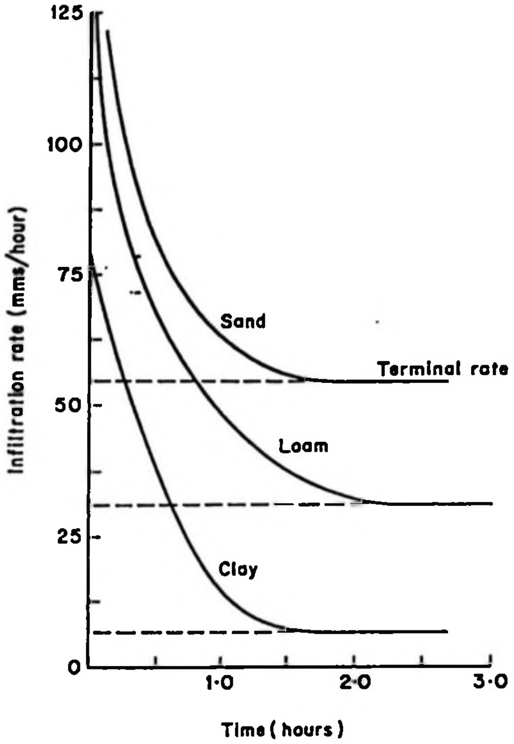


Figure 2.1 Typical infiltration rates for various soils (source: Withers and Vipond, 1974)

Using the basic principles of flow through soils, it can be shown that the rate of downward movement V_y can be defined by the following equation (Hansen *et. al.*, 1980):

$$V_y = \frac{I_f}{ns} \tag{2.32}$$

where,

I_f = final intake rate,

n = total pore space of the soil,

s = the change in degree of saturation during irrigation.

For downward movement the final intake rate I_f is equal to the permeability of the soil at the degree of saturation (usually about 80 percent; Hansen *et. al.*, 1980) which occurs during irrigation. When observations of intake are being made, it is good to observe the trend with time as an indication of the nature of movement below the surface. When the intake approaches a constant, it can be assumed that water is moving downward in an unrestricted manner. However, when the rate of intake does not approach a constant value, then it can be assumed that the flow is moving laterally, due to restricting layers beneath the surface (Hansen *et al.*, 1980).

Since paddy fields generally have standing water over the soil surface, the percolation rate quickly stabilizes and the soils are saturated. Therefore, techniques developed to analyze steady state drainage can be applied to estimate percolation from the paddy (Wang and Hagan, 1981).

2.10 Seepage across a bund

Water loss from paddy basins among others means comprise of water loss through seepage across bunds. Figure 2.2 is a schematised diagram of water flow across a paddy bund towards a drain.

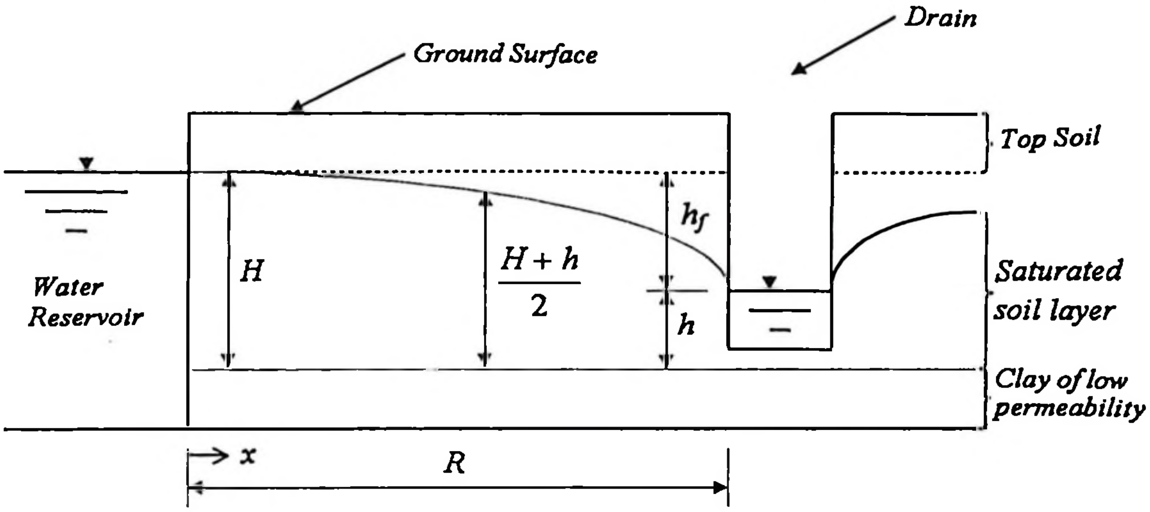


Figure 2.2 Linear flow of ground water towards drains (Hansen *et. al.*, 1980)

Ground water usually flows to the drains from both sides with similar conditions existing on both sides of the drain. Let $2q$ represent the flow into a drain in length L. Then the ground -water flow from one side to the drain is (Hansen *et. al.*, 1980):

$$q = AV \tag{2.33}$$

where,

q = ground water flow from one side of the drain(m^3/s)

A = cross-sectional area(m^2),

V = velocity of flow(m/s).

From Darcy's law using Dupuits approximation as cited by Dake (1983) and Hansen *et al.* (1980):

$$V = k\frac{h_f}{R} \qquad \text{i.e. Darcy's law} \qquad (2.34a)$$

$$= k\left(\frac{H-h}{R}\right) \qquad \text{i.e. Dupuit's approximation (1863)} \qquad (2.34b)$$

where,

k = hydraulic conductivity (m/s),

h_f = difference between water level in the drain and water level in the reservoir (m),

R = bund width (m),

H = depth of water level in the reservoir from clay of low permeability (m),

h = depth of water level in the drain from clay of low permeability (m),

V = Velocity of flow (m/s).

The units of hydraulic conductivity are those of velocity (m/s). This hydraulic conductivity depends primarily on the average size of the pores, which in turn is related to the distribution of particle sizes, particle shape and soil structure. For a given soil the hydraulic conductivity is a function of void ratio. The presence of fissures in a clay results in a much higher value of hydraulic conductivity compared to that of the unfissured material (Craig, 1987).

Considering the depth of saturated soil about midway between the reservoir and the drain as average, then average area of saturated soil, in drain length L ,through which the ground water flows is given by (Hansen *et al.*, 1980; FAO, 1994) :

$$A = \left(\frac{H-h}{2}\right)L \tag{2.35}$$

and the quantity of flow from the reservoir to the drain (Hansen *et. al.*, 1980):

$$q = \left(\frac{H+h}{2}\right)L \times k\left(\frac{H-h}{R}\right)$$

$$= \frac{kL\left(H^2-h^2\right)}{2R} \tag{2.36}$$

Equation 2.36 assumes that the only source of water to the drain is the reservoir and that the flow is steady (Hansen *et. al.*, 1980). Dake (1983) considers the case where there is infiltration into the soil separating the two water bodies from the soil surface, and has the following equation:

$$q_o = k\frac{\left(H^2-h^2\right)}{2R} - \frac{eR}{2} \tag{2.37}$$

where,

q_o = seepage rate from the water body with high water head at x = 0 (m^2/s),

e = uniform infiltration per uniform surface area (m/s).

2.11 Discharge over spillway

The discharge equation for a rectangular broad crested weir using the method of approach energy is given by (Dake, 1983):

$$Q = C_d B_0 \sqrt{g}\left(\frac{2}{3}E\right)^{3/2} \tag{2.38}$$

where, C_d = coefficient of discharge,

B_o = spillway length perpendicular to flow direction,

g = gravitational constant,

E = approach energy measured relative to the crest of the weir

$= (y_{01} - \Delta z_0) + \frac{v_1^2}{2g}$

y_{o1} = upstream depth,

Δz_o = spillway sill height,

v = velocity of approach.

2.12 Characteristics of water flow in paddy fields

Generally, the soil of a paddy field during ponding is regarded as saturated or nearly saturated with water. Air bubbles are trapped in the plowed layer under natural conditions. The saturation gives the flow some characteristics (Juo and Lowe, 1986):

- It is predominantly percolation, with the water moving mainly through the macropores; therefore, the percolation rate (or hydraulic conductivity) is uniform across the field.

- The direction of water movement is fundamentally downward so the soil profile is invested with special chemical and physical properties.
- In stratified conditions two types of flow exists, depending on the thickness and hydraulic conductivity of the upper and lower layers of soil and the depth of the water table.

2.13 Summary

In the view of the cited scientists, it is important for the scientific world to look into indigenous agricultural sciences for improved and sustainable irrigated agriculture. Research into indigenous skills would reveal the hidden sciences in indigenous methods.

In field-to-field irrigation method, there is uncertainty of the time of irrigating to the required depth of ponded water and the time of water travel to the tail end field.

In paddy irrigation, it is commonly shared that the factors which affect surface water storage are initial soil water content, surface water inflow, surface water outflow, vertical seepage (percolation) through the basin base, horizontal seepage across the bunds with water loss through cracks and fissures, evapotranspiration, and rainfall. Each factor is calculated by standard methods of estimating the parameters when modelling the flows. Most models for paddy irrigation applies the principle of continuity to build up water balance and reservoir routing models.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introduction

This chapter incorporates and states the modifications of some of the equations mentioned in Section 2 to suit the conditions of surface water storage in paddy basins in developing the routing model and the computer program. The chapter also describes the study area, the procedures and the materials used in data collection, and states the methods used in data processing and analysis.

3.2 The model

The purpose of the model is to estimate:

- surface water storage (in depth units) in a paddy basin of a given size with given inflow volumes,
- the time of fill of a paddy basin to the required depth,
- the time of fill of the *n*-th paddy basin in a series of paddy basins arranged in a cascade.

A computer program in Microsoft Quick Basic is developed for the model (Section 3.11). The model is developed from the modification of some equations in Section 2. Using the form of Equation 2.13 and incorporating factors associated with water storage in a paddy basin as expressed in Equations 2.15, 2.20, 2.21 and 2.22;

$$\frac{dh}{dt}=\frac{(I_1+I_2)}{2A(h)}-\frac{(O_1+O_2)}{2A(h)}+\frac{R}{dt}-ET_c-\frac{VS}{A(h)}-\frac{HS}{A_s} \qquad (3.1)$$

dh represents change in depth with time . If change in depth, $dh = \Delta h$ and change in time, $dt = \Delta t$, and expressing Equation 3.1 in depth units, yields the equation:

$$\Delta h=\frac{(I_1+I_2)\Delta t}{2A(h)}-\frac{(O_1+O_2)\Delta t}{2A(h)}+R(\Delta t)-ET_c\cdot\Delta t-\frac{VS\cdot\Delta t}{A(h)}-\frac{HS\cdot\Delta t}{A_s} \qquad (3.2)$$

Re-arranging Equation 3.2 with contributing inflows and outflows separated:

$$\Delta h=\left[\frac{(I_1+I_2)\Delta t}{2A(h)}+R(\Delta t)\right]-\left[\frac{(O_1+O_2)\Delta t}{2A(h)}+ET_c\cdot\Delta t+\frac{VS\cdot\Delta t}{A(h)}+\frac{HS\cdot\Delta t}{A_s}\right] \qquad (3.3)$$

where,

I & O = inflow and outflow respectively (m^3/s),

$R(\Delta t)$ = rainfall in time Δt (m),

ET_c = crop evapotranspiration in Δt (m/s),

Δt = time period between time t_1 and t_2 (s),

Δh = change in water level in the paddy basin (m),

$A(h)$ = basin area at depth h (m^2),

A_s = horizontal seepage area (m^2),

HS = net horizontal seepage (m^3/s),

VS = net vertical seepage (m^3/s).

(Note: subscripts 1 and 2 refers to conditions at the beginning and end of time Δt respectively)

Inflows and outflows for Equation 3.3 are obtained from direct measurements in the field across the broad crested weirs as illustrated later under Section 3.9. In using Equation 3.3 it is appropriate to use short time increments for precise results in estimating flows where changes in flow are rapid and large. Flows can be obtained from flow characteristic curve for a given weir if available. Vertical seepage, horizontal seepage, evapotranspiration, and rainfall, are obtained as illustrated later under Sections 3.6, 3.7, 3.8 and 3.10 respectively.

From Equation 3.3, net inflow volume in Δt is then given by the relationship:

$$\Delta Q_n = \left[\frac{(I_1 + I_2)\Delta t}{2} + R(\Delta t)\cdot A(h)\right] - \left[\frac{(O_1 + O_2)\Delta t}{2} + ET_c \cdot \Delta t \cdot A(h) + VS \cdot \Delta t + HS \cdot \Delta t\right] \tag{3.4}$$

where, ΔQ_n = net inflow volume in time Δt.

Change in time can be estimated from the modification of Equation 3.2:

$$\Delta t = \left(\Delta h - R(\Delta t)\right) \Big/ \left[\frac{(I_1 + I_2)}{2A(h)} - \frac{(O_1 + O_2)}{2A(h)} - ET_c - \frac{VS}{A(h)} - \frac{HS}{A_s}\right] \tag{3.5}$$

The computer program developed uses Equations 3.3 and 3.5 for calculating water storage in depth units and time to attain a specified depth of water storage in a paddy basin. The model equation for water storage following Equation 3.3 can be written as:

$$h_m = h_{m-1} + \Delta h_m \tag{3.6a}$$

In expanded form,

$$h_m = h_{m-1} + \sum_{n=1}^{N} q_{n,m} - \sum_{k=1}^{K} u_{k,m}, \qquad m = 1 \ldots M \tag{3.6b}$$

where,

h_{m-1}, h_m = depths of water in the reservoir at the beginning and at the end of the m-th time interval (Δt), respectively;

$q_{n,m}$ = inflow in depth units by the n-th component in the m-th time interval;

$u_{k,m}$ = outflow in depth units by the k-th component in m-th time interval;

M = total number of time intervals;

N = total number of inflow components;

K = total number of outflow components.

At the start of irrigation, h_{m-1} is equal to the initial water level, h_o.

The model equation for time to fill, T_f, for a paddy basin following Equation 3.5 can be written as :

$$T_{f,j} = \sum_{m=1}^{M} \Delta t_m \tag{3.7a}$$

In expanded form,

$$T_{f,j} = \sum_{m=1}^{M} \left[\left(\Delta h_m - R(\Delta t)_m \right) \Big/ \left(I_m - \sum_{k=1}^{K} O_{k,m} \right) \right] \tag{3.7b}$$

where,

$T_{f,j}$ = time to fill for basin j,

Δh_m = the m-th change in depth required,

$R(\Delta t)_m$ = rainfall depth in time Δt contributing to the m-th change in depth,

I_m = average surface inflow in depth units during the m-th change in depth,

$O_{k,m}$ = average outflow in depth units through the k-th outflow element during the m-th change in depth,

M = total number of required changes in depth to attain a specified depth,

K = total number of outflow elements.

Model Equation 3.7b calculates time taken to attain a specified depth in a paddy basin. Time taken to fill J basins in a cascade (i.e. routing time), T_r, would be the summation of times to fill of each respective basin from the time of application of irrigation water. In the model form this would be represented as:

$$T_r = \sum_{j=1}^{J} T_{f,j} \tag{3.8a}$$

In expanded form,

$$T_r = \sum_{j=1}^{J}\sum_{m=1}^{M}\left[\left(\Delta h_{m,j} - R_{\Delta t,m,j}\right)\Big/\left(I_{m,j} - \sum_{k=1}^{K} O_{k,m,j}\right)\right] \tag{3.8b}$$

3.3 The study area

The study area is Kasitu Self-Help Irrigation Scheme where field-to-field irrigation method is practised and its canal layout is shown in Figure 3.1. Kasitu is situated 90km north of Nkhotakota District in Malawi along the western coast of Lake Malawi as shown in Figure 3.2. The location falls at latitude 12.4° South and longitude 34° East. The management of the scheme is under Salima Agricultural Development Division (SLADD).

The area is generally level and the scheme is situated in the dambo land of Kasitu river. Kasitu receives an annual rainfall range of 1,100 to 1,200mm (Nippon Koel, 1993). Rainfall period ranges from December to March. The soils are clay loam soils with alluvial deposits.

Kasitu scheme was constructed in phases with the first phase constructed in 1986 and the second phase constructed in 1989. The scheme was constructed on self-help basis where farmers were involved at the construction stage and finally in the running of the scheme. The scheme's command area is 60 hectares. It was constructed for seed multiplication. The main crop grown is rice (Faya variety). Source of irrigation water is Kasitu river under gravity canal system. The irrigation system comprises of intake structure, field canals and drains network, and flood protection dike. There are no farm road network. The scheme is run by farmers' committee with minimal government intervention, and its average yield for 7 consecutive years (1986/87 to 1992/93) is 3,021kg /ha in paddy (Nippon Koel, 1993).

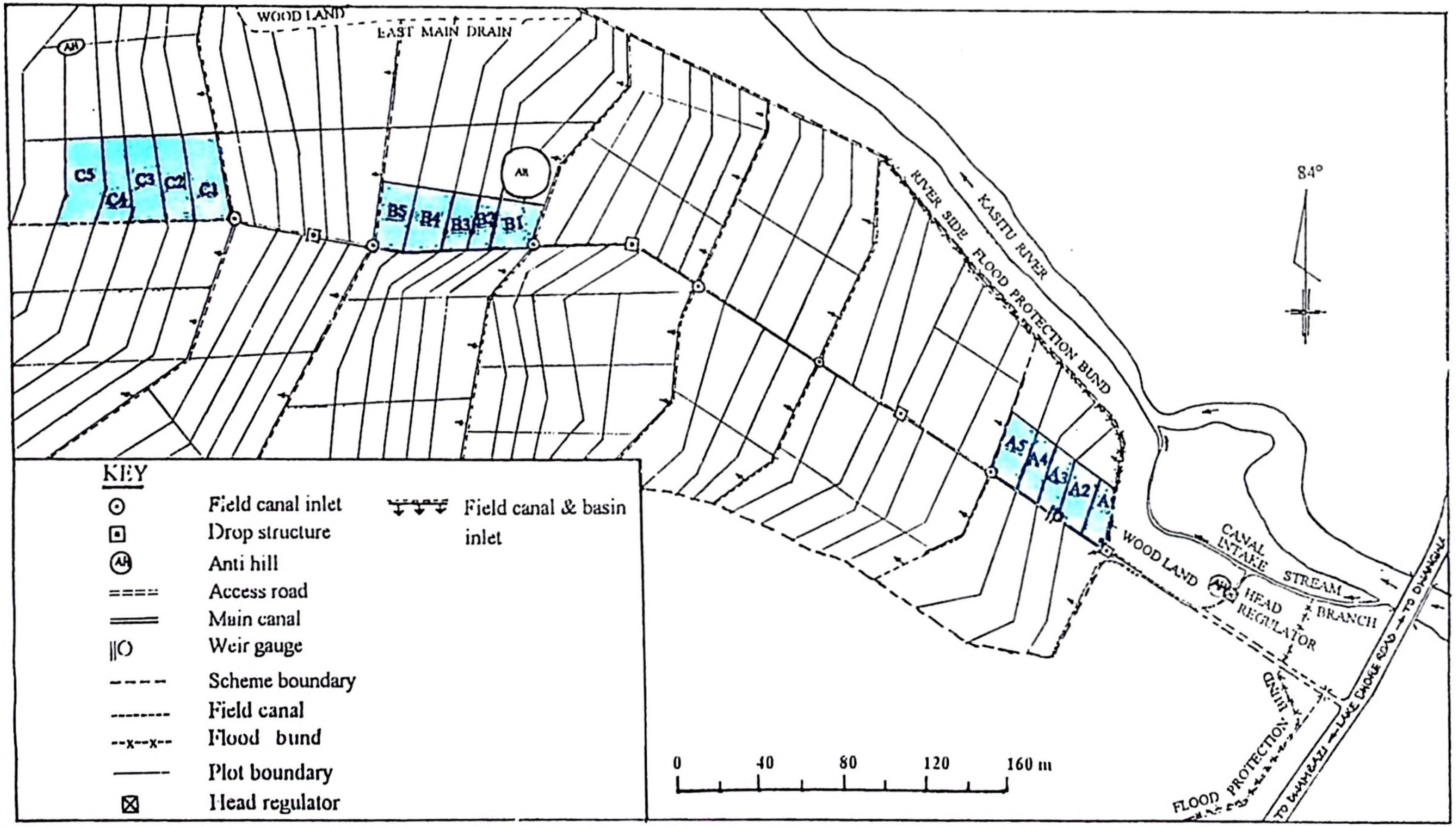


Figure 3.1 Kasitu Self-Help Irrigation Scheme

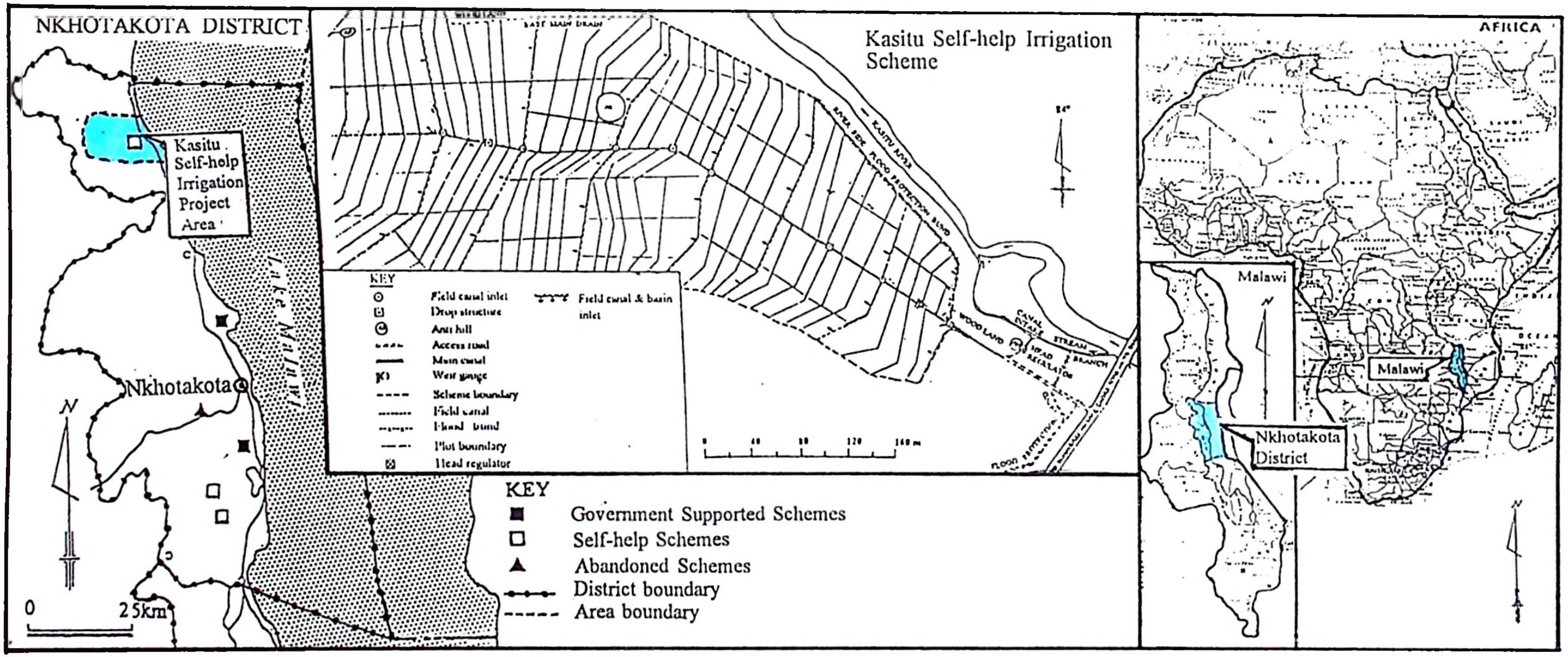


Figure 3.2 Location of Kasitu Self-Help Irrigation Scheme

3.4 Methodology

Three paddy fields each with five basins of different sizes in a cascade were secured at different locations in the scheme as shown in Figure 3.3. These fields were labeled A, B and C as shown in Figure 3.1 and the basins were labeled A1 to A5, B1 to B5 and C1 to C5 respectively. The fields were tilled, tilthed and leveled in readiness for rice growing. The bunds separating the basins were cut in the middle and wooden weirs were fitted as shown in Figure 3.5. The weir height from the basin base was made lower than any point along the surrounding bunds. This was done to ensure that water does not spill over at any point along the surrounding bunds but only through the weir into the next basin; and to avoid submerging the plants during water application before spill over. Graduated staffs were placed in the basin at the right, middle and left of each side of the basin. Similarly, graduated staffs were placed in the neighbouring basins and canals.

Water was admitted from the feeder canal through the weir into the first basin. After filling to the weir height, the water spilled into the next basin through its weir and so on to the last basin of the five in a cascade as shown in Figure 3.3.

The basins were planted with paddy (Faya variety) by transplanting at the spacing of 23 x 23 cm (9 x 9 inch.). The crop was fertilized twice. At development stage NPK fertilizer was applied and just before tussling SA fertilizer was applied.

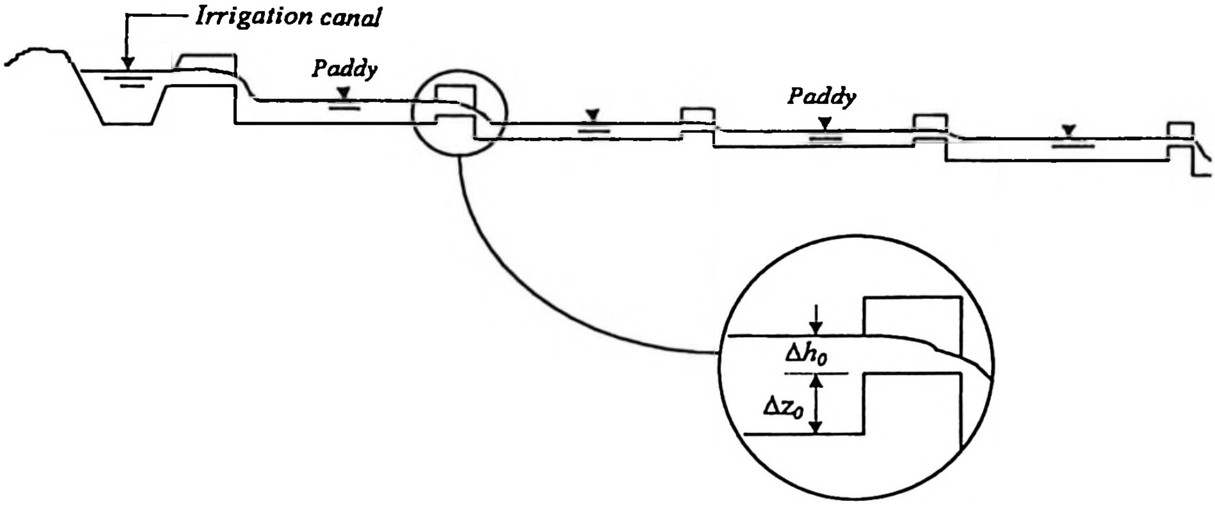


Figure 3.3 A typical cross section of paddy-to-paddy water movement

3.5 Soil characteristics

Soil samples from each basin were collected. Similarly, samples were collected from the surrounding bunds of each basin. The samples from each basin were analyzed in a laboratory for particle size distribution, and bulk density. Soil type in each basin was determined from textural triangle (Brady, 1984). The samples from the surrounding bunds were tested for hydraulic conductivity (k) by the method of "Constant Head" as outlined by Craig (1987) and Hansen *et. al.* (1980).

3.6 Infiltration

In this study, a double-ring infiltrometer was used for measuring intake rate characteristic of the soil. The double-ring infiltrometer has been found to be a rapid and simple field technique (Talsma, 1969) as cited by British Society of Soil Science (1997). However, it suffers from several disadvantages, for instance the overestimation of sorptivity due to the flow through macropores (Clothier and White, 1981) as cited by 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 (Bouwer, 1986) as cited by British Society of Soil Science (1997). This method of reducing the error was considered in the test. In addition, measurements of the hydraulic properties by using a ponded method have often shown a considerable spartial variability (Sharma *et, al.*, 1980) as cited by British Society of Soil Science (1997), due to the structural heterogeneity of the soil and the flow through macropores.

Infiltration tests were conducted in each paddy field after field preparation before transplanting on unsaturated moist soil by the method of double-ring infiltrometer test as described by Landon (1991) to obtain the infiltration characteristic and basic intake rate. Since the soils in paddy basins during growing period are always saturated, Equation 2.18, which estimates cumulative infiltration, I, as a function of time, t, after ponding, was used to estimate water loss through percolation in ponded conditions.

As explained in Section 2.6.4, sorptivity can be obtained by plotting cumulative infiltration against the square root of time where the slope of the line would be sorptivity; and $k \cong k_{sat}$, (saturated hydraulic conductivity) can be obtained directly from infiltration test for a longer time where k_{sat}, would be the residual infiltration rate after the long period (British Society of Soil Science, 1997). When cumulative infiltration is plotted against the square root of time, Equation 2.18 assumes a straight line. Therefore, in Equation 2.18 if $I = y$, $S = b$, $t^{1/2} = x$ and $a = kt$, the equation can be represented in the straight line equation (Mead and Curnow, 1983):

$$y = bx + a \tag{3.9}$$

The values of b and a were obtained from the regression of the values of $t^{1/2}$ and I obtained from the field test. The values of k were then obtained from the relationship:

$$a = kt \tag{3.10}$$

Figure 2.1 suggests that for most soils, a steady infiltration rate is attained after 2.25 hours of infiltration. After 3 hours infiltration stabilizes completely. Since the paddy fields were ponded throughout the period, a six hour period was used in Equation 3.10 to estimate k. The k closely approximates the seepage and percolation rate after a long time (k_{sat}) as explained in Sections 2.8 and 2.9. The values obtained for each field were used in the analysis.

3.7 Seepage across bunds

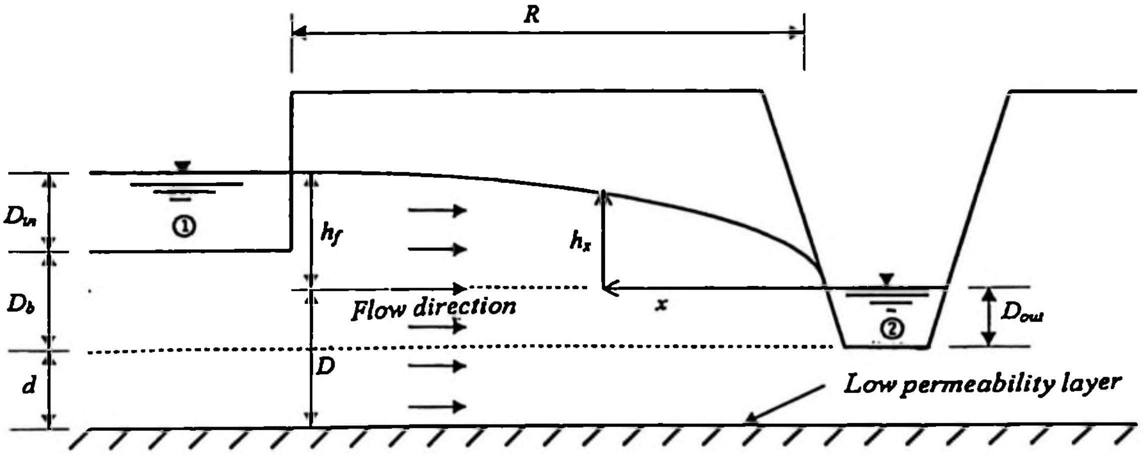


Figure 3.4 A cross- section of a paddy bund

The head loss over the horizontal flow zone equals the difference in water levels of Reservoir ① and Reservoir ② as shown in Figure 3.4. An analytical expression for this head loss may be derived by considering the horizontal flow q_x through a vertical plane of unit width (Smedema and Rycroft, 1983). The gradient $\frac{dh_x}{dx}$ becomes increasingly steeper in the direction of the flow as is expected in view of the fact that an increasing amount of water passes through a decreasing cross-sectional area (q_x increases and h_x decreases in the flow direction).

Using Equations 2.33, 2.34a and 2.34b, the horizontal flow, q_x is given by:

$$q_x = k\frac{h_f}{R}(D+h_x) \tag{3.11}$$

This yields an ellipse of the water table over the distance R. The ellipse shape is close to the actual water table profile (Smedema and Rycroft, 1983).

Equation 3.11 suggests two regions of horizontal flow, through depth D and through depth h_x. From the same principle, seepage per unit width out of Reservoir ① towards Reservoir ② at $x = R$, is given by:

$$q_x = k\frac{h_f}{R}\left(D_{out} + h_f - D_b\right) \tag{3.12}$$

Therefore, seepage across a bund of length l_b will be given by:

$$q_b = k\frac{h_f}{R}l_b\left(D_{out} + h_f - D_b\right) \tag{3.13}$$

where,

q_b = seepage across a bund (m^3/s),

R = bund width (m),

l_b = bund length (m),

h_f = difference in water levels (m),

= $(D_b + D_{in}) - D_{out}$

D_b = difference in base levels (m),

D_{in} = depth of water in the study basin (m),

D_{out} = depth of water in the neighbouring basin/canal (m),

k = horizontal hydraulic conductivity (m/s).

Equation 3.13 was used to estimate seepage across paddy bunds.

3.8 Evapotranspiration

Daily evapotranspiration was estimated by Pan Evaporation method as outlined by Pruitt and Doorenbos (1977). Evaporation pans provide direct estimation of the aggregated effects of radiation, wind, temperature, and humidity on evaporation from a described open water surface. However, reflection of solar radiation from a water surface is only 5% to 9%, versus 20% to 25% for most vegetation. Differences in heat storage, heat transfer, colour location, and other environmental factors between the pan and the crop field all influence the accuracy with which pan evaporation data can be used to estimate field evapotranspiration. Nevertheless, when carefully located and calibrated, pans can be used to give reasonable predictions on crop water requirements for periods of ten days or longer.

Colorado Sunken Pan was used from the nearest weather station. Crop type and crop development stage were used to obtain crop coefficient (k_c). Daily wind speed, daily humidity, pan type and pan environment data were used to obtain pan coefficient (k_p). Pan evaporation (E_p)data was collected on daily basis.

Crop evapotranspiration (ET_c) was used in the analysis and was obtained by using the relationship (James, 1988):

$$ET_c = k_c \cdot k_p \cdot E_p \qquad (3.14)$$

where

ET_c = crop evapotranspiration,

k_c = crop coefficient,

k_p = pan coefficient,

E_p = pan evaporation.

3.9 Water Measurements

Initial water levels in paddy basins were read from graduated staffs placed in the paddy basin and were recorded just before irrigation water entered into each basin. Similarly, water levels were read in the adjacent canals or basins.

Water was allowed into the first basin adjacent to the feeder canal through a wooden weir as shown in Figure 3.5.

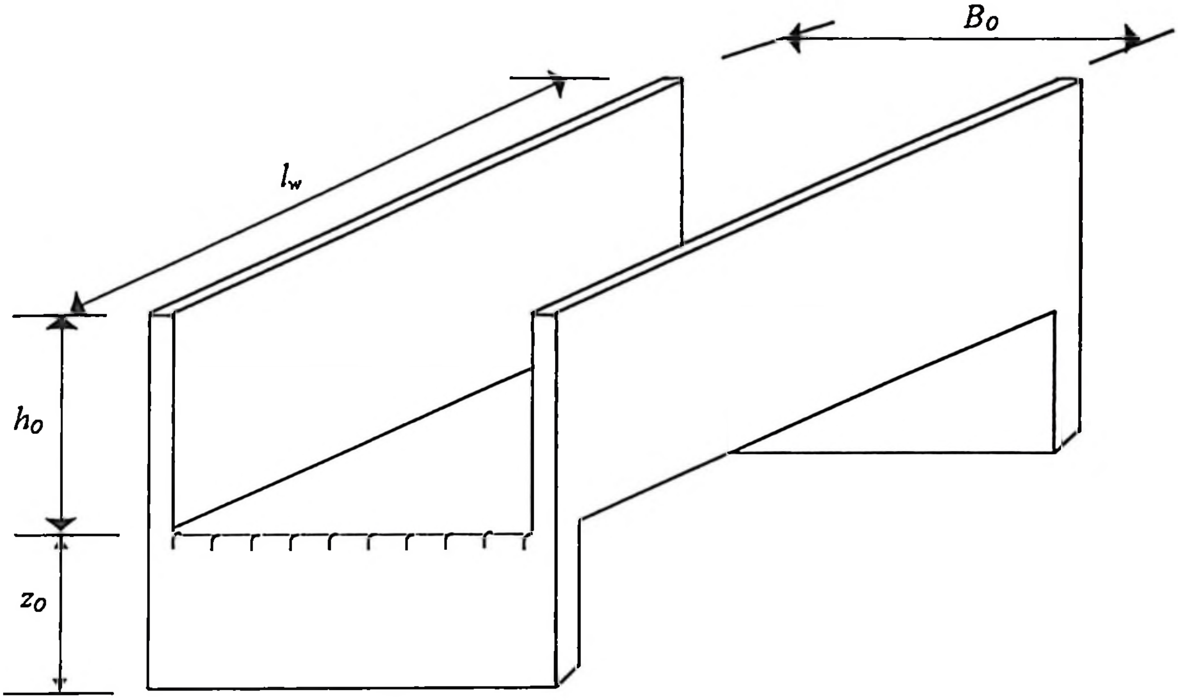


Figure 3.5 Sketch of a wooden weir.

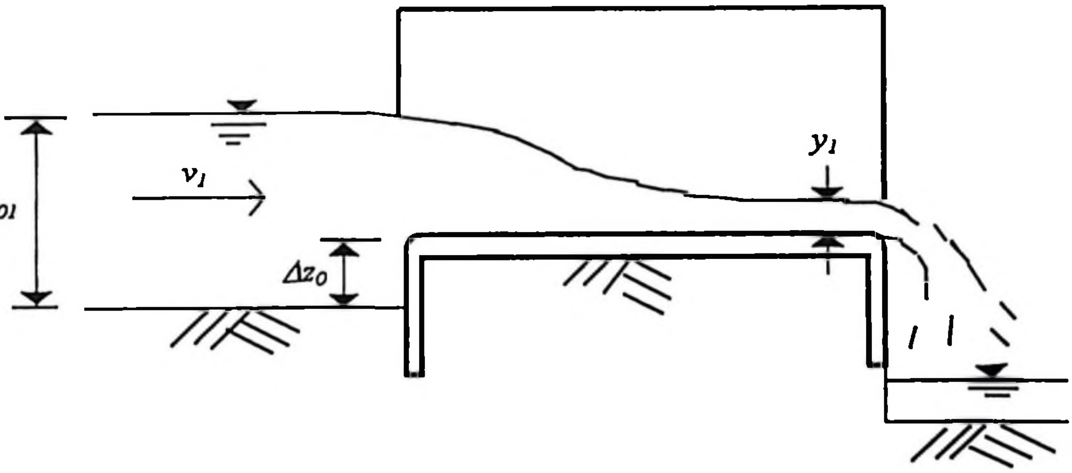


Figure 3.6 Water flowing across a bund through a wooden weir.

The water level above the weir crest, Δh_o, where $\Delta h_o = y_{ol} - \Delta z_o$, was measured by using a thin stiff flat blade placed flat on the weir base and a thin stiff right angled ruler placed at a distance equal to or greater than $4y_l$: where y_l is the critical depth over the broad crested wooden weir.

The water levels at the graduated staffs and water levels above the crest height at the inlet weir and outlet weir were measured at time intervals of ten minutes and recorded. Sample measurements are shown in Appendix A. The time of fill to the weir crest at the outlet weir for each basin was recorded. Sample measurements are shown in Appendix B. Outflows from basins A1, B1, and C1 were the inflows to A2, B2, and C2 respectively and so on. The measurements for A1, B1, and C1 continued until basins A2, B2, and C2 filled and spilled into A3, B3, and C3. Similarly, measurements for A2, B2, and C2 continued until basins A3, B3, and C3 filled and spilled into A4, B4, and C4 respectively and so on.

In field A, water was routed from the first basin (A1) to the last basin (A5) eleven times. In field B, water was routed from the first basin (B1) to the last basin (B5) eight times. In field C, water was routed from the first basin (C1) to the last basin (C5) nine times. In all these routing processes water levels from the graduated staffs in the basins and in the adjacent canal or basin were read and recorded. Similarly, water levels above the crest, $y_{0l}-\Delta z_0$ as shown in Figure 3.6, of the inlet and outlet weir were read and recorded at intervals of ten minutes. Five sets of data for a complete route from basin A1 to basin A5 in each field were used for the analysis.

The wooden weirs for water inflow and outflow measurements were calibrated by the method of direct calibration to obtain the discharge coefficient, C_d . Ten direct measurements of water collected in a specified time and the average water level above the weir crest in the specified time interval were used in Equation 2.38 to obtain C_d. The discharge coefficients determined were used to estimate discharge for the routing process.

The water levels above the weir crest, Δh_o, weir width, B_o ; and weir coefficient, C_d ; were used in Equation 2.38 to obtain discharge. The upstream velocity in a paddy basin is too small and negligible, hence the term $\frac{V_1^2}{2g}$ in Equation 2.38 is taken to be zero.

3.10 Rainfall

Rainfall amount was measured by using a rain gauge installed in the field under study. Rainfall records were taken from the on set of irrigation into the study field. These measurements were taken at the same time intervals as for inflow and outflow water measurement times whenever it was raining.

3.11 The Computer Program

The computer program estimates the various components of Equation 3.3 from raw data entered. It also offers an option to enter data processed by other methods other than the methods employed in this study.

3.11.1 Input

Data requirement for the model comprise of:

- Soil data:
    - soil porosity,
    - soil sorptivity,
    - soil depth to be saturated if not saturated,
    - soil moisture content on volume basis if not saturated,
    - soil horizontal hydraulic conductivity,
    - soil saturated vertical hydraulic conductivity,
- Crop data:
    - crop type,
    - crop development stage,
    - optionally, crop evapotranspiration,
- Meteorological data:
    - pan type,
    - pan surrounding,
    - wind speed,

  - humidity,
  - pan evaporation,
  - pan coefficient,
- Field characteristics:
  - paddy basin area,
  - bund width,
  - bund lenght,
  - level differences between the bottom of the paddy basin and the bottom of the neighbouring canal or basin,
- Water management:
  - initial water level,
  - rainfall from start of irrigation (or rainfall rate),
  - time step between measurements,
  - water depth over the weir at time *t* for inflow weir and outflow weir,
  - velocity of approach towards the weir at inflow weir and out flow weir,
  - weir coefficient of discharge for each weir,
  - spillway length perpendicular to flow direction for each weir,
  - acceleration due to gravity,
  - optionally, calculated surface inflows and surface outflows,

3.11.2 Main areas of computations

Inflow elements

Inflow elements include surface inflow (I) and rainfall (R). In the case where inflow is measured by using a broad crested weir across the bund, inflow is taken as the average of inflow at the beginning and end of time Δt. Equation 2.38 is used for calculating the flow. Rainfall input is rainfall amount from start of irrigation as accumulated amount after each time increment Δt.

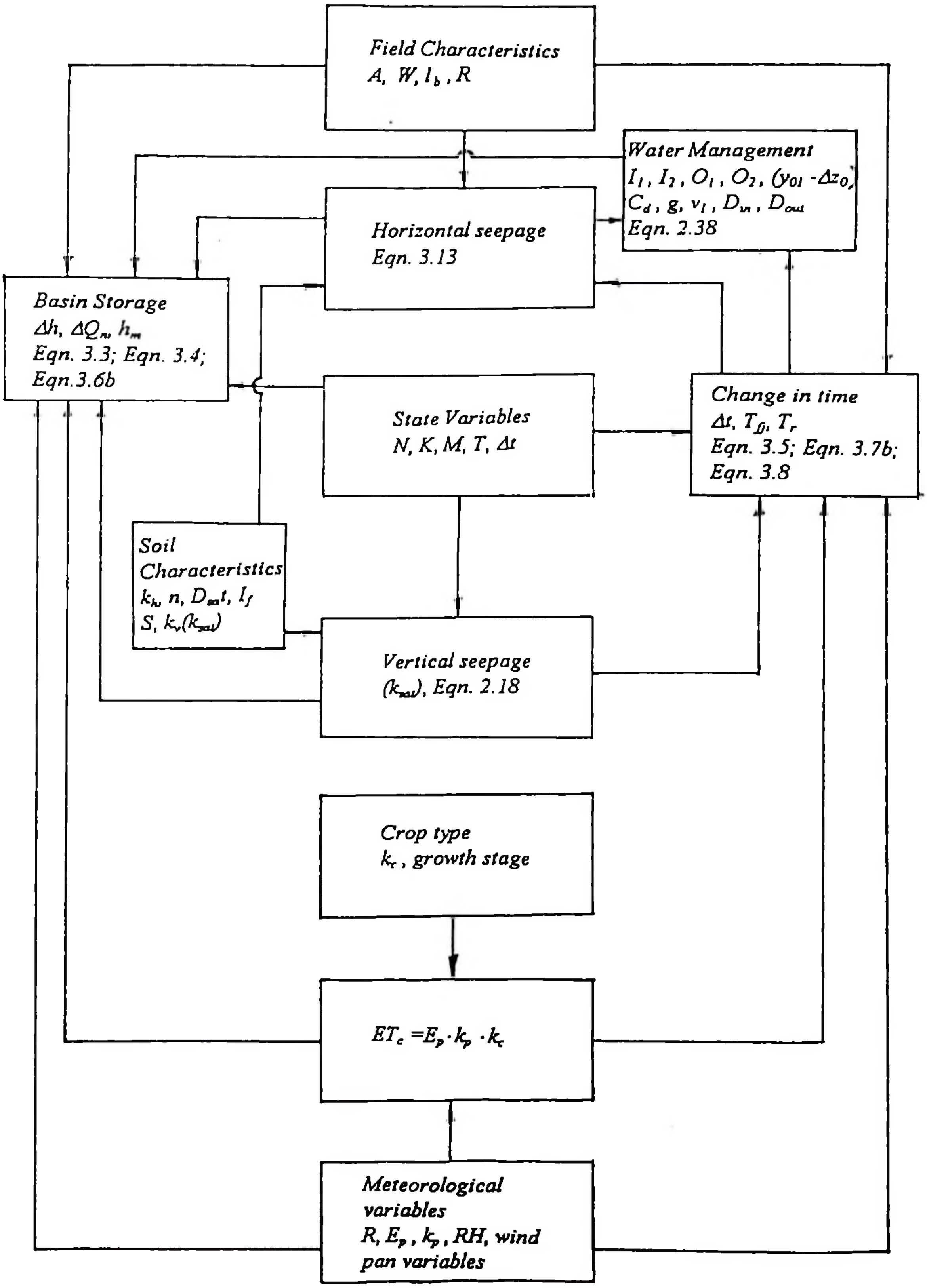
Outflow elements

Outflow elements considered include surface outflow (O) crop evapotranspiration (ET_c), vertical seepage (VS) and horizontal seepage (HS). Outflow used is average outflow in time Δt. Crop evapotranspiration is calculated as outlined in Section 3.8. Horizontal seepage is calculated as outlined in Section 3.7 using Equation 3.13.

3.11.3 Output

The output from the program comprises of the input data, calculated depths for each basin, and calculated time of fill for each basin.

3.11.4 Simplified diagram of the program



CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This section states and discusses the results obtained in data analysis and in using the model equations. The results from the model equations and from data analysis are compared with the physically obtained or published data where possible.

4.1 Soil characteristics

The laboratory analysis of the soil samples collected showed that the soils in the paddy basins were predominantly clayer soils as shown in Table 4.1. The soils in Field C were basically clay soils. From field observations, the soils had numerous cracks and along the bunds rodent holes and large cracks were visible. The soils in Fields A and B were mostly clay loam soils. There were no much cracks as compared to Field C. Never the less, rodent holes were clearly visible.

Table 4.1 Soil characteristics

BASIN	ROCK PARTICLE DISTRIBUTION			DRY BULK DENSITY (g/cm^3)	BULK DENSITY ON WET BASIS (g/cm^3)	TEXTURAL CLASS
	Sand(%)	Silt(%)	Clay(%)			
A1	44	24	32	1.3	1.6	clay loam
A2	50	20	30	1.4	1.7	sandy clay loam
A3	54	18	28	1.2	1.5	sandy clay loam
A4	38	26	36	1.0	1.3	clay loam
A5	30	28	42	1.2	1.3	clay
B1	38	26	36	1.1	1.3	clay loam
B2	50	24	26	1.3	1.5	sandy clay loam
B3	54	20	26	1.2	1.4	sandy clay loam
B4	52	22	26	1.3	1.4	sandy clay loam
B5	42	24	34	1.2	1.5	clay loam
C1	28	28	44	1.0	1.3	clay
C2	24	30	46	1.0	1.2	clay
C3	24	28	48	1.0	1.3	clay
C4	24	30	46	1.0	1.1	clay
C5	14	36	50	1.0	1.1	clay

4.2 Infiltration

The graph of cumulative infiltration against the square root of time elapsed following Equation 2.18, showed a linear relationship as shown in Figure 4.1 which made it possible to estimate the infiltration rate at a specified longer period after ponding. Basically, for most soils as shown in Figure 2.1, infiltration stabilizes to a constant rate after a period of 2.5 hours. A 6-hour period was chosen to take into consideration the fact that as irrigation progresses surface sealing takes place by the fine soil transported by irrigation water hence reduce percolation instead of using a 2.5-hour period to attain constant infiltration rate as shown in Figure 2.1 which does not take into account the sealing effect which results into reduced infiltration rate with time. It was found that after a period of 6 hours at which infiltration is expected to have stabilized, percolation rate in Field A was found to be 4mm/hr, in Field B was found to be 5mm/hr, and in Field C was found to be 8mm/hr. Percolation rate in Field C was expected to be lower than that of Field A and Field B, due to the soil type in Field C. The difference is attributed to water loss through cracks and rodent holes in the lower layers. These values are within the ranges specified in Table 2.2. These infiltration values were used in the analysis as saturated hydraulic conductivity as explained in Sections 2.8 and 2.9.

The water losses through infiltration and percolation were calculated for intervals of time Δt, where in this study was equal to 10 minutes following the time interval for water measurements. Sample results are shown in Appendix C.

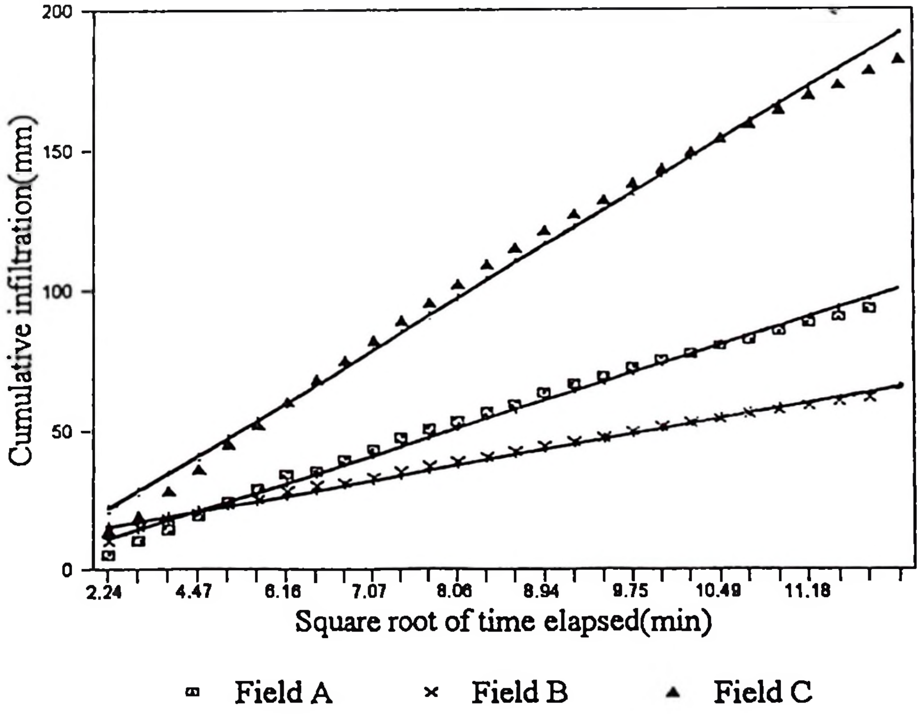


Figure 4.1 Cumulative infiltration against the square root of time elapsed

4.3 Seepage across bunds

Equation 3.13 was used for estimation of horizontal seepage across the bunds surrounding a paddy basin under consideration. Seepage values for all sides of the basin and net seepage values are shown in Appendic C. The values were calculated for a time period Δt. The negative values implies inflow into the basin under consideration and the positive values represents outflow from the basin. Net seepage value (*i.e.* a summation of seepage values across each bund) was used in the model equations.

4.4 Crop evapotranspiration

Crop evapotranspiration rates estimated from pan evaporation by using Equation 3.14 are shown in Appendix C. Water loss from the paddy basin through crop evapotranspiration was calculated for every Δt. The contribution by crop evapotranspiration to the flows was not so significant because it was calculated over a very short time interval (*i.e.* at 10 minutes interval).

4.5 Surface flows

The surface inflows and outflows obtained by using Equation 2.38 are shown in Appendix C. The flows were calculated using Equation 2.38. The values shown are average values of flows at the beginning and end of time Δt. Rainfall amount considered in the analysis is the rainfall amount contributing to flows during time Δt where applicable. This was found by subtracting the initial rainfall amount from the final rainfall amount after a time period Δt.

4.6 Paddy Basin Storage

Paddy basin storage determined by Equation 3.3 yielded the results shown in Appendix B. The direct observed values and the calculated values from Equation 3.3 are in Appendix B. The corresponding net inflow volumes which produced each change are also shown in the same Appendix.

The results from the statistical analysis of the observed changes in water storage (in depth units) and calculated storage by using the method of analysis of variance (ANOVA) at 5% significant level are shown in Table 4.2. The results from all the basins in Field A showed no statistical difference between the observed and the calculated values. The results from four basins out of the five basins in Field B showed no statistical difference between the observed and the calculated values. The results from basin B4 showed statistical difference between the observed and calculated basin storage values. This is not surprising because this basin had a lot of leakage points across the bunds through rodent holes and cracks. The sample field data shown in Appendix A-2 points out this water loss under remarks. The results from two basins out of the five basins in Field C showed no statistical difference between the observed and the calculated values. The results from basins C1, C2, and C3 showed statistical difference between the observed and calculated basin storage values. Field C had a lot of leakage points across the bunds through rodent holes and cracks. As a result a lot of water losses were not counted for. The sample field data shown in Appendix A-3 does not point out this water loss from basins C1 and C2 but the rest of the data had pointed out this water loss. The results in Table

4.2 shows the statistical analysis for all the results which were taken in each basin and used for analysis. The analysis on individual set of results was also conducted and agrees to the results in Table 4.2. These results are shown in Appendix D.

This shows how precise the developed model, the various methods of estimating the model parameters and the measurements taken approximates the actual conditions in field. It's not surprising to see low precision in the values from Field C because of the numerous cracks and rodent holes across the bunds which were observed in the field. Though an effort was made to seal the cracks and the holes, it's certain that not all the holes and the cracks may have been sealed if not effectiveness of sealing. The openings affected the results in such a way that they might have been the source of unaccounted inflows and outflows from the paddy basins. Field A and B are not exceptions but the extent at which they were affected was minimal compared to Field C. Further, the test of correlation on corresponding observed and calculated values showed some high correlation as shown in Table 4.2. This shows that the corresponding values had little off sets from each other in the minus or plus comparison.

Table 4.2 Statistical analysis on observed and calculated basin storage

Basin	Correlation coefficient	F	P-value	F-critical	Significance * Not Significant ** Significant
A1	0.955	0.739	0.392	3.945	*
A2	0.927	0.009	0.926	3.920	*
A3	0.802	0.192	0.662	3.936	*
A4	0.794	1.589	0.210	3.929	*
A5	0.919	0.204	0.653	3.974	*
B1	0.933	0.249	0.619	3.945	*
B2	0.853	0.106	0.745	3.929	*
B3	0.574	0.020	0.889	3.916	*
B4	0.769	6.939	0.010	3.920	**
B5	0.816	0.007	0.933	3.960	*
C1	0.895	6.064	0.015	3.932	**
C2	0.829	7.810	0.006	3.929	**
C3	0.668	20.236	0.016×10^3	3.918	**
C4	0.844	0.439	0.509	3.918	*
C5	0.893	0.306	0.581	3.940	*

Appendix E shows comparisons of observed storage values and calculated storage values. In Appendix E, the notation for the basin in question precedes the words "Observed Depth" and the words "Calculated Depth". The graphical relationships shows that to attain the storage value in the y-axis, it requires the corresponding cumulative net water inflow shown in the x-axis. Cumulative net water inflow refers to the summation of the differences between total inflow and total outflow at times t_1, t_2, t_3, and so on.

4.7 Time taken to fill a specified depth

The time of fill for each basin is shown in Appendix B. Not all the times of fill coincided with the time point of water measurements. Some basins were fillingin between the time period Δt (i. e. 10 minutes). This is reflected in times of fill not being in multiples of 10 which was the time period Δt. The times of fill which coincided with the time point of measurement are compared in Table 4.3 with the calculated times of fill for the same depth as for the measured by using Equation 3.5. For basins B4, C1, C2, C3 and C4, non of the point measurements coincided with the time of fill as measurements were taken only after time period Δt.

The results show that the model equation closely estimates the measured time of fill. There is a ± 5 minutes difference on average, with the calculated values being mostly higher than the observed. The difference is attributed to the measurement of insitu water depths because of not attaining hundred percent precision in paddy basin leveling. For precise results, Equation 3.5 is dependent on how best Equation

3.3 estimates change in depth which on its self is dependent on how precise its parameters are estimated. For example, as shown in Appendix B where the calculated depth was used to estimate time taken, the equation showed hundred percent precision in estimating the time Δt used in the calculations. This shows that the time of fill of a specified depth in a paddy basin is dependent on basin size and the associated inflows and outflows. As shown in Table 2.1 in Section 2.4, basin size is dependent on soil type for a given stream size. The time of water availability in the basin at the lower end in a cascade is a function of the filling of the preceding basins.

Table 4.3 Time of fill for a paddy basin

BASIN	AREA (m^2)	DEPTH TO FILL (m)	OBSERVED(O) TIME TAKEN (min)	CALCULATED(C) TIMETAKEN(min) Equation 3.9	DIFFERENCE (min) O - C
A1	275.97	0.052	40	42	-2
A2	433.23	0.020	55	49	6
		0.024	53	60	-7
		0.019	42	48	-6
		0.021	33	40	-7
A3	314.96	0.041	52	59	-7
		0.021	50	53	-3
		0.024	50	46	4
A4	342.01	0.021	80	72	8
		0.019	50	47	3
		0.021	40	37	3
		0.034	50	52	-2
A5	348.04	0.032	50	47	3
B1	393.87	0.025	20	25	-5
		0.032	20	29	-9
		0.031	20	23	-3
B2	329.30	0.031	30	38	-8
B3	379.16	0.041	60	61	-1
		0.036	55	59	-4
B5	420.38	0.034	65	71	-6
		0.020	40	45	-5
		0.019	42	47	-5
C5	470.65	0.035	73	74	-1

Table 4.4 (a) Observed and simulated time of fill for a paddy basin

BASIN	AREA (m^2)	DEPTH TO FILL (m)	OBSERVED TIME TAKEN (min)	CALCULATED TIME TAKEN (min) Equation 3.9	MEAN TIME (min) TAKEN TO FILL	LONGITUDINAL DISTANCE (m)
A1	275.97	0.052	40	42	41	Inlet : 0 Outlet : 9.25
A2	433.23	0.020	55	49	52	Inlet : 9.25 Outlet : 25.55
A3	314.96	0.024	50	46	48	Inlet : 25.55 Outlet : 37.15
A4	342.01	0.034	50	52	51	Inlet : 37.15 Outlet : 49.65
A5	348.04	0.032	50	47	49	Inlet : 49.65 Outlet : 62.60
TOTAL	-	-	245 (4.08 hrs)	236 (3.93 hrs)	241 (4.02 hrs)	62.60

Table 4.4 (b) Observed and simulated time of fill for a paddy basin

BASIN	AREA (m^2)	DEPTH TO FILL (m)	OBSERVED TIME TAKEN (min)	CALCULATED TIME TAKEN (min) Equation 3.9	MEAN TIME (min) TAKEN TO FILL	LONGITUDINAL DISTANCE (m)
B1	393.87	0.031	20	23	22	Inlet : 0 Outlet : 20.4
B2	329.30	0.031	30	38	34	Inlet : 20.4 Outlet : 35.9
B3	379.16	0.041	60	61	61	Inlet : 35.9 Outlet : 52.6
TOTAL	-	-	110 (1.83 hrs)	122 (2.03 hrs)	117 (1.95 hrs)	52.6

Table 4.4 (a) and (b) shows the observed and simulated times of fill for each basin from Field A and for three basins in Field B. The time taken to fill say five basins in series in a cascade is the summation of the times of fill of each basin. For example the observed time of fill of the five basins labeled A1 to A5 in Table 4.4 is 4hours and 5minutes (245min), while the simulated time of fill for the basins is 3hours and 56minutes (236min). While for Field B where the routing was interrupted after filling the third basin took 1 hour and 50 minutes. The simulated time gives 2 hours and 2 minutes.

The distance covered by the water front in filling the five basins in Field A is 62.60m in an observed time period of 4hours and 5minutes. For the simulated time period it covered the same distance in 3hours and 56minutes. On average the time taken is 4 hours and 1 minute. Similarly, in Field B the distance covered by the water front in filling three basins in a cascade is 52.6m from inlet of basin B1 to outlet of basin B3 in an observed time period of 1 hour and 50 minutes. The simulated time for the three basins in Field B is 2 hours and 2 minutes. On average the time taken is 1 hour and 57 minutes.

4.8 Yield

Agricultural innovation or technology basically aims at obtaining high yields with minimal inputs such as financial, material and labour requirement; or maintaining the required yield with decreasing inputs. Therefore, it was necessary to obtain yield from the basins under study for a check against the required or the expected yield. The results are shown in Table 4.5. The yield obtained is above the recorded average yield of 3,021kg/ha for seven consecutive years (1986/87 to 1992/93) as stated in Section 3.3. Therefore, there is no noticeable immediate ill effect on yield in employing the method in this one season study.

The high yields obtained does not mean that the method improves the yield but the method may not affect the yield if recommended agricultural practices are followed while the advantages of the method (as outlined in Section 2.5) are being utilized. The difference from the recorded yield is due to the fact that most farmers at the scheme do not follow most of the recommended crop husbandry practices. For example most farmers at the scheme apply fertilizer only at tussling stage (top dressing) instead of applying at initial stage (basal dressing) as well.

Table 4.5 Basin Areas and Yield

BASIN	AREA(m^2)	YIELD(tons/ha)
A1	275.97	3.9
A2	433.23	4.4
A3	314.96	4.4
A4	342.01	4.2
A5	348.04	3.6
B1	393.87	3.6
B2	329.30	3.7
B3	379.16	4.3
B4	551.90	3.9
B5	420.38	3.9
C1	496.75	3.2
C2	512.90	3.6
C3	434.50	4.3
C4	341.16	3.5
C5	470.65	4.3

4.9 Computer program testing

Computer program testing data input is shown in Appendix F as a print out from the program. The output results from the program are also shown in Appendix F together with the results processed by a spread sheet for one routing in Field-to-Field irrigation method. The results from the computer program tallies with the results from spreadsheet computation with a precision of two decimal places (i.e. to a centimeter). Therefore, the computer program developed can be used reliably in calculating the depths and time taken in routing irrigation water.

The program has instructions at different stages in the calculation process. It is advisable to adhere to the prompt messages in using the program.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Field-to-field irrigation method is the most common method practiced by rice farmers because of its easiness in operation. It is a common method in rice fields in the sub-Saharan Africa. In times of water scarcity or low flows, a farmer is tempted to tap water available in the neighbouring basin which has received water.

The factors which affect water storage in a paddy basin and hence time of fill include the initial soil water content, surface water inflow, surface water outflow, vertical seepage and percolation through the basin base, horizontal seepage across the bunds with water loss through cracks and fissures, evapotranspiration, and rainfall.

In using the model developed, it was found that there is a good agreement between the observed and modeled results. The results from the statistical analysis of the observed changes in water storage (in depth units) and calculated storage by using the method of analysis of variance (ANOVA) at 5% significant level for Field A showed no significant difference. Those from Field B showed no significant difference in four of the five basins, while those from Field C showed no significant difference in two of the five basins, the reason being unaccounted water losses through rodent holes and cracks.

Further, the test of correlation on corresponding observed and calculated values showed some high correlation between the observed and measured values. This suggests that the corresponding values had little off sets from each other in the minus or plus comparison.

This shows that the model developed has a high precision in predicting paddy basin water storage with given inflows and outflows in a specified time period, hence it predicts closely the time of fill to a given depth in a paddy basin. The model is not location based because it employs standard methods of estimating its parameters. It simply requires local data at the location of application.

The computer program developed is a simple tool to ease the calculation process involved and hence save time and eliminate simple errors in the process.

5.2 Recommendations

The method of field-to-field should be adopted in the design process of paddy basin irrigation systems. As has been reported that most schemes in Malawi do not have devices to measure how much water is applied, which may also be the case in other countries, the weirs required in the method should also serve as water measuring devices. The availability of water for irrigation and capital for investment is decreasing, therefore this simple method which is relatively cheap to implement, may suit the condition because it requires less number of canals in as much as it is a common method practiced by rice farmers in scarce or low water flows. Since the rice crop at different stages require different water depths, adjustable weirs should be used or several weirs along the bund with different weir crest heights.

6.0 REFERENCES

Adams M. E., 1982; *Agricultural Extension in Developing countries*; Longman Group Ltd.; First Edition; Essex, UK; pp26, 42.

Agricultural Development Council(ADC), 1978; *Irrigation policy and management in Southeast Asia*; IRRI; Manila; Philippines; p64.

American Society of Agricultural Engineers (ASAE), 1993; *Transactions of the ASAE*, Sept.-Oct., 1993; Volume 36, No. 5; U.S.A., General Edition; pp1353 – 1361.

American Society of Agricultural Engineers (ASAE), 1986; *Transactions of the ASAE*, Nov.-Dec., 1986; Volume 29, No. 6; U.S.A., General Edition; pp1572 – 1581.

American Society of Agricultural Engineers (ASAE), April 1982; *Agricultural Engineering*; Volume 63, No. 4; U.S.A., ASAE, General Edition; p27.

Booher L. J., 1974; *Surface Irrigation*; FAO Agricultural Development Paper; FAO, Rome; pp12-15.

Boyd M. J., Pilgrim D. H., Cordery, 1979; *Journal of Hydrology : Research papers*; July, 1979; Volume 42, No. 3/4; Oxford, Elsevier Scientific Publishing Company; pp209-230.

Brady N. C., 1984; *The Nature and Properties of Soils*; Macmillan Publishing Company; New York; Ninth Edition; p44.

Bredero T. J., 1991; *Crop-Water Management Research*; New Delhi, Mohan Primlani for Oxford & IBH Publishing Co. Pvt. Ltd.; pp17 – 115.

British Society of Soil Science, 1997; *Soil Use and Management*, Volume 13, An international journal published for the British Society of Soil Science; CAB International; UK; pp131 – 170.

Central Board of Irrigation and Power(CBIP), July 1989; *Irrigation and Power Journal*; Volume 46, No. 3; New Delhi; p35.

Chow V. T., Maidment, D. R. and Mays L. W., 1988; *Applied Hydrology*; Mc Graw-Hill; New York; USA; p61.

CODA and Partners, 1994; *Malawi Agriculture Sector Study*; Volume 3, Annex 8, Irrigation Development; Lilongwe; Malawi; pp1 – 67.

Craig R. F., 1987; *Soil Mechanics*; Chapman and Hall; London; Fourth Edition; pp36 – 44.

Dake J. M. K., 1983; *Essentials of Engineering Hydraulics*; The Macmillan Press Ltd.; London; Second Edition, pp119; 297 – 300.

Doneen L. D. and Westcot D. W., 1988; *Irrigation Practice and Water Management*; Oxfold & IBH Publishing Co. Pvt. Ltd.; New Delhi; pp42 – 52.

DVWK(German Association for Water Resources and Land Improvement), 1985; *Traditional Schemes and Pontential for their Improvement*, Irrigation Symposium, Kongre_ Wasser Berlin; Berlin, Verlag Paul Parey; p254.

FAO, 1995; *Irrigation in Africa In Figures*; Water Reports 7; Rome; p13.

FAO, 1994; *Irrigation Water Delivery Models*, Water Reports 2; Proceedings of the FAO Expert Consultation, Rome, Italy; pp54 – 62.

FAO, 1986; *Irrigation in Africa South of the Sahara*, FAO. 5; Rome; pp59 - 63.

FAO/UNESCO, 1973; *Irrigation, Drainage and Salinity*; An International Source Book; Hutchison & Co. Ltd.; London; First Edition; p310.

Fenton J. D., 1992; *Reservoir routing*, Hydrological Science – Journal – des Sciences Hydrologique, 37.3; pp233 – 246.

Hansen V. E., Israelsen O. W. and Stringham G. E.,1980; *Irrigation principles and practices*; John Wiley and Sons, Inc.; Toronto; Fourth Edition; pp248 – 250.

IIMI, 1992; *Outlook On Agriculture*; Volume 21, No. 4; Colombo, CAB International;pp279 – 286.

IRRI, 1989; *International Rice Research Institute, Annual Report for 1988*; Philippines, IRRI; pp308 – 317.

James L. G. , 1988; *Principles of Farm Irrigation Systems Design*; New York; John Willey & Sons Inc.; pp13 – 18, 30 – 33.

Juo A. S. R. and Lowe J. A., 1986; *The Wetlands and Rice in Subsaharan Africa*, Proceedings of an international conference on wetland utilization for rice production in Subsaharan Africa, 4 - 8 November 1985, Ibadan, Nigeria; International Institute of Tropical Agriculture; Ibadan; Nigeria; pp69 – 86.

Kay M., 1986; *Surface Irrigation Systems and Practice*; Cransfield Press; England; First Edition; pp24, 28, 36.

Landon J. R., 1991; *Booker Tropical Soil Manual*, A hand book for Soil Survey and Agricultural Land evaluation in the tropics and subtropics; Longman Scientific & Technical; England; p68.

Linsley, JR. R. K.; Kohler M. A.; Paulhus J. L. H.,1988; *Hydrology For Engineers*; UK, Mc Grawh-Hill Book Company(UK) Limited, SI Metric Edition; pp258 – 268, 429 – 434.

Mead, R. and Curnow, R. N., 1983 ; *Statistical Methods in Agriculture and Experimental Biology*; London, Chapman and Hall Ltd., First Edition; pp10 –46, 125 – 153.

Mosher A. T., 1966; *Getting Agriculture Moving*, Essentials for Development and Modernization; Published for The Agricultural Development Council; Frederick A. Praeger, Publishers; New York; p17.

Nippon Koel, 1993; *Feasibility Study On Bwanje Valley Smallholder Irrigation Development Project*; Volume II, Annexes; Nippon Koel Co., Ltd, Pacific Consultants International; Malawi; pp T_23 – 33, F_15.

Pruitt W. O. and Doorenbos J., 1977; Irrigation and Drainage paper; *Crop Water Requirements*, FAO 24; Rome; p31.

Robertson, J. A., Cassidy, J. J. and Chaundhry, M. H., 1988; *Hydraulic Engineering*; Houghton Miflin, Boston, USA; pp28 –29.

Sakamoto K., 1988; *The structure of Technology, Economy and Society of Traditional Agriculture in Equatorial Africa*; Dept. of Agricultural and Forestry Economics; Kyoto University, Japan; p42.

Smedema L. K. and Rycroft D. W., 1983; *Land drainage*, Planning and design of agricultural drainage systems; B. T. Batsford Ltd.; London; First Edition; pp130 – 133.

USAID-TABA(United States Agency for International Development, Technical Assistance Bureau/Asia), 1973; *Research needs for on-farm watermanagement*; Proceedings of an International Symposium, October 1973; Park City, Utah; p23.

Velde, E. J. V, 1989; *Irrigation Management in Pakistan Mountain Environment*; Country Paper-Pakistan No. 3; Colombo, International Irrigation Management Institute; p21.

Walker, W. R. and Skogerboe, G. V., 1987; *Surface Irrigation: Theory and Practice*; New Jersey, Prentice-Hall, Englewood Cliffs; p19.

Wang J. and Hagan R. E., 1981; *Irrigation Rice Production Systems: Design Procedures*; Westview Tropical Agriculture Series, No 3; U.S.A., Westview Press, Inc.; pp109 - 200.

Withers B. and Vipond V.,1974; *Irrigation*, design and practice; B T Batsford Limited, London; First Edition; pp230 – 243.

APPENDICES

APPENDIX A

Water measurement data

Appendix A-1 Water measurement data for Field A

BASIN	ELAPSED TIME, t (min)	SURFACE FLOW AT INFLOW WEIR Yo1- Zo(cm)	 AT OUTFLOW WEIR Yo1- Zo(cm)	 Rainfall (mm)	WATER LEVEL IN BASIN (STAFF READING) (cm)	AVERAGE DEPTH IN ADJACENT PLOT OR DRAIN (cm) Side A	 Side B	 Side C	 Side D	REMARKS
A1	0.000	0.0	0.0	0.0	9.8	21.7	19.0	12.6	6.2	Inflow into A1 at 8.50am
A1	10.000	3.8	0.0	0.0	10.3	21.7	19.0	12.6	6.2	
A1	20.000	4.9	0.0	0.0	12.2	21.7	19.0	12.6	6.2	
A1	30.000	5.0	0.0	0.0	13.6	21.7	19.0	12.6	6.2	
A1	40.000	5.3	0.0	0.0	15.0	21.7	19.0	12.6	6.2	Fill and spill into A2 at 9.30am
A1	50.000	5.9	1.9	0.0	16.5	21.7	19.0	12.8	6.2	
A1	60.000	6.3	3.4	0.0	17.9	21.7	19.0	13.3	6.2	
A1	70.000	6.4	4.1	0.0	18.8	21.7	19.0	13.9	6.2	
A1	80.000	6.3	4.6	0.0	19.5	21.7	19.0	14.9	6.2	
A1	90.000	6.3	4.8	0.0	19.8	21.7	19.0	15.9	6.2	
A2	0.000	0.0	0.0	0.0	12.6	15.0	12.3	12.6	5.7	Spill into A2 at 9.30am
A2	10.000	1.9	0.0	0.0	12.8	16.5	12.3	12.6	5.7	
A2	20.000	3.4	0.0	0.0	13.3	17.9	12.3	12.6	5.7	
A2	30.000	4.1	0.0	0.0	13.9	18.8	12.3	12.6	5.7	
A2	40.000	4.6	0.0	0.0	14.9	19.5	12.3	12.6	5.7	
A2	50.000	4.8	0.0	0.0	15.9	19.8	12.3	12.6	5.7	
A2	60.000	4.8	0.0	0.0	16.8	19.8	12.3	12.6	5.7	Fill and spill into A3 at 10.33am
A2	70.000	5.3	0.8	0.0	17.7	19.8	12.3	12.6	5.7	
A2	80.000	5.4	1.9	0.0	18.6	19.8	12.3	13.1	5.7	
A2	90.000	5.8	2.8	0.0	19.5	19.8	12.3	14.0	5.7	
A2	100.000	5.8	3.6	0.0	20.3	19.8	12.3	15.2	5.7	
A2	110.000	5.8	4.2	0.0	20.8	19.8	12.3	16.4	5.7	
A2	120.000	5.8	4.4	0.0	21.0	19.8	12.3	17.4	5.7	
A3	0.000	0.0	0.0	0.0	12.8	17.8	20.8	15.4	9.3	Spill into A3 at 10.33am
A3	12.000	1.8	0.0	0.0	13.3	18.6	20.8	15.4	9.3	
A3	22.000	3.1	0.0	0.0	14.2	19.7	20.8	15.4	9.3	
A3	32.000	4.1	0.0	0.0	15.4	20.5	20.8	15.4	9.3	
A3	42.000	4.4	0.0	0.0	16.7	21.2	20.8	15.4	9.3	Fill and spill into A4 at 11.22am
A3	52.000	4.8	0.6	0.0	17.8	21.7	20.8	15.4	9.3	
A3	62.000	4.9	2.8	0.0	18.6	21.7	20.8	16.3	9.3	
A3	72.000	5.6	3.4	0.0	19.5	21.7	20.8	17.1	9.3	
A3	82.000	5.8	4.4	0.0	20.4	21.7	20.8	18.2	9.3	
A3	92.000	5.9	5.2	0.0	21.2	21.7	20.8	19.4	9.3	
A4	0.000	0.0	0.0	0.0	15.4	16.5	21.5	13.6	14.3	Fill and spill into A4 at 11.22am
A4	20.000	2.3	0.0	0.0	16.2	18.4	21.5	13.6	14.3	
A4	30.000	3.3	0.0	0.0	17.1	19.3	21.5	13.6	14.3	
A4	40.000	3.7	0.0	0.0	18.0	20.0	21.5	13.6	14.3	Fill and spill into A5 at 12.07am
A4	50.000	4.2	0.7	0.0	18.9	20.4	21.5	13.6	14.3	
A4	60.000	4.3	2.2	0.0	19.7	20.7	21.5	14.1	14.3	
A4	70.000	4.7	2.8	0.0	20.6	20.7	21.5	14.8	14.3	
A4	80.000	5.0	3.5	0.0	21.3	20.7	21.5	15.5	14.3	
A4	90.000	5.0	4.3	0.0	21.9	20.7	21.5	16.4	14.3	
A4	100.000	5.5	4.8	0.0	22.4	20.7	21.5	17.5	14.3	
A4	110.000	5.3	4.9	0.0	22.9	20.7	21.5	18.4	14.3	
A5	0.000	0.0	0.0	0.0	13.1	18.3	22.7	8.5	11.7	Fill and spill into A5 at 12.07am
A5	20.000	2.5	0.0	0.0	13.8	20.1	22.7	8.5	11.7	
A5	30.000	3.4	0.0	0.0	14.4	20.6	22.7	8.5	11.7	
A5	40.000	3.9	0.0	0.0	15.2	21.6	22.7	8.5	11.7	
A5	50.000	4.3	0.0	0.0	16.3	22.1	22.7	8.5	11.7	Leakage into A5
A5	60.000	4.5	1.9	0.0	16.8	22.1	22.7	8.5	11.7	Fill and spill out of A5 at 12.57pm

		SURFACE FLOW				AVERAGE DEPTH IN ADJACENT PLOT OR DRAIN (cm)				
BASIN	ELAPSED TIME, t (min)	AT INFLOW WEIR Yo1- Zo(cm)	AT OUTFLOW WEIR Yo1- Zo(cm)	Rainfall (mm)	WATER LEVEL IN BASIN (STAFF READING) (cm)	Side A	Side B	Side C	Side D	REMARKS
A1	0.000	4.0	0.0	0.0	13.6	23.3	21.5	15.4	9.2	Inflow into A1 at 11.00am
A1	10.000	5.0	0.0	0.0	15.2	23.3	21.5	15.4	9.2	Fill and spill into A2 at 11.08am
A1	20.000	5.4	1.9	0.0	16.6	23.3	21.5	15.6	9.2	
A1	30.000	5.5	2.6	0.0	17.7	23.3	21.5	16.1	9.2	
A1	40.000	5.4	3.6	0.0	18.4	23.3	21.5	16.6	9.2	
A1	50.000	5.6	4.0	0.0	18.9	23.3	21.5	17.3	9.2	
A1	60.000	5.7	4.4	0.0	18.9	23.3	21.5	18.0	9.2	
A2	0.000	0.0	0.0	0.0	15.4	15.2	14.5	14.1	9.5	Spill into A2 at 11.08am
A2	12.000	1.9	0.0	0.0	15.6	16.6	14.5	14.1	9.5	
A2	22.000	2.6	0.0	0.0	16.1	17.7	14.5	14.1	9.5	
A2	32.000	3.6	0.0	0.0	16.6	18.4	14.5	14.1	9.5	Fill and spill into A3 at 11.50am
A2	42.000	4.0	0.0	0.0	17.3	18.9	14.5	14.1	9.5	
A2	52.000	4.4	1.3	0.0	18.0	18.9	14.5	14.5	9.5	
A2	62.000	4.3	1.9	0.0	18.5	18.9	14.5	14.8	9.5	
A2	72.000	4.7	2.4	0.0	19.2	18.9	14.5	15.2	9.5	
A2	82.000	4.9	2.9	0.0	19.8	18.9	14.5	16.0	9.5	
A2	92.000	5.3	3.3	0.0	20.2	13.9	14.5	16.7	9.5	
A2	102.000	5.0	3.8	0.0	20.5	13.9	14.5	17.5	9.5	
A3	0.000	0.0	0.0	0.0	14.1	17.3	18.8	16.0	8.8	Spill into A3 at 11.50am
A3	10.000	1.3	0.0	0.0	14.5	18.0	18.8	16.0	8.8	
A3	20.000	1.9	0.0	0.0	14.8	18.5	18.8	16.0	8.8	
A3	30.000	2.4	0.0	0.0	15.2	19.2	18.8	16.0	8.8	
A3	40.000	2.9	0.0	0.0	16.0	19.8	18.8	16.0	8.8	Fill and spill into A4 at 12.35pm
A3	50.000	3.3	0.0	0.0	16.7	20.2	18.8	16.0	8.8	
A3	60.000	3.8	1.7	0.0	17.5	20.5	18.8	16.4	8.8	
A3	70.000	3.7	2.2	0.0	18.0	20.5	18.8	16.8	8.8	
A3	80.000	4.3	2.6	0.0	18.6	20.5	18.8	17.3	8.8	
A3	90.000	4.4	3.3	0.0	19.2	20.5	18.8	18.0	8.8	
A3	100.000	4.4	3.8	0.0	19.7	20.5	18.8	18.8	8.8	
A4	0.000	0.0	0.0	0.0	16.1	16.7	20.7	13.5	16.0	Spill into A4 at 12.35pm
A4	20.000	2.3	0.0	0.0	16.7	17.6	20.7	13.5	16.0	
A4	30.000	2.9	0.0	0.0	17.4	18.0	20.7	13.5	16.0	
A4	40.000	3.4	0.0	0.0	18.2	19.0	20.7	13.5	16.0	Fill and spill into A5 at 1.15pm
A4	50.000	3.9	1.2	0.0	19.2	19.3	20.7	13.5	16.0	
A4	60.000	4.4	2.4	0.0	20.2	20.2	20.7	14.0	16.0	
A4	70.000	4.9	3.2	0.0	20.6	20.2	20.7	14.5	16.0	
A4	80.000	4.9	3.7	0.0	20.9	20.2	20.7	15.1	16.0	
A4	90.000	5.4	4.2	0.0	21.6	20.2	20.7	16.6	16.0	
A5	0.000	0.0	0.0	0.0	13.4	19.1	23.3	7.3	9.3	Fill and spill into A5 at 1.15pm
A5	15.000	2.7	0.0	0.0	14.1	20.4	23.3	7.3	9.3	
A5	25.000	3.3	0.0	0.0	14.6	21.4	23.3	7.3	9.3	
A5	35.000	4.2	0.0	0.0	15.6	22.1	23.3	7.3	9.3	Fill and spill out of A5 at 1.58pm
A5	45.000	4.8	1.4	0.0	16.8	23.0	23.3	7.3	9.3	
A5	55.000	5.2	2.4	0.0	17.8	23.2	23.3	7.3	9.3	

Appendix A-2 Water measurement data for Field B

BASIN	ELAPSED TIME, t (min)	SURFACE FLOW AT INFLOW WEIR Yo1- Zo(cm)	SURFACE FLOW AT OUTFLOW WEIR Yo1- Zo(cm)	Rainfall (mm)	WATER LEVEL IN BASIN (STAFF READING) (cm)	AVERAGE DEPTH IN ADJACENT PLOT OR DRAIN (cm) Side A	Side B	Side C	Side D	REMARKS
B1	0.000	0.0	0.0	0.0	8.2	11.5	12.7	9.3	5.3	Inflow into B1 at 8.30am
B1	10.000	5.8	0.0	0.0	9.4	11.5	12.7	9.3	5.3	Leakage out of B1
B1	20.000	6.3	0.0	0.0	10.9	11.5	12.7	9.3	5.3	
B1	30.000	6.7	3.2	0.0	12.1	11.5	12.7	10.0	5.3	
B1	40.000	6.8	4.3	0.0	13.3	11.5	12.7	11.0	5.3	
B1	50.000	6.8	4.7	0.0	14.0	11.5	12.7	12.1	5.3	
B1	60.000	6.8	5.3	0.0	14.4	11.5	12.7	13.1	5.3	
B1	70.000	6.7	5.4	0.0	14.8	11.5	12.7	14.2	5.3	
B1	80.000	6.8	5.8	0.0	15.1	11.5	12.7	15.1	5.3	
B1	90.000	6.8	5.9	0.0	15.3	11.5	12.7	15.9	5.3	
B2	0.000	0.0	0.0	0.0	9.3	10.9	7.5	10.7	9.5	Spill into B2 at 8.50am
B2	10.000	3.2	0.0	0.0	10.0	12.1	7.5	10.7	9.5	
B2	20.000	4.3	0.0	0.0	11.0	13.3	7.5	10.7	9.5	
B2	30.000	4.7	0.0	0.0	12.1	14.0	7.5	10.7	9.5	Fill and spill into B3 at 9.25am
B2	40.000	5.3	1.4	0.0	13.1	14.4	7.5	10.7	9.5	
B2	50.000	5.4	2.4	0.0	14.2	14.8	7.5	11.5	9.5	
B2	60.000	5.8	3.3	0.0	15.1	15.1	7.5	12.4	9.5	
B2	70.000	5.9	3.8	0.0	15.9	15.3	7.5	13.4	9.5	
B2	80.000	6.2	4.3	0.0	16.3	15.3	7.5	14.2	9.5	
B2	90.000	6.2	4.7	0.0	16.6	15.3	7.5	15.3	9.5	
B2	100.000	6.3	4.8	0.0	16.9	15.3	7.5	16.2	9.5	
B3	0.000	0.0	0.0	0.0	10.7	12.6	11.3	5.9	4.8	Spill into B3 at 9.25am
B3	15.000	2.4	0.0	0.0	11.5	14.2	11.3	5.9	4.8	
B3	25.000	3.3	0.0	0.0	12.4	15.1	11.3	5.9	4.8	
B3	35.000	3.8	0.0	0.0	13.4	15.9	11.3	5.9	4.8	
B3	45.000	4.3	0.0	0.0	14.2	16.3	11.3	5.9	4.8	Fill and spill into B4 at 10.17am
B3	55.000	4.7	1.5	0.0	15.3	16.6	11.3	5.9	4.8	
B3	65.000	4.8	2.3	0.0	16.2	16.9	11.3	5.9	4.8	
B3	75.000	4.9	2.8	0.0	16.8	16.9	11.3	6.4	4.8	
B3	85.000	5.1	3.8	0.0	17.7	16.9	11.3	7.2	4.8	
B3	95.000	5.4	4.3	0.0	18.3	16.9	11.3	7.8	4.8	
B3	105.000	5.3	4.9	0.0	18.9	16.9	11.3	8.6	4.8	
B3	115.000	5.6	5.2	0.0	19.3	16.9	11.3	9.5	4.8	
B3	125.000	5.4	5.6	0.0	19.7	16.9	11.3	10.4	4.8	
B3	135.000	5.6	5.8	0.0	19.9	16.9	11.3	11.3	4.8	Leakage out of B3 to off the garden
B4	0.000	0.0	0.0	0.0	5.9	15.3	11.5	11.5	6.3	Spill into B4 at 10.17am
B4	23.000	2.8	0.0	0.0	6.4	16.8	11.5	11.5	6.3	
B4	33.000	3.8	0.0	0.0	7.2	17.7	11.5	11.5	6.3	
B4	43.000	4.3	0.0	0.0	7.8	18.3	11.5	11.5	6.3	
B4	53.000	4.9	0.0	0.0	8.6	18.9	11.5	11.5	6.3	
B4	63.000	5.2	0.0	0.0	9.5	19.3	11.5	11.5	6.3	Heavy leakage from B4 into B5
B4	73.000	5.6	0.0	0.0	10.4	19.7	11.5	11.5	6.3	
B4	83.000	5.8	0.0	0.0	11.3	19.9	11.5	11.5	6.3	
B4	93.000	5.8	0.0	0.0	11.8	19.9	11.5	11.5	6.3	Fill and spill into B5 at 11.50am
B4	103.000	5.8	2.3	0.0	12.6	19.9	11.5	11.9	6.3	Leakage out of B4 into B5
B4	113.000	6.3	3.2	0.0	13.4	19.9	11.5	12.3	6.3	
B4	123.000	6.0	3.5	0.0	13.9	19.9	11.5	12.7	6.3	
B4	133.000	6.1	4.3	0.0	14.5	19.9	11.5	13.5	6.3	
B4	143.000	6.2	4.6	0.0	14.9	19.9	11.5	14.2	6.3	Leakage out of B4 into B5
B5	0.000	0.0	0.0	0.0	11.5	11.8	12.8	1.7	12.5	Spill into B5 at 11.50am
B5	10.000	2.3	0.0	0.0	11.9	12.6	12.8	1.7	12.5	
B5	20.000	3.2	0.0	0.0	12.3	13.4	12.8	1.7	12.5	
B5	30.000	3.5	0.0	0.0	12.7	13.9	12.8	1.7	12.5	
B5	40.000	4.3	0.0	0.0	13.5	14.5	12.8	1.7	12.5	Fill and spill out of B5 at 12.30pm
B5	50.000	4.6	1.3	0.0	14.2	14.9	12.8	1.7	12.5	Leakage out of B4 into B5
B5	60.000	5.0	1.8	0.0	14.8	14.9	12.8	1.7	12.5	
B5	70.000	5.2	2.7	0.0	15.6	14.9	12.8	1.7	12.5	

BASIN	ELAPSED TIME, t (min)	SURFACE FLOW			WATER LEVEL IN BASIN (STAFF READING) (cm)	AVERAGE DEPTH IN ADJACENT PLOT OR DRAIN (cm)				REMARKS
		AT INFLOW WEIR Yo1- Zo(cm)	AT OUTFLOW WEIR Yo1- Zo(cm)	Rainfall (mm)		Side A	Side B	Side C	Side D	
B1	0.000	0.0	0.0	0.0	7.3	14.3	9.0	6.0	4.5	Inflow into B1 at 8.20am
B1	10.000	7.1	0.0	0.0	8.7	14.3	9.0	6.0	4.5	
B1	20.000	7.1	0.0	0.0	10.5	14.3	9.0	6.0	4.5	Fill and spill into B2 at 8.40am
B1	30.000	7.1	2.4	0.0	11.9	14.3	9.0	6.5	4.5	
B1	40.000	7.2	3.5	0.0	13.1	14.3	9.0	7.4	4.5	
B1	50.000	7.2	4.3	0.0	13.9	14.3	9.0	8.8	4.5	
B1	60.000	7.3	4.8	0.0	14.6	14.3	9.0	10.3	4.5	
B1	70.000	7.3	4.9	0.0	15.0	14.3	9.0	11.6	4.5	
B1	80.000	7.3	5.4	0.0	15.3	14.3	9.0	12.9	4.5	
B1	90.000	7.3	5.4	0.0	15.5	14.3	9.0	13.8	4.5	
B2	0.000	0.0	0.0	0.0	9.0	11.2	8.3	10.6	7.7	Spill into B2 at 8.40am
B2	10.000	3.4	0.0	0.0	9.6	12.7	8.3	10.6	7.7	
B2	20.000	4.6	0.0	0.0	10.8	13.8	8.3	10.6	7.7	Fill and spill into B3 at 9.10am
B2	30.000	5.2	0.0	0.0	12.1	14.4	8.3	10.6	7.7	
B2	40.000	5.3	1.3	0.0	13.1	14.8	8.3	10.6	7.7	
B2	50.000	5.5	2.3	0.0	14.1	15.0	8.3	11.3	7.7	
B2	60.000	5.7	3.2	0.0	15.2	15.2	8.3	12.0	7.7	
B2	70.000	5.4	3.7	0.0	15.7	15.2	8.3	12.9	7.7	
B2	80.000	5.2	4.0	0.0	15.8	14.8	8.3	13.7	7.7	
B2	90.000	5.0	4.0	0.0	16.0	14.8	8.3	14.7	7.7	
B2	100.000	4.7	3.8	0.0	16.0	14.8	8.3	15.7	7.7	
B2	110.000	4.8	3.8	0.0	16.0	14.8	8.3	15.7	7.7	
B3	0.000	0.0	0.0	0.0	10.6	12.1	8.5	8.5	4.8	Spill into B3 at 9.10am
B3	20.000	2.3	0.0	0.0	11.3	14.1	8.5	8.5	4.8	
B3	30.000	3.2	0.0	0.0	12.0	15.2	8.5	8.5	4.8	
B3	40.000	3.7	0.0	0.0	12.9	15.7	8.5	8.5	4.8	
B3	50.000	4.0	0.0	0.0	13.7	15.8	8.5	8.5	4.8	Fill and spill into B4 at 10.10am
B3	60.000	4.0	0.0	0.0	14.7	16.0	8.5	8.5	4.8	
B3	70.000	3.8	1.8	0.0	15.7	16.0	8.5	8.5	4.8	
B3	80.000	3.8	2.3	0.0	15.7	16.0	8.5	9.0	4.8	
B3	90.000	3.8	2.7	0.0	16.7	16.0	8.5	9.2	4.8	
B3	100.000	3.8	3.1	0.0	17.1	16.0	8.5	9.5	4.8	
B3	110.000	3.8	3.4	0.0	17.5	16.0	8.5	10.0	4.8	
B3	120.000	4.2	3.7	0.0	17.8	16.0	8.5	10.5	4.8	
B4	0.000	0.0	0.0	0.0	8.5	14.7	9.2	10.6	6.2	Spill into B4 at 10.10am
B4	20.000	2.3	0.0	0.0	9.0	15.7	9.2	10.6	6.2	
B4	30.000	2.7	0.0	0.0	9.2	16.7	9.2	10.6	6.2	
B4	40.000	3.1	0.0	0.0	9.5	17.1	9.2	10.6	6.2	
B4	50.000	3.4	0.0	0.0	10.0	17.5	9.2	10.6	6.2	
B4	60.000	3.7	0.0	0.0	10.5	17.8	9.2	10.6	6.2	
B4	70.000	3.8	0.0	0.0	10.6	17.8	9.2	10.6	6.2	
B4	80.000	4.1	0.0	0.0	11.3	17.8	9.2	10.6	6.2	Fill and spill into B5 at 11.38am
B4	90.000	4.3	1.1	0.0	11.8	17.8	9.2	10.7	6.2	
B4	100.000	4.5	1.7	0.0	12.3	17.8	9.2	10.9	6.2	
B4	110.000	4.7	2.3	0.0	12.7	17.8	9.2	11.1	6.2	
B4	120.000	4.7	2.7	0.0	13.1	17.8	9.2	11.5	6.2	
B4	130.000	5.0	3.3	0.0	13.5	17.8	9.2	12.1	6.2	
B4	140.000	5.4	3.8	0.0	14.1	17.8	9.2	12.7	6.2	Leakage out of B3 into B4
B4	150.000	5.5	4.2	0.0	14.4	17.8	9.2	13.2	6.2	
B5	0.000	0.0	0.0	0.0	10.6	11.7	11.5	0.8	11.3	Spill into B5 at 11.38am
B5	2.000	1.1	0.0	0.0	10.7	11.8	11.5	0.8	11.3	
B5	12.000	1.7	0.0	0.0	10.9	12.3	11.5	0.8	11.3	
B5	22.000	2.3	0.0	0.0	11.1	12.7	11.5	0.8	11.3	
B5	32.000	2.7	0.0	0.0	11.5	13.1	11.5	0.8	11.3	Leakage out of B5
B5	42.000	3.3	0.0	0.0	12.1	13.5	11.5	0.8	11.3	Leakage out of B5
B5	52.000	3.8	0.0	0.0	12.7	14.1	11.5	0.8	11.3	
B5	62.000	4.2	0.0	0.0	13.2	14.4	11.5	0.8	11.3	Fill and spill out of B5 at 12.45pm
B5	72.000	4.4	1.3	0.0	14.1	14.4	11.5	0.8	11.3	
B5	82.000	5.1	1.8	0.0	14.7	14.4	11.5	0.8	11.3	

Appendix A-3 Water measurement data for Field C

BASIN	ELAPSED TIME, t (min)	SURFACE FLOW			WATER LEVEL IN BASIN (STAFF READING) (cm)	AVERAGE DEPTH IN ADJACENT PLOT OR DRAIN (				REMARKS
		AT INFLOW WEIR Yo1- Zo(cm)	AT OUTFLOW WEIR Yo1- Zo(cm)	Rainfall (mm)		Side A	Side B	Side C	Side D	
C1	0.000	0.0	0.0	0.0	16.1	14.5	12.2	10.2	5.8	Inflow into C1 at 8.00am
C1	10.000	4.8	0.0	0.0	16.4	14.5	12.2	10.2	5.8	
C1	20.000	5.8	0.0	0.0	17.1	14.5	12.2	10.2	5.8	Fill and spill into C2 at 8.25am
C1	30.000	5.7	0.6	0.0	18.1	14.5	12.2	10.2	5.8	
C1	40.000	5.3	1.8	0.0	18.8	14.5	12.2	10.2	5.8	
C1	50.000	5.3	2.0	0.0	19.2	14.5	12.2	10.5	5.8	
C1	60.000	4.8	2.8	0.0	19.7	14.5	12.2	10.9	5.8	
C1	70.000	5.1	3.0	0.0	19.9	14.5	12.2	11.2	5.8	
C1	80.000	5.3	3.3	0.0	20.2	14.5	12.2	11.7	5.8	
C1	90.000	5.3	3.4	0.0	20.4	14.5	12.2	12.0	5.8	
C2	0.000	0.0	0.0	0.0	10.2	17.6	12.3	12.7	6.2	Spill into C2 at 8.25am
C2	25.000	2.0	0.0	0.0	10.5	19.2	12.3	12.7	6.2	Fill and spill into C3 at 9.00am
C2	35.000	2.8	0.0	0.0	10.9	19.7	12.3	12.7	6.2	
C2	45.000	3.0	0.7	0.0	11.2	19.9	12.3	12.7	6.2	
C2	55.000	3.3	1.4	0.0	11.7	20.2	12.3	12.7	6.2	
C2	65.000	3.4	1.8	0.0	12.0	20.4	12.3	13.0	6.2	
C2	75.000	3.7	2.0	0.0	12.3	20.4	12.3	13.1	6.2	
C2	85.000	3.8	2.3	0.0	12.5	20.4	12.3	13.7	6.2	
C2	95.000	3.8	2.5	0.0	12.9	20.4	12.3	13.7	6.2	
C2	105.000	3.9	2.8	0.0	13.1	20.4	12.3	14.1	6.2	
C2	115.000	4.1	3.1	0.0	13.1	20.4	12.3	14.6	6.2	
C2	125.000	4.1	3.2	0.0	13.5	20.4	12.3	14.9	6.2	
C2	135.000	4.1	3.6	0.0	13.5	20.4	12.3	15.3	6.2	
C3	0.000	0.0	0.0	0.0	12.7	10.9	15.0	5.6	2.7	Spill into C3 at 9.00am
C3	30.000	1.8	0.0	0.0	13.0	12.0	15.0	5.6	2.7	
C3	40.000	2.0	0.0	0.0	13.1	12.3	15.0	5.6	2.7	
C3	50.000	2.3	0.0	0.0	13.7	12.5	15.0	5.6	2.7	
C3	60.000	2.5	0.0	0.0	13.7	12.9	15.0	5.6	2.7	
C3	70.000	2.8	0.0	0.0	14.1	13.1	15.0	5.6	2.7	Fill and spill into C4 at 10.20am
C3	80.000	3.1	0.0	0.0	14.6	13.1	15.0	5.6	2.7	
C3	90.000	3.2	0.7	0.0	14.9	13.5	15.0	5.6	2.7	
C3	100.000	3.6	1.3	0.0	15.3	13.5	15.0	5.6	2.7	
C3	110.000	3.8	1.5	0.0	15.6	13.5	15.0	5.8	2.7	
C3	120.000	4.0	1.3	0.0	16.0	13.5	15.0	6.0	2.7	
C3	130.000	4.1	2.3	0.0	16.4	13.5	15.0	6.3	2.7	
C3	140.000	4.3	2.4	0.0	16.8	13.5	15.0	6.6	2.7	
C3	150.000	4.3	2.3	0.0	17.2	13.5	15.0	7.1	2.7	Leakage out of C3 to main drain
C3	160.000	4.3	2.3	0.0	17.5	13.5	15.0	7.4	2.7	
C4	0.000	0.0	0.0	0.0	5.6	14.6	12.3	5.4	6.7	Spill into C4 at 10.20am
C4	30.000	1.5	0.0	0.0	5.8	15.6	12.3	5.4	6.7	
C4	40.000	1.8	0.0	0.0	6.0	16.0	12.3	5.4	6.7	
C4	50.000	2.3	0.0	0.0	6.3	16.4	12.3	5.4	6.7	
C4	60.000	2.4	0.0	0.0	6.6	16.8	12.3	5.4	6.7	
C4	70.000	2.8	0.0	0.0	7.1	17.2	12.3	5.4	6.7	Leakage out of C4 into C5
C4	80.000	2.8	0.0	0.0	7.4	17.5	12.3	5.4	6.7	
C4	90.000	3.0	0.0	0.0	7.9	17.5	12.3	5.4	6.7	
C4	100.000	3.0	0.0	0.0	8.2	17.5	12.3	5.4	6.7	Heavy leakage out of C4 into C5
C4	110.000	3.2	0.0	0.0	8.9	17.5	12.3	5.4	6.7	Fill and spill into C5 at 12.10pm
C4	120.000	3.3	1.5	0.0	9.5	17.5	12.3	5.4	6.7	
C4	130.000	3.7	2.0	0.0	10.0	17.5	12.3	5.7	6.7	
C4	140.000	3.8	2.6	0.0	10.5	17.5	12.3	5.9	6.7	
C4	150.000	3.8	3.0	0.0	10.8	17.5	12.3	6.2	6.7	Heavy leakage out of C4 into C5
C4	160.000	3.8	3.3	0.0	11.2	17.5	12.3	6.5	6.7	
C4	170.000	3.7	3.6	0.0	11.4	17.5	12.3	6.8	6.7	
C4	180.000	3.8	3.8	0.0	11.6	17.5	12.3	7.2	6.7	
C4	190.000	3.6	3.8	0.0	11.7	17.5	12.3	7.5	6.7	
C4	200.000	3.4	3.8	0.0	11.8	17.5	12.3	7.9	6.7	
C5	0.000	0.0	0.0	0.0	7.2	11.7	23.5	11.3	7.7	Spill into C5 at 12.10pm
C5	5.000	1.7	0.0	0.0	7.2	12.2	23.5	11.3	7.7	
C5	15.000	2.5	0.0	0.0	7.5	13.2	23.5	11.3	7.7	
C5	25.000	3.7	0.0	0.0	8.0	14.4	23.5	11.3	7.7	
C5	35.000	4.4	0.0	0.0	8.6	15.2	23.5	11.3	7.7	Leakage from C4 into C5
C5	45.000	5.0	0.0	0.0	9.3	15.2	23.5	11.3	7.7	Leakage from C4 into C5
C5	55.000	5.3	0.5	0.0	10.0	15.2	23.5	11.3	7.7	Fill and spill out of C5 at 1.01pm
C5	65.000	5.6	1.8	0.0	11.1	15.2	23.5	11.3	7.7	Heavy leakage from C5
C5	75.000	5.7	2.4	0.0	11.6	15.2	23.5	11.3	7.7	
C5	85.000	6.0	3.0	0.0	12.2	15.2	23.5	11.3	7.7	

BASIN	ELAPSED TIME, t (min)	SURFACE FLOW			WATER LEVEL IN BASIN (STAFF READING) (cm)	AVERAGE DEPTH IN ADJACENT PLOT OR DRAIN				REMARKS
		AT INFLOW WEIR Yo1- Zo(cm)	AT OUTFLOW WEIR Yo1- Zo(cm)	Rainfall (mm)		Side A	Side B	Side C	Side D	
C1	0.000	0.0	0.0	0.0	15.2	16.0	17.3	11.5	2.0	Inflow into c1 at 7.50am
C1	10.000	8.8	0.0	0.0	16.8	16.0	17.3	11.5	2.0	Fill and spill into C2 at 8.08am
C1	20.000	8.9	1.3	0.0	18.3	16.0	17.3	11.5	2.0	
C1	30.000	7.4	2.7	0.0	19.7	16.0	17.3	12.1	2.0	
C1	40.000	7.8	3.7	0.0	20.7	16.0	17.3	12.6	2.0	
C1	50.000	7.8	4.4	0.0	21.5	16.0	17.3	13.3	2.0	
C1	60.000	7.9	5.0	0.0	22.1	16.0	17.3	14.3	2.0	
C1	70.000	7.8	5.3	0.0	22.5	16.0	17.3	15.2	2.0	
C1	80.000	8.3	5.6	0.0	22.9	16.0	17.3	15.8	2.0	
C1	90.000	7.9	5.7	0.0	23.1	16.0	17.3	16.8	2.0	
C2	0.000	0.0	0.0	0.0	12.0	17.7	13.7	13.7	10.3	Spill into C2 at 8.08am
C2	10.000	2.3	0.0	0.5	12.4	19.2	13.7	13.7	10.3	
C2	20.000	3.5	0.0	1.5	12.9	20.4	13.7	13.7	10.3	
C2	30.000	4.7	0.0	1.8	13.9	21.7	13.7	13.7	10.3	Fill and spill into C3 at 8.45am
C2	40.000	5.3	1.1	2.2	14.5	22.3	13.7	13.7	10.3	
C2	50.000	5.9	2.2	2.4	15.5	22.9	13.7	13.7	10.3	
C2	60.000	6.3	2.9	2.7	16.5	23.4	13.7	14.7	10.3	
C2	70.000	6.6	3.7	3.0	17.3	23.4	13.7	15.6	10.3	
C2	80.000	6.3	4.6	3.5	18.0	23.4	13.7	16.2	10.3	
C2	90.000	6.2	4.8	4.0	18.4	23.4	13.7	16.9	10.3	
C3	0.000	0.0	0.0	0.0	12.5	14.4	11.5	4.5	2.7	Fill and spill into C3 at 8.45am
C3	25.000	2.0	0.0	0.0	12.9	15.5	11.5	4.5	2.7	
C3	35.000	2.4	0.0	0.0	13.2	16.1	11.5	4.5	2.7	
C3	45.000	2.9	0.0	0.0	13.8	16.5	11.5	4.5	2.7	
C3	55.000	3.3	0.0	0.0	14.4	17.0	11.5	4.5	2.7	Fill and spill into C4 at 9.50am
C3	65.000	3.7	0.0	0.0	15.0	17.4	11.5	4.5	2.7	
C3	75.000	3.9	1.1	0.0	15.4	17.7	11.5	4.5	2.7	
C3	85.000	4.7	1.6	0.0	16.0	17.7	11.5	4.9	2.7	
C3	95.000	4.9	2.3	0.0	16.8	17.7	11.5	5.2	2.7	
C3	105.000	5.3	2.8	0.0	17.5	17.7	11.5	5.7	2.7	
C3	115.000	5.3	3.5	0.0	18.2	17.7	11.5	6.6	2.7	
C3	125.000	5.4	3.4	0.0	18.7	17.7	11.5	7.6	2.7	
C4	0.000	0.0	0.0	0.0	8.5	15.6	22.3	8.6	6.7	Spill into C4 at 9.50am
C4	20.000	1.8	0.0	0.5	8.8	16.9	22.3	8.6	6.7	
C4	30.000	2.3	0.0	0.7	9.2	17.6	22.3	8.6	6.7	
C4	40.000	2.5	0.0	1.0	9.6	18.1	22.3	8.6	6.7	
C4	50.000	3.0	0.0	1.1	10.1	18.5	22.3	8.6	6.7	
C4	60.000	4.1	0.0	1.1	10.8	18.9	22.3	8.6	6.7	Fill and spill into C5 at 10.55am
C4	70.000	4.4	1.1	1.5	11.8	19.2	22.3	8.6	6.7	Leakage out of C3 into C4
C4	80.000	4.1	2.2	1.8	12.8	19.6	22.3	9.0	6.7	
C4	90.000	4.3	2.5	2.3	13.2	19.6	22.3	9.3	6.7	
C4	100.000	4.3	2.8	2.5	13.6	19.6	22.3	9.6	6.7	
C4	110.000	4.3	3.3	3.0	14.0	19.6	22.3	10.0	6.7	Leakage from C3 into C4
C5	0.000	0.0	0.0	0.0	8.6	11.3	23.5	11.3	8.0	Spill into C5 at 10.55am
C5	15.000	2.2	0.0	0.3	9.0	12.8	23.5	11.3	8.0	
C5	25.000	2.5	0.0	0.8	9.3	13.2	23.5	11.3	8.0	
C5	35.000	2.8	0.0	1.0	9.6	13.6	23.5	11.3	8.0	Fill and spill out of C5 at 11.30am
C5	45.000	3.3	1.0	1.5	10.0	14.0	23.5	11.3	8.0	
C5	55.000	3.3	1.3	2.5	10.4	14.0	23.5	11.3	8.0	
C5	65.000	3.7	1.5	3.0	10.8	14.0	23.5	11.3	8.0	
C5	75.000	4.1	2.2	3.7	11.3	14.0	23.5	11.3	8.0	Leakage from C4 into C5
C5	85.000	4.2	2.3	4.1	11.7	14.0	23.5	11.3	8.0	

APPENDIX B

Processed and observed basin water storage

Appendix B-1 Processed and observed basin water storage for Field A

BASIN	TIME(min) t1	TIME(min) t2	OBSERVED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	NET INFLOW VOLUME IN TIME t (m^3) (Eqn 3.4)	CALCULATED CHANGE IN TIME (Eqn 3.5) Using calculated h	OBSERVED TIME TO FILL(TTF) (min)
A1	0.000	10.000	0.005	0.005	1.408	10.000	40.000
A1	10.000	20.000	0.019	0.014	3.755	10.000	
A1	20.000	30.000	0.014	0.017	4.571	10.000	
A1	30.000	40.000	0.014	0.018	4.864	10.000	
A1	40.000	50.000	0.015	0.018	4.940	10.000	
A1	50.000	60.000	0.014	0.015	4.271	10.000	
A1	60.000	70.000	0.009	0.012	3.358	10.000	
A1	70.000	80.000	0.007	0.009	2.526	10.000	
A1	80.000	90.000	0.003	0.007	1.932	10.000	
A2	0.000	10.000	0.002	0.001	0.301	10.000	63.000
A2	10.000	20.000	0.005	0.004	1.752	10.000	
A2	20.000	30.000	0.006	0.007	3.066	10.000	
A2	30.000	40.000	0.010	0.009	3.898	10.000	
A2	40.000	50.000	0.010	0.010	4.410	10.000	
A2	50.000	60.000	0.009	0.011	4.560	10.000	
A2	60.000	70.000	0.009	0.011	4.758	10.000	
A2	70.000	80.000	0.009	0.010	4.524	10.000	
A2	80.000	90.000	0.009	0.009	3.866	10.000	
A2	90.000	100.000	0.008	0.007	3.062	10.000	
A2	100.000	110.000	0.005	0.005	2.008	10.000	
A2	110.000	120.000	0.002	0.003	1.363	10.000	
A3	0.000	12.000	0.005	0.002	0.520	12.000	49.000
A3	12.000	22.000	0.009	0.006	1.900	10.000	
A3	22.000	32.000	0.012	0.011	3.483	10.000	
A3	32.000	42.000	0.013	0.014	4.496	10.000	
A3	42.000	52.000	0.011	0.016	4.954	10.000	
A3	52.000	62.000	0.008	0.013	3.999	10.000	
A3	62.000	72.000	0.009	0.010	3.012	10.000	
A3	72.000	82.000	0.009	0.008	2.504	10.000	
A3	82.000	92.000	0.008	0.004	1.136	10.000	
A4	0.000	20.000	0.008	0.005	1.595	20.000	45.000
A4	20.000	30.000	0.009	0.008	2.575	10.000	
A4	30.000	40.000	0.009	0.011	3.652	10.000	
A4	40.000	50.000	0.009	0.013	4.284	10.000	
A4	50.000	60.000	0.008	0.012	4.028	10.000	
A4	60.000	70.000	0.009	0.010	3.504	10.000	
A4	70.000	80.000	0.007	0.010	3.379	10.000	
A4	80.000	90.000	0.006	0.008	2.648	10.000	
A4	90.000	100.000	0.005	0.006	2.196	10.000	
A4	100.000	110.000	0.005	0.006	2.031	10.000	
A5	0.000	20.000	0.007	0.004	1.426	20.000	50.000
A5	20.000	30.000	0.006	0.006	2.232	10.000	
A5	30.000	40.000	0.008	0.009	3.140	10.000	
A5	40.000	50.000	0.011	0.011	3.782	10.000	
A5	50.000	60.000	0.005	0.010	3.363	10.000	

BASIN	TIME(min)		OBSERVED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	NET INFLOW VOLUME IN TIME t (m^3) (Eqn 3.4)	CALCULATED CHANGE IN TIME (Eqn 3.5) Using calculated h	OBSERVED TIME TO FILL(TTF) (min)
	t1	t2					
A1	0.000	10.000	0.016	0.014	3.957	10.000	8.000
A1	10.000	20.000	0.014	0.016	4.335	10.000	
A1	20.000	30.000	0.011	0.014	3.737	10.000	
A1	30.000	40.000	0.007	0.010	2.763	10.000	
A1	40.000	50.000	0.005	0.007	1.958	10.000	
A1	50.000	60.000	0.000	0.006	1.633	10.000	
A2	0.000	12.000	0.002	0.001	0.365	12.000	42.000
A2	12.000	22.000	0.005	0.003	1.274	10.000	
A2	22.000	32.000	0.005	0.005	2.248	10.000	
A2	32.000	42.000	0.007	0.007	3.129	10.000	
A2	42.000	52.000	0.007	0.008	3.285	10.000	
A2	52.000	62.000	0.005	0.006	2.793	10.000	
A2	62.000	72.000	0.007	0.006	2.414	10.000	
A2	72.000	82.000	0.006	0.005	2.237	10.000	
A2	82.000	92.000	0.004	0.005	2.091	10.000	
A2	92.000	102.000	0.003	0.003	1.504	10.000	
A3	0.000	10.000	0.004	0.001	0.179	10.000	45.000
A3	10.000	20.000	0.003	0.003	0.883	10.000	
A3	20.000	30.000	0.004	0.005	1.484	10.000	
A3	30.000	40.000	0.008	0.007	2.107	10.000	
A3	40.000	50.000	0.007	0.009	2.719	10.000	
A3	50.000	60.000	0.008	0.009	2.726	10.000	
A3	60.000	70.000	0.005	0.007	2.059	10.000	
A3	70.000	80.000	0.006	0.006	1.879	10.000	
A3	80.000	90.000	0.006	0.005	1.637	10.000	
A3	90.000	100.000	0.005	0.002	0.767	10.000	
A4	0.000	20.000	0.006	0.005	1.581	20.000	40.000
A4	20.000	30.000	0.007	0.007	2.255	10.000	
A4	30.000	40.000	0.008	0.009	3.080	10.000	
A4	40.000	50.000	0.010	0.010	3.581	10.000	
A4	50.000	60.000	0.010	0.010	3.558	10.000	
A4	60.000	70.000	0.004	0.010	3.423	10.000	
A4	70.000	80.000	0.003	0.009	3.079	10.000	
A4	80.000	90.000	0.007	0.008	2.885	10.000	
A5	0.000	15.000	0.007	0.004	1.249	15.000	43.000
A5	15.000	25.000	0.005	0.007	2.285	10.000	
A5	25.000	35.000	0.010	0.009	3.295	10.000	
A5	35.000	45.000	0.012	0.011	3.843	10.000	
A5	45.000	55.000	0.010	0.010	3.403	10.000	

Appendix B-2 Processed and observed basin water storage for Field B

BASIN	TIME(min) t1	TIME(min) t2	OBSERVED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	NET INFLOW VOLUME IN TIME t (m^3) (Eqn 3.4)	CALCULATED CHANGE IN TIME(Eqn 3.5) Using calculated h(min)	OBSERVED TIME TAKEN TO FILL(TTF) (min)
B1	0.000	10.000	0.012	0.006	2.294	10.000	20.000
B1	10.000	20.000	0.015	0.013	5.273	10.000	
B1	20.000	30.000	0.012	0.012	4.702	10.000	
B1	30.000	40.000	0.012	0.008	3.185	10.000	
B1	40.000	50.000	0.007	0.006	2.318	10.000	
B1	50.000	60.000	0.004	0.004	1.625	10.000	
B1	60.000	70.000	0.004	0.003	1.055	10.000	
B1	70.000	80.000	0.003	0.002	0.683	10.000	
B1	80.000	90.000	0.002	0.001	0.381	10.000	
B2	0.000	10.000	0.007	0.003	0.925	10.000	35.000
B2	10.000	20.000	0.010	0.009	2.803	10.000	
B2	20.000	30.000	0.011	0.011	3.744	10.000	
B2	30.000	40.000	0.010	0.012	3.997	10.000	
B2	40.000	50.000	0.011	0.011	3.508	10.000	
B2	50.000	60.000	0.009	0.008	2.729	10.000	
B2	60.000	70.000	0.008	0.006	2.126	10.000	
B2	70.000	80.000	0.004	0.005	1.661	10.000	
B2	80.000	90.000	0.003	0.003	1.156	10.000	
B2	90.000	100.000	0.003	0.002	0.811	10.000	
B3	0.000	15.000	0.008	0.003	0.993	15.000	52.000
B3	15.000	25.000	0.009	0.006	2.252	10.000	
B3	25.000	35.000	0.010	0.009	3.230	10.000	
B3	35.000	45.000	0.008	0.011	4.005	10.000	
B3	45.000	55.000	0.011	0.012	4.399	10.000	
B3	55.000	65.000	0.009	0.011	4.170	10.000	
B3	65.000	75.000	0.006	0.010	3.810	10.000	
B3	75.000	85.000	0.009	0.009	3.342	10.000	
B3	85.000	95.000	0.006	0.008	3.000	10.000	
B3	95.000	105.000	0.006	0.007	2.537	10.000	
B3	105.000	115.000	0.004	0.006	2.173	10.000	
B3	115.000	125.000	0.004	0.005	1.814	10.000	
B3	125.000	135.000	0.002	0.004	1.419	10.000	
B4	0.000	23.000	0.005	0.002	0.933	23.000	93.000
B4	23.000	33.000	0.008	0.003	1.794	10.000	
B4	33.000	43.000	0.006	0.005	2.586	10.000	
B4	43.000	53.000	0.008	0.006	3.231	10.000	
B4	53.000	63.000	0.009	0.007	3.782	10.000	
B4	63.000	73.000	0.009	0.008	4.232	10.000	
B4	73.000	83.000	0.009	0.008	4.628	10.000	
B4	83.000	93.000	0.005	0.009	4.762	10.000	
B4	93.000	103.000	0.008	0.007	3.971	10.000	
B4	103.000	113.000	0.008	0.005	3.018	10.000	
B4	113.000	123.000	0.005	0.004	2.460	10.000	
B4	123.000	133.000	0.006	0.003	1.596	10.000	
B4	133.000	143.000	0.004	0.002	0.982	10.000	
B5	0.000	10.000	0.004	0.001	0.432	10.000	40.000
B5	10.000	20.000	0.004	0.004	1.730	10.000	
B5	20.000	30.000	0.004	0.006	2.424	10.000	
B5	30.000	40.000	0.008	0.007	3.148	10.000	
B5	40.000	50.000	0.007	0.008	3.549	10.000	
B5	50.000	60.000	0.006	0.008	3.490	10.000	
B5	60.000	70.000	0.008	0.008	3.241	10.000	

BASIN	TIME(min) t1	TIME(min) t2	OBSERVED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3 5)	NET INFLOW VOLUME IN TIME t (m^3) (Eqn 3 4)	CALCULATED CHANGE IN TIME(Eqn 3 5) Using calculated h(mm)	OBSERVED TIME TAKEN TO FILL(TTF) (min)
B1	0.000	10.000	0.014	0.008	3.228	10.000	20.000
B1	10.000	20.000	0.018	0.017	6.792	10.000	
B1	20.000	30.000	0.014	0.015	6.008	10.000	
B1	30.000	40.000	0.012	0.012	4.704	10.000	
B1	40.000	50.000	0.008	0.009	3.684	10.000	
B1	50.000	60.000	0.007	0.007	2.924	10.000	
B1	60.000	70.000	0.004	0.007	2.594	10.000	
B1	70.000	80.000	0.003	0.005	2.165	10.000	
B1	80.000	90.000	0.002	0.005	1.807	10.000	
B2	0.000	10.000	0.006	0.003	1.043	10.000	30.000
B2	10.000	20.000	0.012	0.009	3.122	10.000	
B2	20.000	30.000	0.013	0.013	4.299	10.000	
B2	30.000	40.000	0.010	0.013	4.398	10.000	
B2	40.000	50.000	0.010	0.011	3.692	10.000	
B2	50.000	60.000	0.011	0.009	2.863	10.000	
B2	60.000	70.000	0.005	0.006	1.827	10.000	
B2	70.000	80.000	0.001	0.003	0.855	10.000	
B2	80.000	90.000	0.002	0.001	0.332	10.000	
B2	90.000	100.000	0.000	0.000	0.138	10.000	
B2	100.000	110.000	0.000	0.000	0.155	10.000	
B3	0.000	20.000	0.007	0.003	1.210	20.000	60.000
B3	20.000	30.000	0.007	0.006	2.123	10.000	
B3	30.000	40.000	0.009	0.008	3.086	10.000	
B3	40.000	50.000	0.008	0.010	3.689	10.000	
B3	50.000	60.000	0.010	0.010	3.924	10.000	
B3	60.000	70.000	0.010	0.009	3.314	10.000	
B3	70.000	80.000	0.000	0.007	2.503	10.000	
B3	80.000	90.000	0.010	0.006	2.124	10.000	
B3	90.000	100.000	0.004	0.005	1.755	10.000	
B3	100.000	110.000	0.004	0.004	1.412	10.000	
B3	110.000	120.000	0.003	0.004	1.419	10.000	
B4	0.000	20.000	0.005	0.001	0.375	20.000	88.000
B4	20.000	30.000	0.002	0.002	1.019	10.000	
B4	30.000	40.000	0.003	0.003	1.388	10.000	
B4	40.000	50.000	0.005	0.003	1.731	10.000	
B4	50.000	60.000	0.005	0.004	2.042	10.000	
B4	60.000	70.000	0.001	0.004	2.255	10.000	
B4	70.000	80.000	0.007	0.004	2.477	10.000	
B4	80.000	90.000	0.005	0.005	2.498	10.000	
B4	90.000	100.000	0.005	0.004	2.228	10.000	
B4	100.000	110.000	0.004	0.003	1.937	10.000	
B4	110.000	120.000	0.004	0.003	1.554	10.000	
B4	120.000	130.000	0.004	0.002	1.171	10.000	
B4	130.000	140.000	0.006	0.002	0.939	10.000	
B4	140.000	150.000	0.003	0.001	0.669	10.000	
B5	0.000	2.000	0.001	-0.000	-0.019	2.000	67.000
B5	2.000	12.000	0.002	0.001	0.410	10.000	
B5	12.000	22.000	0.002	0.002	0.939	10.000	
B5	22.000	32.000	0.004	0.003	1.443	10.000	
B5	32.000	42.000	0.006	0.005	2.011	10.000	
B5	42.000	52.000	0.006	0.006	2.685	10.000	
B5	52.000	62.000	0.005	0.008	3.278	10.000	
B5	62.000	72.000	0.009	0.008	3.339	10.000	
B5	72.000	82.000	0.006	0.008	3.426	10.000	

Appendix B-3 Processed and observed basin water storage for Field C

BASIN	TIME(min) t1	TIME(min) t2	OBSERVED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	NET INFLOW VOLUME IN TIME t (m^3) (Eqn 3.4)	CALCULATED CHANGE IN TIME(Eqn 3.5) Using calculated h	OBSERVED TIME TAKEN TO FILL(TTF) (min)
C1	0.000	10.000	0.003	0.002	1.016	10.000	25.000
C1	10.000	20.000	0.007	0.007	3.286	10.000	
C1	20.000	30.000	0.010	0.007	3.690	10.000	
C1	30.000	40.000	0.007	0.006	2.891	10.000	
C1	40.000	50.000	0.004	0.004	2.161	10.000	
C1	50.000	60.000	0.005	0.003	1.406	10.000	
C1	60.000	70.000	0.002	0.002	0.793	10.000	
C1	70.000	80.000	0.003	0.002	0.789	10.000	
C1	80.000	90.000	0.002	0.001	0.672	10.000	
C2	0.000	25.000	0.003	-0.001	-0.287	25.000	35.000
C2	25.000	35.000	0.004	0.002	0.878	10.000	
C2	35.000	45.000	0.003	0.002	1.259	10.000	
C2	45.000	55.000	0.005	0.002	1.192	10.000	
C2	55.000	65.000	0.003	0.002	1.039	10.000	
C2	65.000	75.000	0.003	0.002	1.034	10.000	
C2	75.000	85.000	0.002	0.002	1.052	10.000	
C2	85.000	95.000	0.004	0.002	0.880	10.000	
C2	95.000	105.000	0.002	0.001	0.693	10.000	
C2	105.000	115.000	0.000	0.001	0.570	10.000	
C2	115.000	125.000	0.004	0.001	0.481	10.000	
C2	125.000	135.000	0.000	0.000	0.196	10.000	
C3	0.000	30.000	0.003	-0.001	-0.311	30.000	80.000
C3	30.000	40.000	0.001	0.001	0.484	10.000	
C3	40.000	50.000	0.006	0.002	0.707	10.000	
C3	50.000	60.000	0.000	0.002	0.941	10.000	
C3	60.000	70.000	0.004	0.003	1.190	10.000	
C3	70.000	80.000	0.005	0.003	1.503	10.000	
C3	80.000	90.000	0.003	0.004	1.578	10.000	
C3	90.000	100.000	0.004	0.003	1.508	10.000	
C3	100.000	110.000	0.003	0.004	1.557	10.000	
C3	110.000	120.000	0.004	0.004	1.576	10.000	
C3	120.000	130.000	0.004	0.003	1.366	10.000	
C3	130.000	140.000	0.004	0.003	1.244	10.000	
C3	140.000	150.000	0.004	0.002	1.084	10.000	
C3	150.000	160.000	0.003	0.002	0.852	10.000	
C4	0.000	30.000	0.002	-0.000	-0.103	30.000	110.000
C4	30.000	40.000	0.002	0.002	0.545	10.000	
C4	40.000	50.000	0.003	0.003	0.942	10.000	
C4	50.000	60.000	0.003	0.004	1.254	10.000	
C4	60.000	70.000	0.005	0.005	1.542	10.000	
C4	70.000	80.000	0.003	0.005	1.774	10.000	
C4	80.000	90.000	0.005	0.006	1.897	10.000	
C4	90.000	100.000	0.003	0.006	2.019	10.000	
C4	100.000	110.000	0.007	0.006	2.146	10.000	
C4	110.000	120.000	0.006	0.006	1.959	10.000	
C4	120.000	130.000	0.005	0.005	1.711	10.000	
C4	130.000	140.000	0.005	0.005	1.565	10.000	
C4	140.000	150.000	0.003	0.003	1.147	10.000	
C4	150.000	160.000	0.004	0.002	0.776	10.000	
C4	160.000	170.000	0.002	0.001	0.369	10.000	
C4	170.000	180.000	0.002	0.000	0.078	10.000	
C4	180.000	190.000	0.001	-0.000	-0.110	10.000	
C4	190.000	200.000	0.001	-0.001	-0.383	10.000	
C5	0.000	5.000	0.000	-0.000	-0.100	5.000	51.000
C5	5.000	15.000	0.003	0.001	0.615	10.000	
C5	15.000	25.000	0.005	0.003	1.625	10.000	
C5	25.000	35.000	0.006	0.006	2.712	10.000	
C5	35.000	45.000	0.007	0.008	3.549	10.000	
C5	45.000	55.000	0.007	0.009	4.076	10.000	
C5	55.000	65.000	0.011	0.008	3.922	10.000	
C5	65.000	75.000	0.005	0.007	3.402	10.000	
C5	75.000	85.000	0.006	0.006	3.030	10.000	

BASIN	TIME(min) t1	t2	OBSERVED CHANGE IN DEPTH h(m)	CALCULATED CHANGE IN DEPTH h(m) (Eqn 3.3)	NET INFLOW VOLUME IN TIME t (m^3) (Eqn 3.4)	CALCULATED CHANGE IN TIME(Eqn 3.5) Using calculated h	OBSERVED TIME TAKEN TO FILL(TTF) (min)
C1	0.000	10.000	0.016	0.007	3.549	10.000	18.000
C1	10.000	20.000	0.015	0.015	7.548	10.000	
C1	20.000	30.000	0.014	0.011	5.637	10.000	
C1	30.000	40.000	0.010	0.007	3.668	10.000	
C1	40.000	50.000	0.008	0.006	2.920	10.000	
C1	50.000	60.000	0.006	0.004	2.127	10.000	
C1	60.000	70.000	0.004	0.003	1.497	10.000	
C1	70.000	80.000	0.004	0.003	1.335	10.000	
C1	80.000	90.000	0.002	0.002	1.105	10.000	
C2	0.000	10.000	0.004	0.001	0.281	10.000	37.000
C2	10.000	20.000	0.005	0.004	1.926	10.000	
C2	20.000	30.000	0.010	0.006	2.988	10.000	
C2	30.000	40.000	0.006	0.008	3.998	10.000	
C2	40.000	50.000	0.010	0.008	4.095	10.000	
C2	50.000	60.000	0.010	0.009	4.125	10.000	
C2	60.000	70.000	0.008	0.008	3.881	10.000	
C2	70.000	80.000	0.007	0.006	2.959	10.000	
C2	80.000	90.000	0.004	0.004	1.931	10.000	
C3	0.000	25.000	0.004	-0.000	-0.044	25.000	65.000
C3	25.000	35.000	0.003	0.002	0.755	10.000	
C3	35.000	45.000	0.006	0.003	1.194	10.000	
C3	45.000	55.000	0.006	0.004	1.667	10.000	
C3	55.000	65.000	0.006	0.005	2.120	10.000	
C3	65.000	75.000	0.004	0.005	2.198	10.000	
C3	75.000	85.000	0.006	0.005	2.351	10.000	
C3	85.000	95.000	0.008	0.006	2.444	10.000	
C3	95.000	105.000	0.007	0.005	2.223	10.000	
C3	105.000	115.000	0.007	0.004	1.770	10.000	
C3	115.000	125.000	0.005	0.003	1.462	10.000	
C4	0.000	20.000	0.003	0.001	0.379	20.000	65.000
C4	20.000	30.000	0.004	0.003	1.010	10.000	
C4	30.000	40.000	0.004	0.004	1.413	10.000	
C4	40.000	50.000	0.005	0.005	1.755	10.000	
C4	50.000	60.000	0.007	0.008	2.765	10.000	
C4	60.000	70.000	0.010	0.011	3.632	10.000	
C4	70.000	80.000	0.010	0.009	2.925	10.000	
C4	80.000	90.000	0.004	0.007	2.342	10.000	
C4	90.000	100.000	0.004	0.006	2.094	10.000	
C4	100.000	110.000	0.004	0.005	1.776	10.000	
C5	0.000	15.000	0.004	0.000	0.166	15.000	35.000
C5	15.000	25.000	0.003	0.002	1.066	10.000	
C5	25.000	35.000	0.003	0.003	1.218	10.000	
C5	35.000	45.000	0.004	0.003	1.539	10.000	
C5	45.000	55.000	0.004	0.004	1.688	10.000	
C5	55.000	65.000	0.004	0.003	1.482	10.000	
C5	65.000	75.000	0.005	0.003	1.623	10.000	
C5	75.000	85.000	0.004	0.003	1.392	10.000	

APPENDIX C

Processed basin inflows and outflows

Appendix C-1 Processed basin inflows and outflows for Field A

BASIN	TIME(min)		INFLOW		OUTFLOW							
	t1	t2	Surface inflow (m^3/s) (Eqn 2.38)	Rainfall amount after time, Dt(mm)	Surface outflow (m^3/s) (Eqn 2.38)	ETc (mm/min)	SEEPAGE(m^3/s) (Eqn 3.13) Side A	Side B	Side C	Side D	Net seepage across bunds, HS(m^3)	Percolation losses,VS (m^3)
A1	0.000	10.000	0.0053	0.0	0.0000	0.0028	-6.040E-08	5.859E-09	3.700E-08	1.421E-08	-2.000E-06	0.186
A1	10.000	20.000	0.0078	0.0	0.0000	0.0028	-7.590E-08	1.473E-08	7.890E-08	2.680E-08	2.672E-05	0.186
A1	20.000	30.000	0.0081	0.0	0.0000	0.0028	-7.685E-08	2.394E-08	1.191E-07	3.797E-08	6.245E-05	0.186
A1	30.000	40.000	0.0088	0.0	0.0000	0.0028	-6.892E-08	3.512E-08	1.673E-07	5.075E-08	1.105E-04	0.186
A1	40.000	50.000	0.0103	0.0	0.0020	0.0028	-5.057E-08	4.963E-08	2.239E-07	6.621E-08	1.735E-04	0.186
A1	50.000	60.000	0.0114	0.0	0.0048	0.0028	-2.424E-08	6.543E-08	2.771E-07	8.231E-08	2.404E-04	0.186
A1	60.000	70.000	0.0117	0.0	0.0064	0.0028	-2.628E-09	7.673E-08	3.074E-07	9.351E-08	2.850E-04	0.186
A1	70.000	80.000	0.0114	0.0	0.0076	0.0028	1.672E-08	8.615E-08	3.185E-07	1.027E-07	3.144E-04	0.186
A1	80.000	90.000	0.0114	0.0	0.0081	0.0028	2.569E-08	9.035E-08	3.085E-07	1.067E-07	3.187E-04	0.186
A2	0.000	10.000	0.0020	0.0	0.0000	0.0023	-1.059E-07	1.912E-08	1.338E-07	-5.535E-09	2.487E-05	0.292
A2	10.000	20.000	0.0048	0.0	0.0000	0.0023	-1.269E-07	2.296E-08	1.541E-07	-3.082E-09	2.823E-05	0.292
A2	20.000	30.000	0.0064	0.0	0.0000	0.0028	-1.458E-07	2.801E-08	1.798E-07	6.918E-10	3.762E-05	0.292
A2	30.000	40.000	0.0076	0.0	0.0000	0.0028	-1.683E-07	3.751E-08	2.259E-07	8.994E-09	6.244E-05	0.292
A2	40.000	50.000	0.0081	0.0	0.0000	0.0028	-1.836E-07	4.837E-08	2.762E-07	1.981E-08	9.645E-05	0.292
A2	50.000	60.000	0.0081	0.0	0.0000	0.0028	-1.903E-07	5.931E-08	3.249E-07	3.170E-08	1.354E-04	0.292
A2	60.000	70.000	0.0094	0.0	0.0006	0.0028	-1.938E-07	7.135E-08	3.771E-07	4.562E-08	1.801E-04	0.292
A2	70.000	80.000	0.0097	0.0	0.0023	0.0028	-1.940E-07	8.449E-08	4.220E-07	6.159E-08	2.245E-04	0.292
A2	80.000	90.000	0.0108	0.0	0.0042	0.0028	-1.909E-07	9.873E-08	4.592E-07	7.959E-08	2.680E-04	0.292
A2	90.000	100.000	0.0108	0.0	0.0061	0.0028	-1.854E-07	1.123E-07	4.825E-07	9.730E-08	3.040E-04	0.292
A2	100.000	110.000	0.0108	0.0	0.0077	0.0028	-1.806E-07	1.212E-07	4.848E-07	1.092E-07	3.208E-04	0.292
A2	110.000	120.000	0.0108	0.0	0.0083	0.0028	-1.784E-07	1.249E-07	4.718E-07	1.141E-07	3.194E-04	0.292
A3	0.000	12.000	0.0022	0.0	0.0000	0.0011	-1.802E-07	3.510E-08	1.900E-07	-2.107E-08	1.714E-05	0.255
A3	12.000	22.000	0.0049	0.0	0.0000	0.0011	-2.193E-07	4.488E-08	2.389E-07	-2.072E-08	2.628E-05	0.212
A3	22.000	32.000	0.0074	0.0	0.0000	0.0011	-2.635E-07	5.931E-08	3.095E-07	-1.779E-08	5.245E-05	0.212
A3	32.000	42.000	0.0083	0.0	0.0000	0.0011	-3.066E-07	7.671E-08	3.927E-07	-1.144E-08	9.084E-05	0.212
A3	42.000	52.000	0.0094	0.0	0.0005	0.0011	-3.388E-07	9.287E-08	4.687E-07	-3.480E-09	1.316E-04	0.212
A3	52.000	62.000	0.0097	0.0	0.0046	0.0011	-3.532E-07	1.055E-07	5.088E-07	3.793E-09	1.589E-04	0.212
A3	62.000	72.000	0.0119	0.0	0.0062	0.0011	-3.662E-07	1.205E-07	5.582E-07	1.347E-08	1.956E-04	0.212
A3	72.000	82.000	0.0125	0.0	0.0091	0.0011	-3.759E-07	1.363E-07	6.008E-07	2.473E-08	2.316E-04	0.212
A3	82.000	92.000	0.0128	0.0	0.0117	0.0011	-3.817E-07	1.512E-07	6.322E-07	3.607E-08	2.627E-04	0.212
A4	0.000	20.000	0.0034	0.0	0.0000	0.0019	-2.978E-07	8.793E-08	2.432E-07	-4.420E-08	-1.304E-05	0.461
A4	20.000	30.000	0.0059	0.0	0.0000	0.0019	-3.448E-07	1.059E-07	2.938E-07	-4.583E-08	5.484E-06	0.231
A4	30.000	40.000	0.0070	0.0	0.0000	0.0019	-3.887E-07	1.251E-07	3.478E-07	-4.599E-08	2.294E-05	0.231
A4	40.000	50.000	0.0085	0.0	0.0005	0.0019	-4.265E-07	1.453E-07	4.051E-07	-4.469E-08	4.759E-05	0.231
A4	50.000	60.000	0.0088	0.0	0.0026	0.0019	-4.574E-07	1.643E-07	4.494E-07	-4.231E-08	6.840E-05	0.231
A4	60.000	70.000	0.0101	0.0	0.0038	0.0019	-4.830E-07	1.867E-07	4.975E-07	-3.825E-08	9.779E-05	0.231
A4	70.000	80.000	0.0111	0.0	0.0053	0.0019	-5.005E-07	2.049E-07	5.320E-07	-3.409E-08	1.214E-04	0.231
A4	80.000	90.000	0.0111	0.0	0.0072	0.0019	-5.139E-07	2.210E-07	5.545E-07	-2.981E-08	1.391E-04	0.231
A4	90.000	100.000	0.0128	0.0	0.0085	0.0019	-5.239E-07	2.348E-07	5.641E-07	-2.575E-08	1.496E-04	0.231
A4	100.000	110.000	0.0121	0.0	0.0088	0.0019	-5.329E-07	2.490E-07	5.776E-07	-2.124E-08	1.635E-04	0.231
A5	0.000	20.000	0.0032	0.0	0.0000	0.0028	-2.112E-07	2.547E-08	1.927E-08	-2.984E-08	-2.356E-04	0.469
A5	20.000	30.000	0.0051	0.0	0.0000	0.0028	-2.404E-07	3.048E-08	2.692E-08	-3.137E-08	-1.286E-04	0.235
A5	30.000	40.000	0.0062	0.0	0.0000	0.0028	-2.828E-07	3.768E-08	3.902E-08	-3.236E-08	-1.431E-04	0.235
A5	40.000	50.000	0.0072	0.0	0.0000	0.0028	-3.300E-07	4.857E-08	5.921E-08	-3.173E-08	-1.524E-04	0.235
A5	50.000	60.000	0.0077	0.0	0.0029	0.0028	-3.473E-07	5.390E-08	6.975E-08	-3.069E-08	-1.526E-04	0.235

BASIN	TIME(min)		INFLOW		OUTFLOW							
			Surface inflow (m^3/s) (Eqn 2.38)	Rainfall amount after time, Δt(min)	Surface outflow (m^3/s) (Eqn 2.38)	ETc (mm/min)	SEEPAGE(m^3/s) (Eqn 3.13)				Net seapage across bunds, HS(m^3)	Percolation losses, VS (m^3)
	t1	t2					Side A	Side B	Side C	Side D		
A1	0.000	10.000	0.0081	0.0	0.0000	0.0022	-9.606E-08	2.579E-08	1.295E-07	4.288E-08	6.126E-05	0.186
A1	10.000	20.000	0.0090	0.0	0.0020	0.0022	-8.306E-08	3.762E-08	1.750E-07	5.577E-08	1.112E-04	0.186
A1	20.000	30.000	0.0093	0.0	0.0032	0.0022	-6.661E-08	4.845E-08	2.082E-07	6.702E-08	1.542E-04	0.186
A1	30.000	40.000	0.0090	0.0	0.0053	0.0022	-5.329E-08	5.603E-08	2.266E-07	7.470E-08	1.824E-04	0.186
A1	40.000	50.000	0.0096	0.0	0.0062	0.0022	-4.241E-08	6.179E-08	2.320E-07	8.043E-08	1.991E-04	0.186
A1	50.000	60.000	0.0098	0.0	0.0071	0.0022	-4.241E-08	6.179E-08	2.154E-07	8.043E-08	1.891E-04	0.186
A2	0.000	12.000	0.0020	0.0	0.0000	0.0022	-1.340E-07	3.422E-08	2.383E-07	-1.811E-08	8.669E-05	0.351
A2	12.000	22.000	0.0032	0.0	0.0000	0.0022	-1.527E-07	3.921E-08	2.628E-07	-1.453E-08	8.090E-05	0.292
A2	22.000	32.000	0.0053	0.0	0.0000	0.0022	-1.659E-07	4.454E-08	2.894E-07	-1.031E-08	9.402E-05	0.292
A2	32.000	42.000	0.0062	0.0	0.0000	0.0022	-1.765E-07	5.257E-08	3.259E-07	-3.359E-09	1.192E-04	0.292
A2	42.000	52.000	0.0071	0.0	0.0013	0.0022	-1.767E-07	6.127E-08	3.575E-07	4.830E-09	1.481E-04	0.292
A2	52.000	62.000	0.0069	0.0	0.0023	0.0022	-1.757E-07	6.789E-08	3.803E-07	1.143E-08	1.703E-04	0.292
A2	62.000	72.000	0.0079	0.0	0.0033	0.0022	-1.726E-07	7.773E-08	4.133E-07	2.174E-08	2.041E-04	0.292
A2	72.000	82.000	0.0084	0.0	0.0044	0.0022	-1.684E-07	8.669E-08	4.316E-07	3.155E-08	2.289E-04	0.292
A2	82.000	92.000	0.0094	0.0	0.0054	0.0022	-1.647E-07	9.293E-08	4.394E-07	3.859E-08	2.437E-04	0.292
A2	92.000	102.000	0.0086	0.0	0.0066	0.0022	-1.616E-07	9.776E-08	4.380E-07	4.414E-08	2.510E-04	0.292
A3	0.000	10.000	0.0013	0.0	0.0000	0.0022	-2.085E-07	5.446E-08	2.489E-07	-1.752E-08	4.640E-05	0.212
A3	10.000	20.000	0.0023	0.0	0.0000	0.0022	-2.221E-07	5.834E-08	2.660E-07	-1.673E-08	5.128E-05	0.212
A3	20.000	30.000	0.0033	0.0	0.0000	0.0022	-2.411E-07	6.368E-08	2.893E-07	-1.540E-08	5.789E-05	0.212
A3	30.000	40.000	0.0044	0.0	0.0000	0.0022	-2.688E-07	7.486E-08	3.380E-07	-1.180E-08	7.938E-05	0.212
A3	40.000	50.000	0.0054	0.0	0.0000	0.0022	-2.904E-07	8.523E-08	3.828E-07	-7.625E-09	1.020E-04	0.212
A3	50.000	60.000	0.0066	0.0	0.0022	0.0022	-3.113E-07	9.773E-08	4.294E-07	-1.681E-09	1.284E-04	0.212
A3	60.000	70.000	0.0064	0.0	0.0032	0.0022	-3.200E-07	1.059E-07	4.562E-07	2.669E-09	1.469E-04	0.212
A3	70.000	80.000	0.0080	0.0	0.0041	0.0022	-3.291E-07	1.161E-07	4.884E-07	8.534E-09	1.703E-04	0.212
A3	80.000	90.000	0.0083	0.0	0.0059	0.0022	-3.367E-07	1.266E-07	5.164E-07	1.510E-08	1.929E-04	0.212
A3	90.000	100.000	0.0083	0.0	0.0073	0.0022	-3.418E-07	1.357E-07	5.346E-07	2.111E-08	2.098E-04	0.212
A4	0.000	20.000	0.0034	0.0	0.0000	0.0038	-3.069E-07	1.012E-07	2.722E-07	-5.479E-08	1.406E-05	0.461
A4	20.000	30.000	0.0049	0.0	0.0000	0.0038	-3.372E-07	1.160E-07	3.129E-07	-5.662E-08	2.104E-05	0.231
A4	30.000	40.000	0.0062	0.0	0.0000	0.0038	-3.796E-07	1.338E-07	3.618E-07	-5.763E-08	3.505E-05	0.231
A4	40.000	50.000	0.0076	0.0	0.0011	0.0038	-4.160E-07	1.572E-07	4.268E-07	-5.727E-08	6.639E-05	0.231
A4	50.000	60.000	0.0091	0.0	0.0030	0.0038	-4.618E-07	1.820E-07	4.858E-07	-5.510E-08	9.054E-05	0.231
A4	60.000	70.000	0.0107	0.0	0.0046	0.0038	-4.723E-07	1.923E-07	5.038E-07	-5.373E-08	1.020E-04	0.231
A4	70.000	80.000	0.0107	0.0	0.0057	0.0038	-4.798E-07	2.002E-07	5.123E-07	-5.252E-08	1.081E-04	0.231
A4	80.000	90.000	0.0124	0.0	0.0070	0.0038	-4.957E-07	2.190E-07	5.285E-07	-4.904E-08	1.217E-04	0.231
A5	0.000	15.000	0.0036	0.0	0.0000	0.0022	-2.263E-07	2.665E-08	3.212E-08	-2.046E-08	-1.692E-04	0.352
A5	15.000	25.000	0.0048	0.0	0.0000	0.0022	-2.566E-07	3.080E-08	3.994E-08	-2.036E-08	-1.237E-04	0.235
A5	25.000	35.000	0.0070	0.0	0.0000	0.0022	-3.042E-07	3.980E-08	5.812E-08	-1.875E-08	-1.350E-04	0.235
A5	35.000	45.000	0.0085	0.0	0.0018	0.0022	-3.606E-07	5.186E-08	8.443E-08	-1.432E-08	-1.432E-04	0.235
A5	45.000	55.000	0.0096	0.0	0.0041	0.0022	-3.972E-07	6.295E-08	1.101E-07	-8.544E-09	-1.396E-04	0.235

Appendix C-2 Processed basin inflows and outflows for Field B

BASIN	TIME(min)		INFLOW		OUTFLOW							
	t1	t2	Surface inflow (m^3/s) (Eqn 2.38)	Rainfall amount after time, t(mm)	Surface outflow (m^3/s) (Eqn 2.38)	ETc (mm/min)	SEEPAGE(m^3/s) (Eqn 3.13) Side A	Side B	Side C	Side D	Net seapage across bunds, HS(m^3)	Percolation losses,VS (m^3)
B1	0.000	10.000	8.771E-03	0.0	0.000E+00	0.0030	-4.459E-08	5.760E-08	1.138E-07	5.260E-08	1.077E-04	0.325
B1	10.000	20.000	9.929E-03	0.0	0.000E+00	0.0030	-4.459E-08	8.041E-08	1.621E-07	8.120E-08	1.675E-04	0.325
B1	20.000	30.000	1.089E-02	0.0	4.020E-03	0.0030	-4.015E-08	1.005E-07	1.976E-07	1.083E-07	2.198E-04	0.325
B1	30.000	40.000	1.113E-02	0.0	6.263E-03	0.0030	-3.175E-08	1.222E-07	2.310E-07	1.393E-07	2.764E-04	0.325
B1	40.000	50.000	1.113E-02	0.0	7.157E-03	0.0030	-2.503E-08	1.356E-07	2.436E-07	1.591E-07	3.080E-04	0.325
B1	50.000	60.000	1.113E-02	0.0	8.570E-03	0.0030	-2.058E-08	1.436E-07	2.450E-07	1.710E-07	3.234E-04	0.325
B1	60.000	70.000	1.089E-02	0.0	8.813E-03	0.0030	-1.570E-08	1.517E-07	2.443E-07	1.833E-07	3.381E-04	0.325
B1	70.000	80.000	1.113E-02	0.0	9.811E-03	0.0030	-1.174E-08	1.579E-07	2.420E-07	1.928E-07	3.485E-04	0.325
B1	80.000	90.000	1.113E-02	0.0	1.007E-02	0.0030	-8.973E-09	1.621E-07	2.370E-07	1.992E-07	3.536E-04	0.325
B2	0.000	10.000	4.020E-03	0.0	0.000E+00	0.0030	-1.540E-07	8.869E-08	7.543E-08	-4.237E-09	3.542E-06	0.272
B2	10.000	20.000	6.263E-03	0.0	0.000E+00	0.0030	-1.817E-07	1.084E-07	9.914E-08	1.236E-09	1.629E-05	0.272
B2	20.000	30.000	7.157E-03	0.0	0.000E+00	0.0030	-2.055E-07	1.318E-07	1.289E-07	9.295E-09	3.869E-05	0.272
B2	30.000	40.000	8.570E-03	0.0	1.465E-03	0.0030	-2.230E-07	1.546E-07	1.593E-07	1.848E-08	6.561E-05	0.272
B2	40.000	50.000	8.813E-03	0.0	3.287E-03	0.0030	-2.396E-07	1.812E-07	1.834E-07	3.061E-08	9.340E-05	0.272
B2	50.000	60.000	9.811E-03	0.0	5.300E-03	0.0030	-2.511E-07	2.043E-07	1.996E-07	4.213E-08	1.170E-04	0.272
B2	60.000	70.000	1.007E-02	0.0	6.549E-03	0.0030	-2.588E-07	2.258E-07	2.102E-07	5.357E-08	1.385E-04	0.272
B2	70.000	80.000	1.084E-02	0.0	7.884E-03	0.0030	-2.604E-07	2.369E-07	2.034E-07	5.972E-08	1.474E-04	0.272
B2	80.000	90.000	1.034E-02	0.0	9.009E-03	0.0030	-2.612E-07	2.453E-07	1.985E-07	6.451E-08	1.483E-04	0.272
B2	90.000	100.000	1.111E-02	0.0	9.298E-03	0.0030	-2.618E-07	2.539E-07	1.909E-07	6.946E-08	1.515E-04	0.272
B3	0.000	15.000	3.287E-03	0.0	0.000E+00	0.0030	-1.047E-07	9.747E-08	7.706E-08	3.951E-08	9.842E-05	0.470
B3	15.000	25.000	5.300E-03	0.0	0.000E+00	0.0030	-1.206E-07	1.167E-07	9.933E-08	5.156E-08	8.820E-05	0.313
B3	25.000	35.000	6.549E-03	0.0	0.000E+00	0.0030	-1.359E-07	1.395E-07	1.273E-07	6.683E-08	1.187E-04	0.313
B3	35.000	45.000	7.884E-03	0.0	0.000E+00	0.0030	-1.445E-07	1.588E-07	1.522E-07	8.046E-08	1.482E-04	0.313
B3	45.000	55.000	9.009E-03	0.0	1.147E-03	0.0030	-1.508E-07	1.868E-07	1.900E-07	1.013E-07	1.964E-04	0.313
B3	55.000	65.000	9.298E-03	0.0	2.178E-03	0.0030	-1.548E-07	2.110E-07	2.241E-07	1.200E-07	2.402E-04	0.313
B3	65.000	75.000	9.590E-03	0.0	2.926E-03	0.0030	-1.530E-07	2.278E-07	2.387E-07	1.335E-07	2.682E-04	0.313
B3	75.000	85.000	1.018E-02	0.0	4.626E-03	0.0030	-1.482E-07	2.540E-07	2.599E-07	1.549E-07	3.124E-04	0.313
B3	85.000	95.000	1.109E-02	0.0	5.569E-03	0.0030	-1.436E-07	2.721E-07	2.728E-07	1.701E-07	3.429E-04	0.313
B3	95.000	105.000	1.079E-02	0.0	6.774E-03	0.0030	-1.378E-07	2.907E-07	2.811E-07	1.860E-07	3.720E-04	0.313
B3	105.000	115.000	1.172E-02	0.0	7.405E-03	0.0030	-1.334E-07	3.034E-07	2.778E-07	1.970E-07	3.869E-04	0.313
B3	115.000	125.000	1.109E-02	0.0	8.276E-03	0.0030	-1.284E-07	3.163E-07	2.738E-07	2.083E-07	4.020E-04	0.313
B3	125.000	135.000	1.172E-02	0.0	8.723E-03	0.0030	-1.257E-07	3.229E-07	2.605E-07	2.141E-07	4.030E-04	0.313
B4	0.000	23.000	2.926E-03	0.0	0.000E+00	0.0030	-5.967E-08	1.127E-08	1.645E-08	1.657E-08	-2.122E-05	1.048
B4	23.000	33.000	4.626E-03	0.0	0.000E+00	0.0030	-7.734E-08	1.701E-08	2.661E-08	2.509E-08	-5.172E-06	0.456
B4	33.000	43.000	5.569E-03	0.0	0.000E+00	0.0030	-9.023E-08	2.206E-08	3.582E-08	3.259E-08	1.438E-07	0.456
B4	43.000	53.000	6.774E-03	0.0	0.000E+00	0.0030	-1.057E-07	2.976E-08	5.023E-08	4.405E-08	1.101E-05	0.456
B4	53.000	63.000	7.405E-03	0.0	0.000E+00	0.0030	-1.196E-07	3.976E-08	6.933E-08	5.897E-08	2.905E-05	0.456
B4	63.000	73.000	8.276E-03	0.0	0.000E+00	0.0030	-1.321E-07	5.118E-08	9.151E-08	7.601E-08	5.199E-05	0.456
B4	73.000	83.000	8.723E-03	0.0	0.000E+00	0.0030	-1.403E-07	6.402E-08	1.168E-07	9.518E-08	8.141E-05	0.456
B4	83.000	93.000	8.723E-03	0.0	0.000E+00	0.0030	-1.423E-07	7.177E-08	1.321E-07	1.068E-07	1.010E-04	0.456
B4	93.000	103.000	8.723E-03	0.0	2.637E-03	0.0030	-1.438E-07	8.507E-08	1.518E-07	1.266E-07	1.318E-04	0.456
B4	103.000	113.000	9.875E-03	0.0	4.328E-03	0.0030	-1.432E-07	9.949E-08	1.727E-07	1.482E-07	1.664E-04	0.456
B4	113.000	123.000	9.178E-03	0.0	4.951E-03	0.0030	-1.416E-07	1.091E-07	1.835E-07	1.625E-07	1.881E-04	0.456
B4	123.000	133.000	9.409E-03	0.0	6.742E-03	0.0030	-1.386E-07	1.212E-07	1.901E-07	1.806E-07	2.119E-04	0.456
B4	133.000	143.000	9.641E-03	0.0	7.459E-03	0.0030	-1.359E-07	1.296E-07	1.906E-07	1.932E-07	2.265E-04	0.456
B5	0.000	10.000	2.637E-03	0.0	0.000E+00	0.0030	-1.029E-07	0.000E+00	5.080E-08	-1.905E-08	-4.269E-05	0.347
B5	10.000	20.000	4.328E-03	0.0	0.000E+00	0.0030	-1.146E-07	2.303E-09	5.718E-08	-1.792E-08	-4.380E-05	0.347
B5	20.000	30.000	4.951E-03	0.0	0.000E+00	0.0030	-1.229E-07	4.890E-09	6.394E-08	-1.648E-08	-4.235E-05	0.347
B5	30.000	40.000	6.742E-03	0.0	0.000E+00	0.0030	-1.343E-07	1.091E-08	7.858E-08	-1.273E-08	-3.451E-05	0.347
B5	40.000	50.000	7.459E-03	0.0	1.172E-03	0.0030	-1.417E-07	1.711E-08	9.262E-08	-8.489E-09	-2.427E-05	0.347
B5	50.000	60.000	8.453E-03	0.0	1.909E-03	0.0030	-1.416E-07	2.312E-08	1.056E-07	-4.134E-09	-1.022E-05	0.347
B5	60.000	70.000	8.965E-03	0.0	3.508E-03	0.0030	-1.393E-07	3.212E-08	1.242E-07	2.701E-09	1.180E-05	0.347

BASIN	TIME(min)		INFLOW		OUTFLOW							
	t1	t2	Surface inflow (m^3/s) (Eqn 2.38)	Rainfall amount after time, t(mm)	Surface outflow (m^3/s) (Eqn 2.38)	ETc (mm/min)	SEEPAGE(m^3/s) (Eqn 3.13) Side A	Side B	Side C	Side D	Net seepage across bunds, HS(m^3)	Percolation losses, VS (m^3)
B1	0.000	10.000	1.188E-02	0.0	0.000E+00	0.0026	-5.900E-08	5.685E-08	1.141E-07	4.580E-08	9.465E-05	0.325
B1	10.000	20.000	1.188E-02	0.0	0.000E+00	0.0026	-6.863E-08	8.688E-08	1.778E-07	7.942E-08	1.653E-04	0.325
B1	20.000	30.000	1.188E-02	0.0	2.611E-03	0.0026	-6.997E-08	1.129E-07	2.283E-07	1.115E-07	2.296E-04	0.325
B1	30.000	40.000	1.213E-02	0.0	4.599E-03	0.0026	-6.685E-08	1.368E-07	2.687E-07	1.430E-07	2.890E-04	0.325
B1	40.000	50.000	1.213E-02	0.0	6.263E-03	0.0026	-6.256E-08	1.536E-07	2.851E-07	1.662E-07	3.254E-04	0.325
B1	50.000	60.000	1.238E-02	0.0	7.386E-03	0.0026	-5.738E-08	1.690E-07	2.943E-07	1.878E-07	3.562E-04	0.325
B1	60.000	70.000	1.238E-02	0.0	7.618E-03	0.0026	-5.381E-08	1.780E-07	2.920E-07	2.007E-07	3.702E-04	0.325
B1	70.000	80.000	1.238E-02	0.0	8.813E-03	0.0026	-5.085E-08	1.849E-07	2.845E-07	2.107E-07	3.776E-04	0.325
B1	80.000	90.000	1.238E-02	0.0	8.813E-03	0.0026	-4.873E-08	1.896E-07	2.784E-07	2.175E-07	3.821E-04	0.325
B2	0.000	10.000	4.403E-03	0.0	0.000E+00	0.0019	-1.518E-07	7.800E-08	6.772E-08	2.966E-09	-1.882E-06	0.272
B2	10.000	20.000	6.929E-03	0.0	0.000E+00	0.0019	-1.834E-07	1.005E-07	9.522E-08	1.080E-08	1.390E-05	0.272
B2	20.000	30.000	8.328E-03	0.0	0.000E+00	0.0019	-2.102E-07	1.272E-07	1.302E-07	2.216E-08	4.161E-05	0.272
B2	30.000	40.000	8.570E-03	0.0	1.310E-03	0.0019	-2.282E-07	1.494E-07	1.607E-07	3.293E-08	6.888E-05	0.272
B2	40.000	50.000	9.059E-03	0.0	3.084E-03	0.0019	-2.416E-07	1.730E-07	1.832E-07	4.547E-08	9.603E-05	0.272
B2	50.000	60.000	9.553E-03	0.0	5.061E-03	0.0019	-2.533E-07	2.006E-07	2.103E-07	6.130E-08	1.313E-04	0.272
B2	60.000	70.000	8.813E-03	0.0	6.293E-03	0.0019	-2.561E-07	2.137E-07	2.122E-07	6.920E-08	1.434E-04	0.272
B2	70.000	80.000	8.328E-03	0.0	7.073E-03	0.0019	-2.498E-07	2.163E-07	2.009E-07	7.083E-08	1.430E-04	0.272
B2	80.000	90.000	7.853E-03	0.0	7.073E-03	0.0019	-2.505E-07	2.217E-07	1.890E-07	7.415E-08	1.406E-04	0.272
B2	90.000	100.000	7.157E-03	0.0	6.549E-03	0.0019	-2.505E-07	2.217E-07	1.699E-07	7.415E-08	1.292E-04	0.272
B2	100.000	110.000	7.386E-03	0.0	6.549E-03	0.0019	-2.505E-07	2.217E-07	1.699E-07	7.415E-08	1.292E-04	0.272
B3	0.000	20.000	3.084E-03	0.0	0.000E+00	0.0019	-1.020E-07	1.049E-07	4.702E-08	3.705E-08	1.043E-04	0.626
B3	20.000	30.000	5.061E-03	0.0	0.000E+00	0.0019	-1.186E-07	1.210E-07	6.049E-08	4.601E-08	6.534E-05	0.313
B3	30.000	40.000	6.293E-03	0.0	0.000E+00	0.0019	-1.307E-07	1.427E-07	8.029E-08	5.895E-08	9.078E-05	0.313
B3	40.000	50.000	7.073E-03	0.0	0.000E+00	0.0019	-1.361E-07	1.630E-07	1.002E-07	7.179E-08	1.194E-04	0.313
B3	50.000	60.000	7.073E-03	0.0	0.000E+00	0.0019	-1.414E-07	1.897E-07	1.282E-07	8.962E-08	1.597E-04	0.313
B3	60.000	70.000	6.549E-03	0.0	1.508E-03	0.0019	-1.411E-07	2.178E-07	1.597E-07	1.094E-07	2.075E-04	0.313
B3	70.000	80.000	6.549E-03	0.0	2.178E-03	0.0019	-1.411E-07	2.178E-07	1.510E-07	1.094E-07	2.023E-04	0.313
B3	80.000	90.000	6.549E-03	0.0	2.771E-03	0.0019	-1.377E-07	2.474E-07	1.812E-07	1.312E-07	2.533E-04	0.313
B3	90.000	100.000	6.549E-03	0.0	3.409E-03	0.0019	-1.354E-07	2.597E-07	1.897E-07	1.404E-07	2.726E-04	0.313
B3	100.000	110.000	6.549E-03	0.0	3.915E-03	0.0019	-1.327E-07	2.721E-07	1.943E-07	1.500E-07	2.903E-04	0.313
B3	110.000	120.000	7.610E-03	0.0	4.445E-03	0.0019	-1.303E-07	2.816E-07	1.950E-07	1.574E-07	3.023E-04	0.313
B4	0.000	20.000	2.178E-03	0.0	0.000E+00	0.0019	-8.074E-08	4.490E-08	6.755E-08	5.113E-08	9.941E-05	0.911
B4	20.000	30.000	2.771E-03	0.0	0.000E+00	0.0019	-9.143E-08	4.754E-08	7.218E-08	5.450E-08	4.967E-05	0.456
B4	30.000	40.000	3.409E-03	0.0	0.000E+00	0.0019	-9.734E-08	5.164E-08	7.940E-08	5.974E-08	5.606E-05	0.456
B4	40.000	50.000	3.915E-03	0.0	0.000E+00	0.0019	-1.045E-07	5.881E-08	9.219E-08	6.901E-08	6.932E-05	0.456
B4	50.000	60.000	4.445E-03	0.0	0.000E+00	0.0019	-1.103E-07	6.643E-08	1.059E-07	7.894E-08	8.461E-05	0.456
B4	60.000	70.000	4.626E-03	0.0	0.000E+00	0.0019	-1.107E-07	6.800E-08	1.088E-07	8.101E-08	8.828E-05	0.456
B4	70.000	80.000	5.185E-03	0.0	0.000E+00	0.0019	-1.125E-07	7.952E-08	1.299E-07	9.620E-08	1.159E-04	0.456
B4	80.000	90.000	5.569E-03	0.0	8.723E-04	0.0019	-1.127E-07	8.827E-08	1.445E-07	1.078E-07	1.367E-04	0.456
B4	90.000	100.000	5.962E-03	0.0	1.676E-03	0.0019	-1.121E-07	9.746E-08	1.583E-07	1.201E-07	1.583E-04	0.456
B4	100.000	110.000	6.363E-03	0.0	2.637E-03	0.0019	-1.110E-07	1.051E-07	1.690E-07	1.304E-07	1.761E-04	0.456
B4	110.000	120.000	6.363E-03	0.0	3.354E-03	0.0019	-1.094E-07	1.131E-07	1.765E-07	1.412E-07	1.929E-04	0.456
B4	120.000	130.000	6.982E-03	0.0	4.532E-03	0.0019	-1.072E-07	1.213E-07	1.801E-07	1.523E-07	2.079E-04	0.456
B4	130.000	140.000	7.837E-03	0.0	5.601E-03	0.0019	-1.029E-07	1.342E-07	1.911E-07	1.698E-07	2.353E-04	0.456
B4	140.000	150.000	8.055E-03	0.0	6.508E-03	0.0019	-1.002E-07	1.408E-07	1.924E-07	1.790E-07	2.472E-04	0.456
B5	0.000	2.000	8.723E-04	0.0	0.000E+00	0.0019	-8.637E-08	4.340E-10	3.908E-08	-1.531E-08	-7.459E-06	0.069
B5	2.000	12.000	1.676E-03	0.0	0.000E+00	0.0019	-9.280E-08	1.355E-09	4.188E-08	-1.499E-08	-3.874E-05	0.347
B5	12.000	22.000	2.637E-03	0.0	0.000E+00	0.0019	-9.845E-08	2.347E-09	4.476E-08	-1.461E-08	-3.957E-05	0.347
B5	22.000	32.000	3.354E-03	0.0	0.000E+00	0.0019	-1.059E-07	4.544E-09	5.081E-08	-1.362E-08	-3.848E-05	0.347
B5	32.000	42.000	4.532E-03	0.0	0.000E+00	0.0019	-1.146E-07	8.371E-09	6.060E-08	-1.158E-08	-3.434E-05	0.347
B5	42.000	52.000	5.601E-03	0.0	0.000E+00	0.0019	-1.256E-07	1.284E-08	7.122E-08	-8.875E-09	-3.022E-05	0.347
B5	52.000	62.000	6.508E-03	0.0	0.000E+00	0.0019	-1.318E-07	1.704E-08	8.073E-08	-6.119E-09	-2.412E-05	0.347
B5	62.000	72.000	6.978E-03	0.0	1.172E-03	0.0019	-1.337E-07	2.573E-08	9.931E-08	-6.769E-24	-5.208E-06	0.347
B5	72.000	82.000	8.708E-03	0.0	1.909E-03	0.0019	-1.333E-07	3.232E-08	1.127E-07	4.906E-09	1.003E-05	0.347

Appendix C-3 Processed basin inflows and outflows for Field C

BASIN	TIME(min)		INFLOW		OUTFLOW							
	t1	t2	Surface inflow (m^3/s) (Eqn 2.38)	Rainfall amount after time, d(mm)	Surface outflow (m^3/s) (Eqn 2.38)	ETc (mm/min)	SEAPAGE(m^3/s) (Eqn 3.13) Side A	Side B	Side C	Side D	Net seapage across bunds, ILS(m^3)	Percolation losses,VS (m^3)
C1	0.000	10.000	5.695E-03	0.0	0.000E+00	0.0026	-4.546E-08	8.187E-08	2.343E-08	2.230E-08	4.929E-05	0.68
C1	10.000	20.000	7.564E-03	0.0	0.000E+00	0.0026	-4.770E-08	9.588E-08	3.026E-08	2.866E-08	6.467E-05	0.68
C1	20.000	30.000	7.370E-03	0.0	3.284E-04	0.0026	-4.915E-08	1.170E-07	4.352E-08	3.912E-08	9.027E-05	0.68
C1	30.000	40.000	6.608E-03	0.0	1.707E-03	0.0026	-4.893E-08	1.325E-07	5.358E-08	4.741E-08	1.107E-04	0.68
C1	40.000	50.000	6.608E-03	0.0	1.993E-03	0.0026	-4.836E-08	1.416E-07	5.731E-08	5.250E-08	1.218E-04	0.68
C1	50.000	60.000	5.695E-03	0.0	3.311E-03	0.0026	-4.717E-08	1.533E-07	6.187E-08	5.923E-08	1.363E-04	0.68
C1	60.000	70.000	6.237E-03	0.0	3.672E-03	0.0026	-4.655E-08	1.581E-07	6.246E-08	6.204E-08	1.416E-04	0.68
C1	70.000	80.000	6.608E-03	0.0	4.237E-03	0.0026	-4.545E-08	1.653E-07	6.279E-08	6.637E-08	1.494E-04	0.68
C1	80.000	90.000	6.608E-03	0.0	4.431E-03	0.0026	-4.464E-08	1.702E-07	6.325E-08	6.933E-08	1.549E-04	0.68
C2	0.000	25.000	1.999E-03	0.0	0.000E+00	0.0026	-3.465E-08	6.645E-08	2.334E-08	-6.017E-09	7.369E-05	1.75
C2	25.000	35.000	3.311E-03	0.0	0.000E+00	0.0026	-3.802E-08	7.328E-08	2.714E-08	-4.506E-09	3.474E-05	0.70
C2	35.000	45.000	3.672E-03	0.0	4.053E-04	0.0026	-3.960E-08	7.853E-08	3.019E-08	-3.174E-09	3.957E-05	0.70
C2	45.000	55.000	4.237E-03	0.0	1.143E-03	0.0026	-4.189E-08	8.755E-08	3.563E-08	-5.762E-10	4.843E-05	0.70
C2	55.000	65.000	4.431E-03	0.0	1.673E-03	0.0026	-4.329E-08	9.312E-08	3.733E-08	1.209E-09	5.305E-05	0.70
C2	65.000	75.000	5.030E-03	0.0	1.960E-03	0.0026	-4.326E-08	9.831E-08	4.034E-08	3.164E-09	5.943E-05	0.70
C2	75.000	85.000	5.235E-03	0.0	2.417E-03	0.0026	-4.313E-08	1.027E-07	3.906E-08	4.562E-09	6.137E-05	0.70
C2	85.000	95.000	5.235E-03	0.0	2.739E-03	0.0026	-4.264E-08	1.105E-07	4.395E-08	7.585E-09	7.166E-05	0.70
C2	95.000	105.000	5.443E-03	0.0	3.246E-03	0.0026	-4.227E-08	1.145E-07	4.380E-08	9.210E-09	7.518E-05	0.70
C2	105.000	115.000	5.867E-03	0.0	3.782E-03	0.0026	-4.227E-08	1.145E-07	4.043E-08	9.210E-09	7.316E-05	0.70
C2	115.000	125.000	5.867E-03	0.0	3.966E-03	0.0026	-4.129E-08	1.227E-07	4.330E-08	1.269E-08	8.247E-05	0.70
C2	125.000	135.000	5.857E-03	0.0	4.733E-03	0.0026	-4.129E-08	1.227E-07	4.046E-08	1.269E-08	8.076E-05	0.70
C3	0.000	30.000	1.673E-03	0.0	0.000E+00	0.0026	-6.445E-08	2.685E-07	2.310E-07	9.615E-08	9.563E-04	1.78
C3	30.000	40.000	1.960E-03	0.0	0.000E+00	0.0026	-6.704E-08	2.719E-07	2.314E-07	9.821E-08	3.225E-04	0.59
C3	40.000	50.000	2.417E-03	0.0	0.000E+00	0.0026	-6.643E-08	2.923E-07	2.548E-07	1.111E-07	3.550E-04	0.59
C3	50.000	60.000	2.739E-03	0.0	0.000E+00	0.0026	-7.070E-08	2.923E-07	2.548E-07	1.111E-07	3.525E-04	0.59
C3	60.000	70.000	3.246E-03	0.0	0.000E+00	0.0026	-7.095E-08	3.062E-07	2.689E-07	1.200E-07	3.745E-04	0.59
C3	70.000	80.000	3.782E-03	0.0	0.000E+00	0.0026	-6.823E-08	3.239E-07	2.870E-07	1.318E-07	4.047E-04	0.59
C3	80.000	90.000	3.966E-03	0.0	4.686E-04	0.0026	-7.103E-08	3.347E-07	2.982E-07	1.391E-07	4.206E-04	0.59
C3	90.000	100.000	4.733E-03	0.0	1.186E-03	0.0026	-6.844E-08	3.494E-07	3.133E-07	1.491E-07	4.460E-04	0.59
C3	100.000	110.000	5.133E-03	0.0	1.470E-03	0.0026	-6.632E-08	3.606E-07	3.219E-07	1.568E-07	4.638E-04	0.59
C3	110.000	120.000	5.543E-03	0.0	1.932E-03	0.0026	-6.322E-08	3.757E-07	3.345E-07	1.675E-07	4.887E-04	0.59
C3	120.000	130.000	5.752E-03	0.0	2.791E-03	0.0026	-5.994E-08	3.911E-07	3.457E-07	1.784E-07	5.132E-04	0.59
C3	130.000	140.000	6.178E-03	0.0	2.975E-03	0.0026	-5.616E-08	4.067E-07	3.570E-07	1.898E-07	5.334E-04	0.59
C3	140.000	150.000	6.178E-03	0.0	3.749E-03	0.0026	-5.220E-08	4.226E-07	3.651E-07	2.014E-07	5.621E-04	0.59
C3	150.000	160.000	6.178E-03	0.0	3.749E-03	0.0026	-4.903E-08	4.347E-07	3.723E-07	2.104E-07	5.810E-04	0.59
C4	0.000	30.000	1.470E-03	0.0	0.000E+00	0.0026	-9.300E-08	4.934E-08	2.180E-08	-1.091E-08	-5.839E-05	1.40
C4	30.000	40.000	1.932E-03	0.0	0.000E+00	0.0026	-9.863E-08	5.233E-08	2.373E-08	-1.065E-08	-1.936E-05	0.47
C4	40.000	50.000	2.791E-03	0.0	0.000E+00	0.0026	-1.064E-07	5.690E-08	2.679E-08	-1.011E-08	-1.968E-05	0.47
C4	50.000	60.000	2.975E-03	0.0	0.000E+00	0.0026	-1.142E-07	6.157E-08	3.002E-08	-9.392E-09	-1.917E-05	0.47
C4	60.000	70.000	3.749E-03	0.0	0.000E+00	0.0026	-1.257E-07	6.957E-08	3.581E-08	-7.793E-09	-1.638E-05	0.47
C4	70.000	80.000	3.749E-03	0.0	0.000E+00	0.0026	-1.330E-07	7.451E-08	3.952E-08	-6.594E-09	-1.532E-05	0.47
C4	80.000	90.000	4.157E-03	0.0	0.000E+00	0.0026	-1.418E-07	8.296E-08	4.611E-08	-4.196E-09	-1.013E-05	0.47
C4	90.000	100.000	4.157E-03	0.0	0.000E+00	0.0026	-1.468E-07	8.817E-08	5.030E-08	-2.518E-09	-6.481E-06	0.47
C4	100.000	110.000	4.580E-03	0.0	0.000E+00	0.0026	-1.577E-07	1.007E-07	6.078E-08	2.098E-09	3.563E-06	0.47
C4	110.000	120.000	4.796E-03	0.0	1.261E-03	0.0026	-1.661E-07	1.119E-07	7.054E-08	6.834E-09	1.398E-05	0.47
C4	120.000	130.000	5.694E-03	0.0	1.942E-03	0.0026	-1.726E-07	1.215E-07	7.680E-08	1.133E-08	2.224E-05	0.47
C4	130.000	140.000	5.927E-03	0.0	2.879E-03	0.0026	-1.785E-07	1.314E-07	8.412E-08	1.633E-08	3.203E-05	0.47
C4	140.000	150.000	5.927E-03	0.0	3.568E-03	0.0026	-1.818E-07	1.375E-07	8.705E-08	1.956E-08	3.741E-05	0.47
C4	150.000	160.000	5.927E-03	0.0	4.116E-03	0.0026	-1.858E-07	1.458E-07	9.189E-08	2.416E-08	4.559E-05	0.47
C4	160.000	170.000	5.694E-03	0.0	4.690E-03	0.0026	-1.877E-07	1.500E-07	9.292E-08	2.658E-08	4.904E-05	0.47
C4	170.000	180.000	5.927E-03	0.0	5.086E-03	0.0026	-1.895E-07	1.542E-07	9.294E-08	2.907E-08	5.201E-05	0.47
C4	180.000	190.000	5.465E-03	0.0	5.086E-03	0.0026	-1.904E-07	1.564E-07	9.194E-08	3.035E-08	5.294E-05	0.47
C4	190.000	200.000	5.016E-03	0.0	5.086E-03	0.0026	-1.913E-07	1.585E-07	8.991E-08	3.165E-09	5.328E-05	0.47
C5	0.000	5.000	1.522E-03	0.0	0.000E+00	0.0026	-5.192E-08	2.294E-08	2.599E-08	4.531E-09	4.647E-07	0.32
C5	5.000	15.000	2.714E-03	0.0	0.000E+00	0.0026	-5.875E-08	2.545E-08	2.924E-08	6.854E-09	1.681E-06	0.64
C5	15.000	25.000	4.887E-03	0.0	0.000E+00	0.0026	-6.831E-08	2.991E-08	3.508E-08	1.123E-08	4.753E-06	0.64
C5	25.000	35.000	6.337E-03	0.0	0.000E+00	0.0026	-7.655E-08	3.574E-08	4.279E-08	1.733E-08	1.158E-05	0.64
C5	35.000	45.000	7.677E-03	0.0	0.000E+00	0.0026	-7.976E-08	4.319E-08	5.275E-08	2.559E-08	2.506E-05	0.64
C5	45.000	55.000	8.378E-03	0.0	2.835E-04	0.0026	-8.200E-08	5.134E-08	6.375E-08	3.510E-09	4.091E-05	0.64
C5	55.000	65.000	9.100E-03	0.0	1.937E-03	0.0026	-8.354E-08	6.556E-08	8.314E-08	5.255E-08	7.062E-05	0.64
C5	65.000	75.000	9.344E-03	0.0	2.982E-03	0.0026	-8.344E-08	7.259E-08	9.280E-08	6.150E-08	8.607E-05	0.64
C5	75.000	85.000	1.009E-02	0.0	4.167E-03	0.0026	-8.266E-08	8.150E-08	1.051E-07	7.307E-08	1.062E-04	0.64

BASIN	TIME(min)		INFLOW		OUTFLOW							
			Surface inflow (m^3/s) (Eqn 2.38)	Rainfall amount after time, t(mm)	Surface outflow (m^3/s) (Eqn 2.38)	ETc (mm/min)	SEAPAGE(m^3/s) (Eqn 3.13)				Net seepage across bunds, ΣS(m^3)	Percolation losses,VS (m^3)
	t1	t2					Side A	Side B	Side C	Side D		
C1	0.000	10.000	1.414E-02	0.0	0.000E+00	0.0026	-5.524E-08	7.233E-08	2.013E-08	4.248E-08	4.781E-05	0.68
C1	10.000	20.000	1.438E-02	0.0	1.048E-03	0.0026	-5.983E-08	9.899E-08	3.674E-08	6.267E-08	8.310E-05	0.68
C1	20.000	30.000	1.090E-02	0.0	3.135E-03	0.0026	-6.003E-08	1.264E-07	5.126E-08	8.481E-08	1.215E-04	0.68
C1	30.000	40.000	1.180E-02	0.0	5.030E-03	0.0026	-5.765E-08	1.476E-07	6.239E-08	1.026E-07	1.529E-04	0.68
C1	40.000	50.000	1.180E-02	0.0	6.523E-03	0.0026	-5.427E-08	1.654E-07	6.893E-08	1.179E-07	1.787E-04	0.68
C1	50.000	60.000	1.202E-02	0.0	7.901E-03	0.0026	-5.096E-08	1.793E-07	6.837E-08	1.302E-07	1.962E-04	0.68
C1	60.000	70.000	1.180E-02	0.0	8.623E-03	0.0026	-4.817E-08	1.888E-07	6.501E-08	1.336E-07	2.066E-04	0.68
C1	70.000	80.000	1.295E-02	0.0	9.365E-03	0.0026	-4.515E-08	1.986E-07	6.490E-08	1.473E-07	2.194E-04	0.68
C1	80.000	90.000	1.202E-02	0.0	9.617E-03	0.0026	-4.352E-08	2.035E-07	5.607E-08	1.518E-07	2.207E-04	0.68
C2	0.000	10.000	2.465E-03	0.5	0.000E+00	0.0026	-3.494E-08	9.446E-08	3.788E-08	-2.248E-08	4.501E-05	0.70
C2	10.000	20.000	4.627E-03	1.0	0.000E+00	0.0026	-4.264E-08	1.038E-07	4.395E-08	-2.069E-08	5.066E-05	0.70
C2	20.000	30.000	7.201E-03	0.3	0.000E+00	0.0026	-5.103E-08	1.235E-07	5.743E-08	-1.568E-09	6.852E-05	0.70
C2	30.000	40.000	8.623E-03	0.4	7.994E-04	0.0026	-5.472E-08	1.359E-07	6.638E-08	-1.177E-09	8.149E-05	0.70
C2	40.000	50.000	1.013E-02	0.2	2.261E-03	0.0025	-5.681E-08	1.577E-07	8.273E-08	-3.741E-09	1.079E-04	0.70
C2	50.000	60.000	1.118E-02	0.3	3.422E-03	0.0026	-5.677E-08	1.803E-07	9.109E-08	6.178E-09	1.327E-04	0.70
C2	60.000	70.000	1.198E-02	0.3	4.931E-03	0.0026	-5.156E-08	2.003E-07	9.672E-08	1.547E-08	1.565E-04	0.70
C2	70.000	80.000	1.118E-02	0.5	6.836E-03	0.0026	-4.575E-08	2.180E-07	1.036E-07	2.460E-08	1.803E-04	0.70
C2	80.000	90.000	1.091E-02	0.5	7.287E-03	0.0026	-4.198E-08	2.284E-07	1.035E-07	3.023E-08	1.921E-04	0.70
C3	0.000	25.000	1.950E-03	0.0	0.000E+00	0.0025	-9.923E-08	2.954E-07	2.408E-07	9.410E-08	7.966E-04	1.49
C3	25.000	35.000	2.576E-03	0.0	0.000E+00	0.0026	-1.050E-07	3.062E-07	2.512E-07	1.003E-07	3.316E-04	0.59
C3	35.000	45.000	3.422E-03	0.0	0.000E+00	0.0026	-1.096E-07	3.284E-07	2.725E-07	1.133E-07	3.634E-04	0.59
C3	45.000	55.000	4.154E-03	0.0	0.000E+00	0.0026	-1.130E-07	3.511E-07	2.947E-07	1.270E-07	3.959E-04	0.59
C3	55.000	65.000	4.931E-03	0.0	0.000E+00	0.0026	-1.162E-07	3.744E-07	3.176E-07	1.415E-07	4.304E-04	0.59
C3	65.000	75.000	5.337E-03	0.0	9.231E-04	0.0026	-1.186E-07	3.902E-07	3.333E-07	1.517E-07	4.540E-04	0.59
C3	75.000	85.000	7.060E-03	0.0	1.619E-03	0.0025	-1.163E-07	4.145E-07	3.514E-07	1.675E-07	4.902E-04	0.59
C3	85.000	95.000	7.516E-03	0.0	2.791E-03	0.0026	-1.123E-07	4.477E-07	3.733E-07	1.893E-07	5.429E-04	0.59
C3	95.000	105.000	8.454E-03	0.0	3.749E-03	0.0026	-1.079E-07	4.776E-07	4.012E-07	2.104E-07	5.868E-04	0.59
C3	105.000	115.000	9.454E-03	0.0	5.239E-03	0.0025	-1.025E-07	5.083E-07	4.159E-07	2.321E-07	6.323E-04	0.59
C3	115.000	125.000	8.695E-03	0.0	5.016E-03	0.0026	-9.815E-08	5.307E-07	4.197E-07	2.482E-07	6.603E-04	0.59
C4	0.000	20.000	1.932E-03	0.5	0.000E+00	0.0026	-1.516E-07	6.026E-08	3.719E-08	1.379E-09	-6.332E-05	0.93
C4	20.000	30.000	2.791E-03	0.2	0.000E+00	0.0026	-1.628E-07	6.539E-08	4.226E-08	4.376E-09	-3.047E-05	0.47
C4	30.000	40.000	3.163E-03	0.3	0.000E+00	0.0026	-1.726E-07	7.069E-08	4.765E-08	7.693E-09	-2.792E-05	0.47
C4	40.000	50.000	4.157E-03	0.1	0.000E+00	0.0025	-1.829E-07	7.758E-08	5.493E-08	1.229E-08	-2.290E-05	0.47
C4	50.000	60.000	6.642E-03	0.0	0.000E+00	0.0026	-1.955E-07	8.769E-08	6.573E-08	1.956E-08	-1.353E-05	0.47
C4	60.000	70.000	7.385E-03	0.4	7.922E-04	0.0026	-2.098E-07	1.031E-07	8.300E-08	3.165E-08	4.731E-06	0.47
C4	70.000	80.000	6.642E-03	0.3	2.241E-03	0.0026	-2.239E-07	1.196E-07	9.791E-08	4.574E-08	2.365E-05	0.47
C4	80.000	90.000	7.134E-03	0.5	2.714E-03	0.0026	-2.270E-07	1.265E-07	1.026E-07	5.133E-08	3.242E-05	0.47
C4	90.000	100.000	7.134E-03	0.2	3.217E-03	0.0026	-2.299E-07	1.336E-07	1.074E-07	5.845E-08	4.175E-05	0.47
C4	100.000	110.000	7.134E-03	0.5	4.116E-03	0.0026	-2.324E-07	1.409E-07	1.111E-07	6.529E-08	5.091E-05	0.47
C5	0.000	15.000	2.241E-03	0.3	0.000E+00	0.0026	-6.198E-08	3.991E-08	4.835E-08	1.927E-08	4.100E-05	0.97
C5	15.000	25.000	2.714E-03	0.5	0.000E+00	0.0026	-6.539E-08	4.319E-08	5.275E-08	2.285E-08	3.204E-05	0.64
C5	25.000	35.000	3.217E-03	0.2	0.000E+00	0.0026	-6.897E-08	4.660E-08	5.733E-08	2.666E-08	3.703E-05	0.64
C5	35.000	45.000	4.116E-03	0.5	8.020E-04	0.0025	-7.254E-08	5.134E-08	6.375E-08	3.209E-08	4.478E-05	0.64
C5	45.000	55.000	4.116E-03	1.0	1.189E-03	0.0026	-7.290E-08	5.631E-08	7.050E-08	3.793E-08	5.510E-05	0.64
C5	55.000	65.000	4.837E-03	0.5	1.473E-03	0.0026	-7.294E-08	6.151E-08	7.759E-08	4.417E-08	6.620E-05	0.64
C5	65.000	75.000	5.700E-03	0.7	2.617E-03	0.0025	-7.254E-08	6.833E-08	8.694E-08	5.255E-08	8.116E-05	0.64
C5	75.000	85.000	5.910E-03	0.4	2.797E-03	0.0026	-7.186E-08	7.404E-08	9.479E-08	5.971E-08	9.401E-05	0.64

APPENDIX D

Statistical Analysis

Appendix D-1 Statistical Analysis for basin storage in Field A

BASIN	MEASURED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	CORRELATION COEFFICIENT	F	P-value	F-critical	SIGNIFICANCE * Not significant ** Significant
A1	0.005	0.005	0.843	0.283	0.602	4.414	*
A1	0.019	0.014					
A1	0.014	0.017					
A1	0.014	0.018					
A1	0.015	0.018					
A1	0.014	0.015					
A1	0.009	0.012					
A1	0.007	0.009					
A1	0.003	0.007					
A2	0.002	0.001	0.943	0.018	0.894	4.260	*
A2	0.005	0.004					
A2	0.006	0.007					
A2	0.010	0.009					
A2	0.010	0.010					
A2	0.009	0.011					
A2	0.009	0.011					
A2	0.009	0.010					
A2	0.009	0.009					
A2	0.008	0.007					
A2	0.005	0.005					
A2	0.002	0.003					
A3	0.005	0.002	0.775	0.006	0.940	4.414	*
A3	0.009	0.006					
A3	0.012	0.011					
A3	0.013	0.014					
A3	0.011	0.016					
A3	0.003	0.013					
A3	0.009	0.010					
A3	0.009	0.008					
A3	0.008	0.004					
A4	0.008	0.005	0.567	0.662	0.425	4.351	*
A4	0.009	0.008					
A4	0.009	0.011					
A4	0.009	0.013					
A4	0.008	0.012					
A4	0.009	0.010					
A4	0.007	0.010					
A4	0.006	0.008					
A4	0.005	0.006					
A4	0.005	0.006					
A5	0.007	0.004	0.428	0.059	0.814	4.965	*
A5	0.006	0.006					
A5	0.008	0.009					
A5	0.011	0.011					
A5	0.005	0.010					

BASIN	MEASURED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	CORRELATION COEFFICIENT	F	P-value	F-critical	SIGNIFICANCE * Not significant — Significant
A1	0.016	0.014	0.955	0.361	0.559	4.747	*
A1	0.014	0.016					
A1	0.011	0.014					
A1	0.007	0.010					
A1	0.005	0.007					
A1	0.000	0.006					
A2	0.002	0.001	0.836	0.030	0.863	4.351	*
A2	0.005	0.003					
A2	0.005	0.005					
A2	0.007	0.007					
A2	0.007	0.008					
A2	0.005	0.006					
A2	0.007	0.006					
A2	0.006	0.005					
A2	0.004	0.005					
A2	0.003	0.003					
A3	0.004	0.001	0.788	0.100	0.755	4.351	*
A3	0.003	0.003					
A3	0.004	0.005					
A3	0.008	0.007					
A3	0.007	0.009					
A3	0.008	0.009					
A3	0.005	0.007					
A3	0.006	0.006					
A3	0.006	0.005					
A3	0.005	0.002					
A4	0.006	0.005	0.266	0.892	0.359	4.494	*
A4	0.007	0.007					
A4	0.008	0.009					
A4	0.010	0.010					
A4	0.010	0.010					
A4	0.004	0.010					
A4	0.003	0.009					
A4	0.007	0.008					
A5	0.007	0.004	0.812	0.052	0.824	4.965	*
A5	0.005	0.007					
A5	0.010	0.009					
A5	0.012	0.011					
A5	0.010	0.010					

Appendix D-2 Statistical Analysis for basin storage in Field B

BASIN	OBSERVED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	CORRELATION COEFFICIENT	F	P-value	F-critical	SIGNIFICANCE * Not Significant ** Significant
B1	0.012	0.006	0.913	0.581	0.456	4.414	*
B1	0.015	0.013					
B1	0.012	0.012					
B1	0.012	0.008					
B1	0.007	0.006					
B1	0.004	0.004					
B1	0.004	0.003					
B1	0.003	0.002					
B1	0.002	0.001					
B2	0.007	0.003	0.878	0.070	0.794	4.351	*
B2	0.010	0.009					
B2	0.011	0.011					
B2	0.010	0.012					
B2	0.011	0.011					
B2	0.009	0.008					
B2	0.008	0.006					
B2	0.004	0.005					
B2	0.003	0.003					
B2	0.003	0.002					
B3	0.008	0.003	0.591	0.103	0.751	4.225	*
B3	0.009	0.006					
B3	0.010	0.009					
B3	0.008	0.011					
B3	0.011	0.012					
B3	0.009	0.011					
B3	0.006	0.010					
B3	0.009	0.009					
B3	0.006	0.008					
B3	0.006	0.007					
B3	0.004	0.006					
B3	0.004	0.005					
B3	0.002	0.004					
B4	0.005	0.002	0.587	2.365	0.136	4.225	*
B4	0.008	0.003					
B4	0.006	0.005					
B4	0.008	0.006					
B4	0.009	0.007					
B4	0.009	0.008					
B4	0.009	0.008					
B4	0.005	0.009					
B4	0.008	0.007					
B4	0.008	0.005					
B4	0.005	0.004					
B4	0.006	0.003					
B4	0.004	0.002					
B5	0.004	0.001	0.758	0.024	0.879	4.600	*
B5	0.004	0.004					
B5	0.004	0.006					
B5	0.008	0.007					
B5	0.007	0.008					
B5	0.006	0.008					
B5	0.008	0.008					

BASIN	OBSERVED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	CORRELATION COEFFICIENT	F	P-value	F-critical	SIGNIFICANCE * Not Significant * * Significant
B1	0.014	0.008	0.892	0.022	0.883	4.414	*
B1	0.018	0.017					
B1	0.014	0.015					
B1	0.012	0.012					
B1	0.008	0.009					
B1	0.007	0.007					
B1	0.004	0.007					
B1	0.003	0.005					
B1	0.002	0.005					
B2	0.006	0.003	0.929	0.002	0.965	4.301	*
B2	0.012	0.009					
B2	0.013	0.013					
B2	0.010	0.013					
B2	0.010	0.011					
B2	0.011	0.009					
B2	0.005	0.006					
B2	0.001	0.003					
B2	0.002	0.001					
B2	0.000	0.000					
B2	0.000	0.000					
B3	0.007	0.003	0.537	0.018	0.896	4.301	*
B3	0.007	0.006					
B3	0.009	0.008					
B3	0.008	0.010					
B3	0.010	0.010					
B3	0.010	0.009					
B3	0.000	0.007					
B3	0.010	0.006					
B3	0.004	0.005					
B3	0.004	0.004					
B3	0.003	0.004					
B4	0.005	0.001	0.180	4.330	0.047	4.196	**
B4	0.002	0.002					
B4	0.003	0.003					
B4	0.005	0.003					
B4	0.005	0.004					
B4	0.001	0.004					
B4	0.007	0.004					
B4	0.005	0.005					
B4	0.005	0.004					
B4	0.004	0.003					
B4	0.004	0.003					
B4	0.004	0.002					
B4	0.006	0.002					
B4	0.003	0.001					
B5	0.001	-0.000	0.884	0.003	0.960	4.414	*
B5	0.002	0.001					
B5	0.002	0.002					
B5	0.004	0.003					
B5	0.006	0.005					
B5	0.006	0.006					
B5	0.005	0.008					
B5	0.009	0.008					
B5	0.006	0.008					

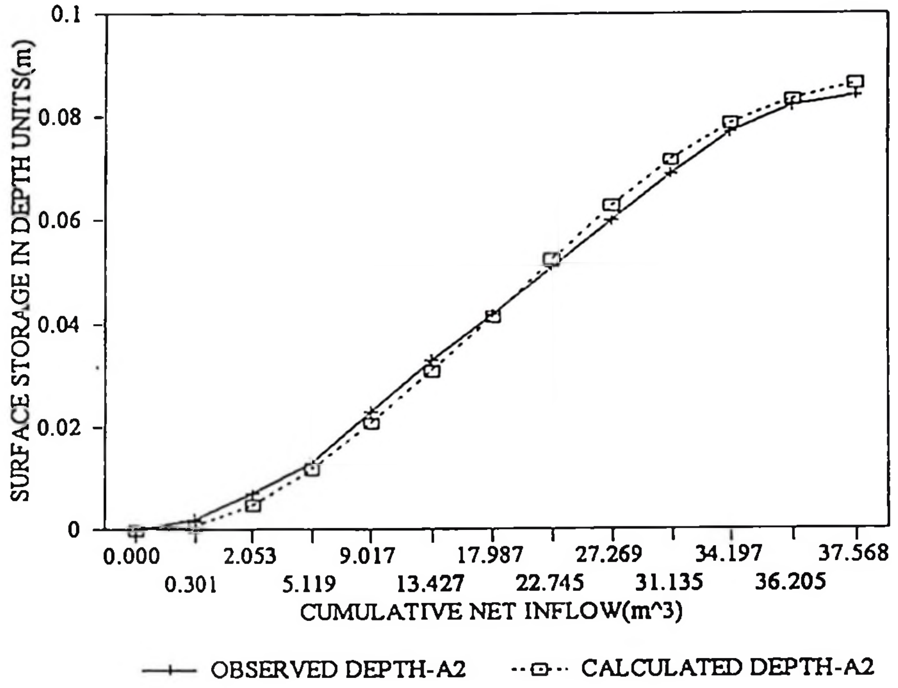
Appendix D-3 Statistical Analysis for basin storage in Field C

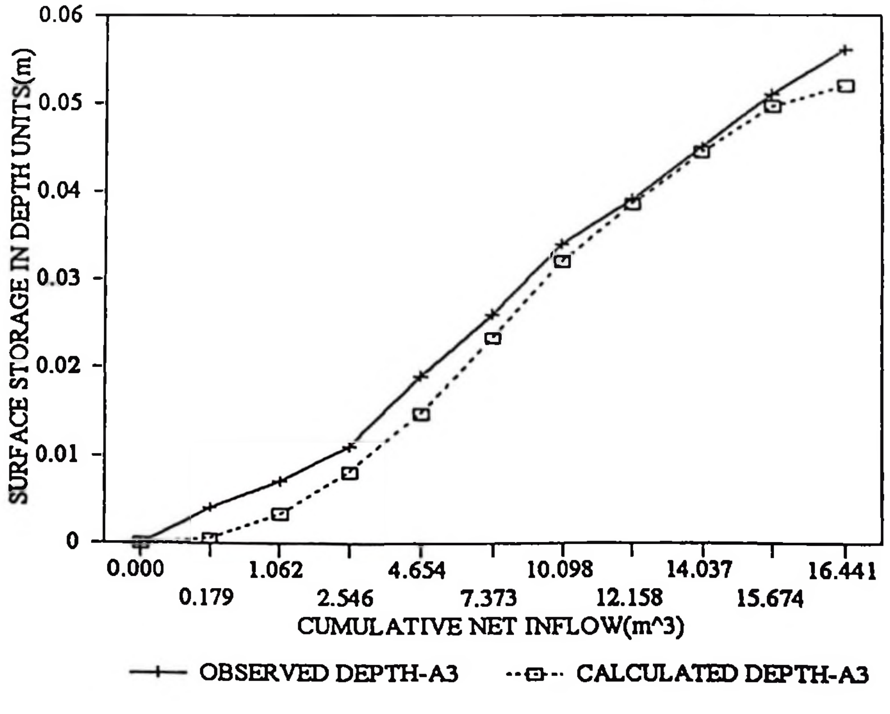
BASIN	OBSERVED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	CORRELATION COEFFICIENT	F	P-value	F-critical	SIGNIFICANCE * Not Significant ** Significant
C1	0.003	0.002	0.945	0.592	0.451	4.414	*
C1	0.007	0.007					
C1	0.010	0.007					
C1	0.007	0.006					
C1	0.004	0.004					
C1	0.005	0.003					
C1	0.002	0.002					
C1	0.003	0.002					
C1	0.002	0.001					
C2	0.003	-0.001	0.369	5.144	0.033	4.260	**
C2	0.004	0.002					
C2	0.003	0.002					
C2	0.005	0.002					
C2	0.003	0.002					
C2	0.003	0.002					
C2	0.002	0.002					
C2	0.004	0.002					
C2	0.002	0.001					
C2	0.000	0.001					
C2	0.004	0.001					
C2	0.000	0.000					
C3	0.003	-0.001	0.262	2.552	0.121	4.196	*
C3	0.001	0.001					
C3	0.006	0.002					
C3	0.000	0.002					
C3	0.004	0.003					
C3	0.005	0.003					
C3	0.003	0.004					
C3	0.004	0.003					
C3	0.003	0.004					
C3	0.004	0.004					
C3	0.004	0.003					
C3	0.004	0.003					
C3	0.004	0.002					
C3	0.003	0.002					
C4	0.002	-0.000	0.835	0.195	0.662	4.113	*
C4	0.002	0.002					
C4	0.003	0.003					
C4	0.003	0.004					
C4	0.005	0.005					
C4	0.003	0.005					
C4	0.005	0.006					
C4	0.003	0.006					
C4	0.007	0.006					
C4	0.006	0.006					
C4	0.005	0.005					
C4	0.005	0.005					
C4	0.003	0.003					
C4	0.004	0.002					
C4	0.002	0.001					
C4	0.002	0.000					
C4	0.001	-0.000					
C4	0.001	-0.001					
C5	0.000	-0.000	0.867	0.010	0.920	4.414	*
C5	0.003	0.001					
C5	0.005	0.003					
C5	0.006	0.006					
C5	0.007	0.008					
C5	0.007	0.009					
C5	0.011	0.008					
C5	0.005	0.007					
C5	0.006	0.006					

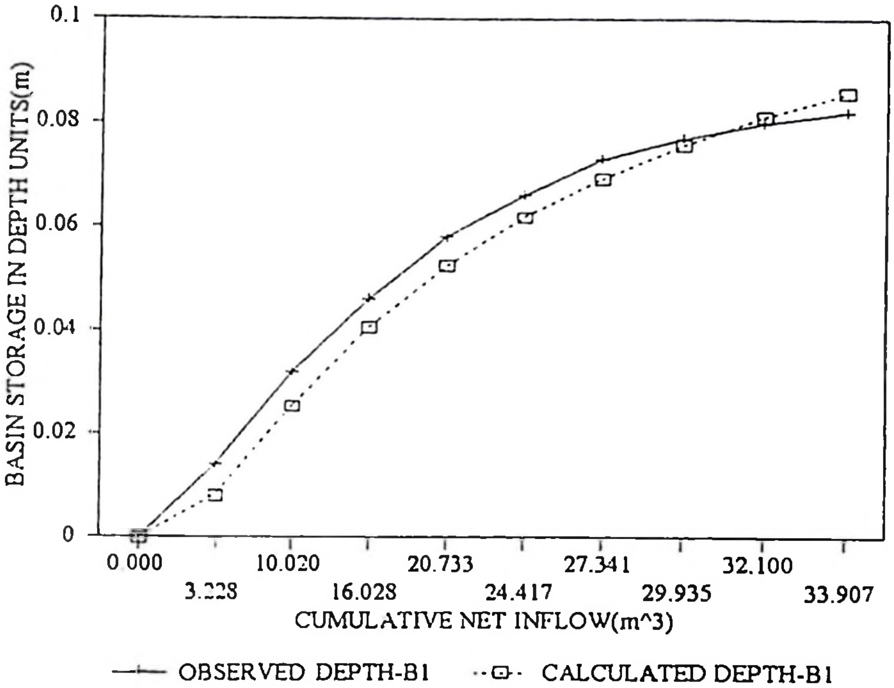
BASIN	OBSERVED CHANGE IN DEPTH, h(m)	CALCULATED CHANGE IN DEPTH, h(m) (Eqn 3.3)	CORRELATION COEFFICIENT	F	P-value	F-critical	SIGNIFICANCE * Not Significant ** Significant
C1	0.016	0.007	0.856	0.753	0.397	4.414	*
C1	0.015	0.015					
C1	0.014	0.011					
C1	0.010	0.007					
C1	0.008	0.006					
C1	0.006	0.004					
C1	0.004	0.003					
C1	0.004	0.003					
C1	0.002	0.002					
C2	0.004	0.001	0.758	0.863	0.365	4.414	*
C2	0.005	0.004					
C2	0.010	0.006					
C2	0.006	0.008					
C2	0.010	0.008					
C2	0.010	0.008					
C2	0.008	0.008					
C2	0.007	0.006					
C2	0.004	0.004					
C3	0.004	-0.000	0.644	4.103	0.055	4.301	*
C3	0.003	0.002					
C3	0.006	0.003					
C3	0.006	0.004					
C3	0.006	0.005					
C3	0.004	0.005					
C3	0.006	0.005					
C3	0.008	0.006					
C3	0.007	0.005					
C3	0.007	0.004					
C3	0.005	0.003					
C4	0.003	0.001	0.843	0.073	0.790	4.351	*
C4	0.004	0.003					
C4	0.004	0.004					
C4	0.005	0.005					
C4	0.007	0.008					
C4	0.010	0.011					
C4	0.010	0.009					
C4	0.004	0.007					
C4	0.004	0.006					
C4	0.004	0.005					
C5	0.004	0.000	0.275	2.614	0.125	4.494	*
C5	0.003	0.002					
C5	0.003	0.003					
C5	0.004	0.003					
C5	0.004	0.004					
C5	0.004	0.003					
C5	0.005	0.003					
C5	0.004	0.003					

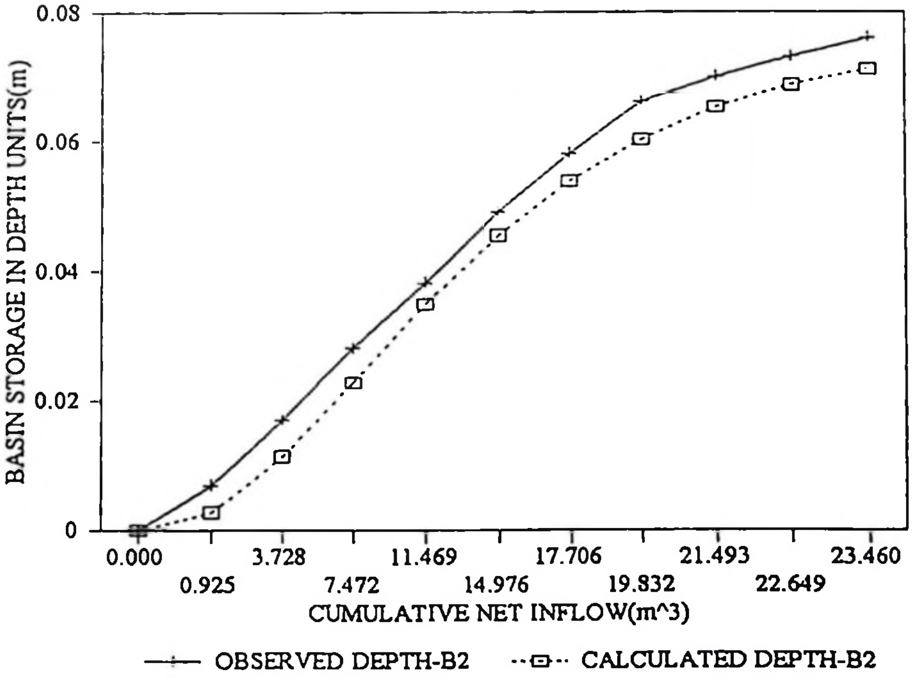
APPENDIX E

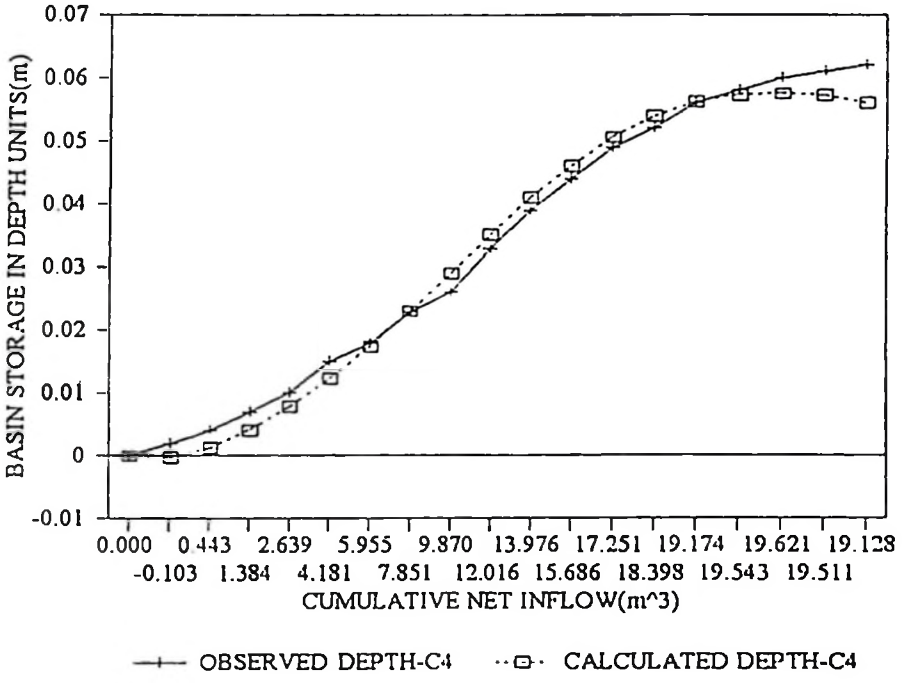
Graphical comparison of observed and calculated basin water storage

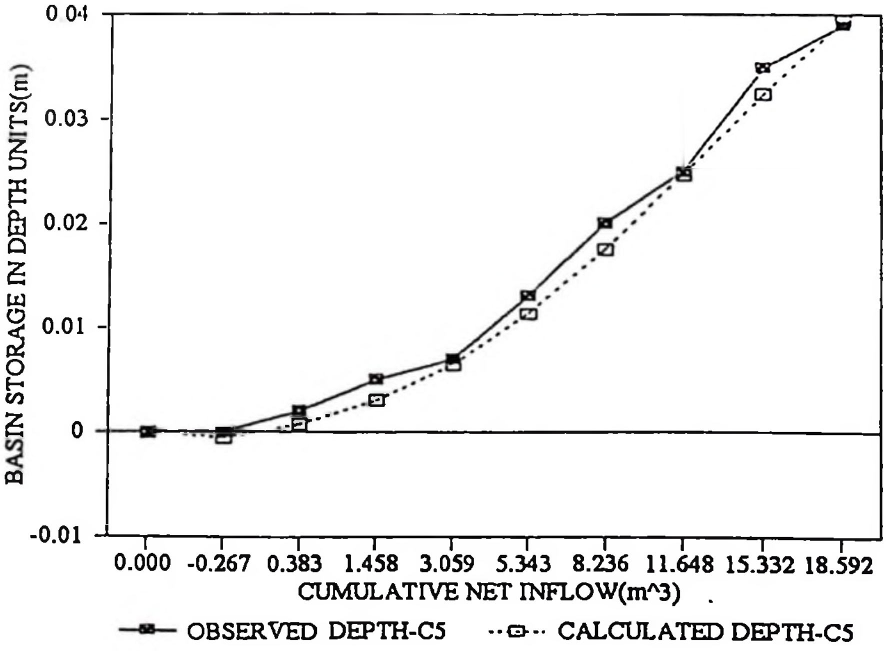


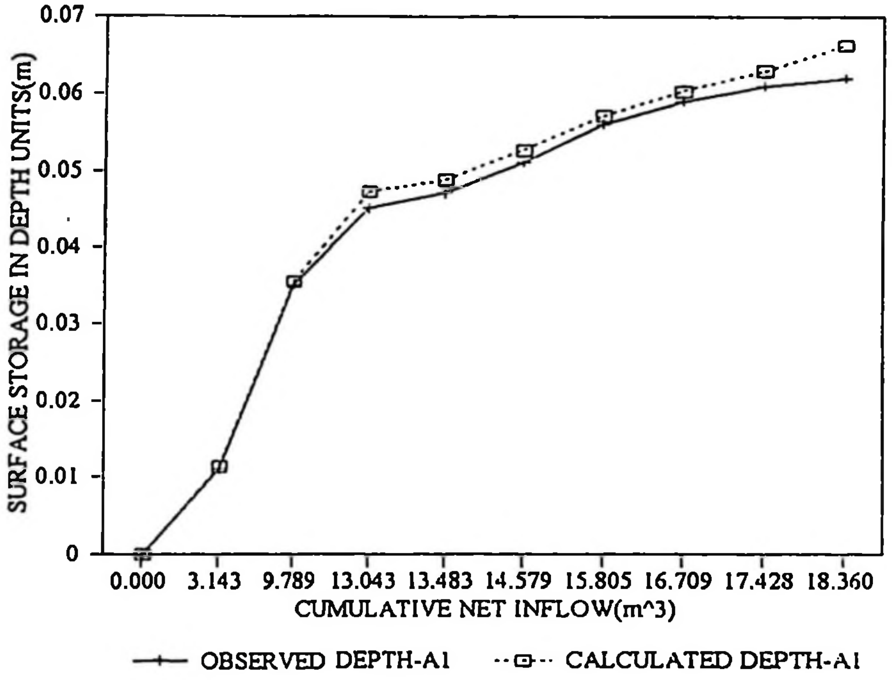


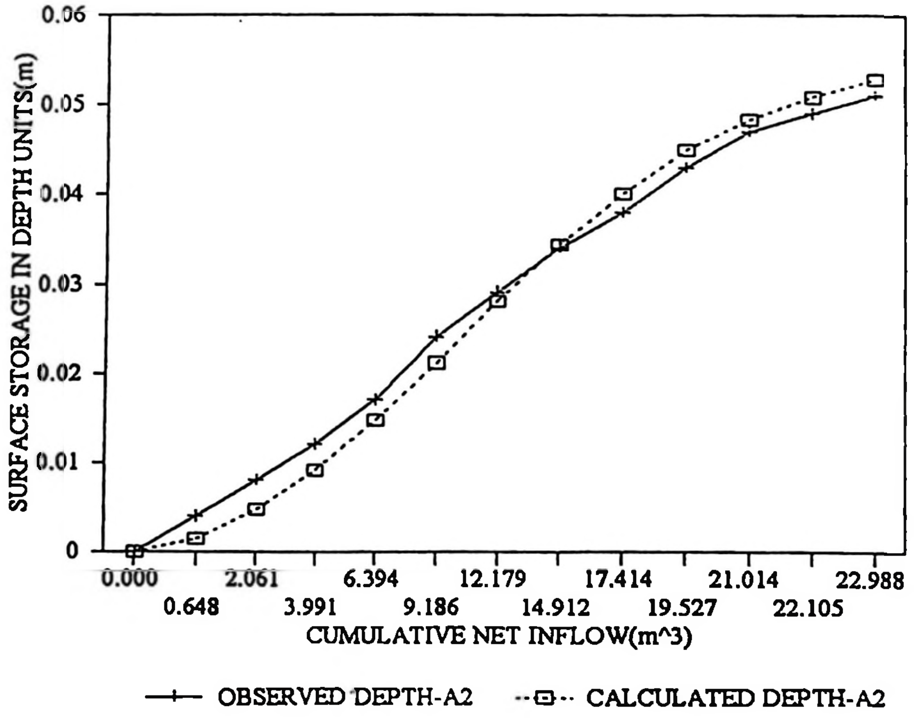

0.1
0.08
0.06
0.04
0.02
0
BASIN STORAGE IN DEPTH UNITS(m)
0.000
3.228
10.020
16.028
20.733
24.417
27.341
29.935
32.100
33.907
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-B1
CALCULATED DEPTH-B1

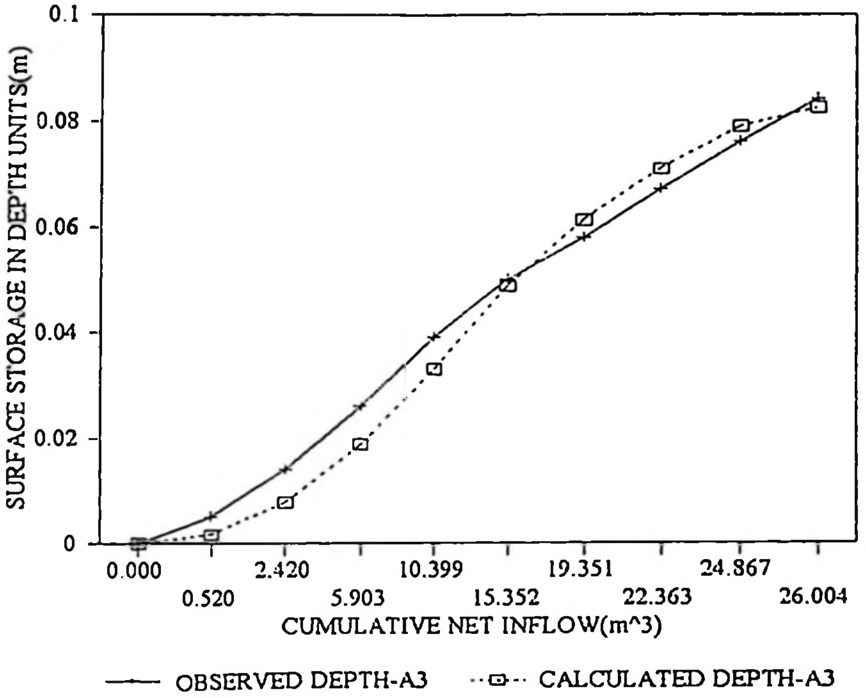

0.08
0.06
0.04
0.02
0
BASIN STORAGE IN DEPTH UNITS(m)
0.000
0.925
3.728
7.472
11.469
14.976
17.706
19.832
21.493
22.649
23.460
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-B2
CALCULATED DEPTH-B2

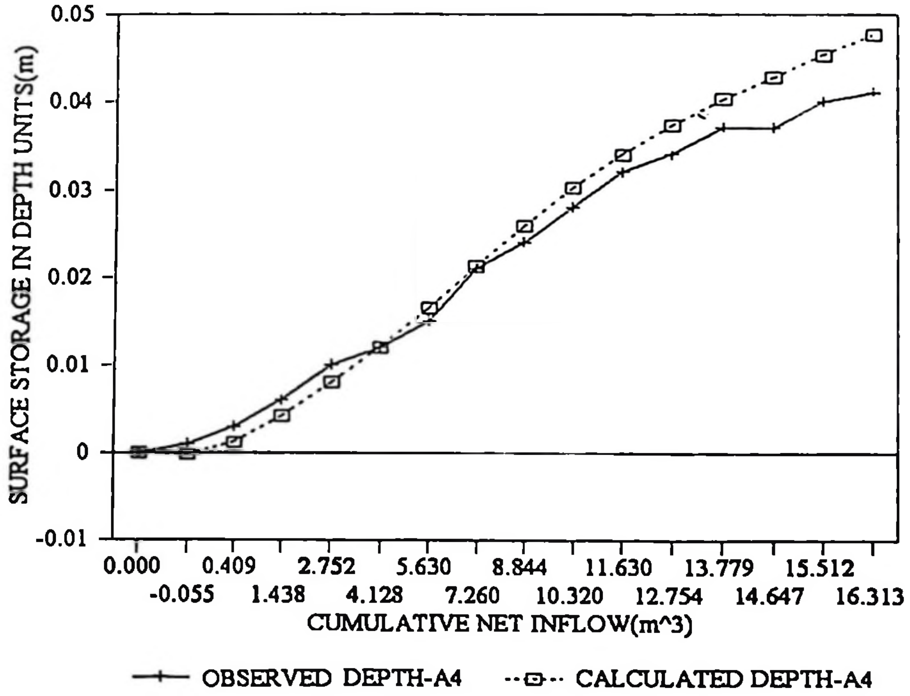

0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
BASIN STORAGE IN DEPTH UNITS(m)
0.000 0.443 2.639 5.955 9.870 13.976 17.251 19.174 19.621 19.128
-0.103 1.384 4.181 7.851 12.016 15.686 18.398 19.543 19.511
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-C4
CALCULATED DEPTH-C4

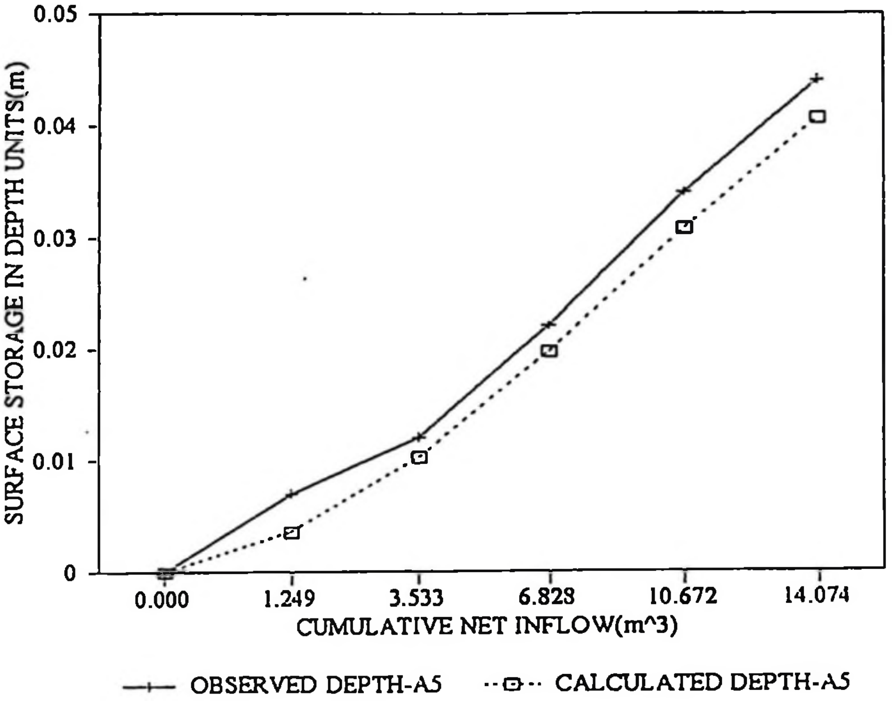

0.04
0.03
0.02
0.01
0
-0.01
BASIN STORAGE IN DEPTH UNITS(m)
0.000 -0.267 0.383 1.458 3.059 5.343 8.236 11.648 15.332 18.592
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-C5
CALCULATED DEPTH-C5

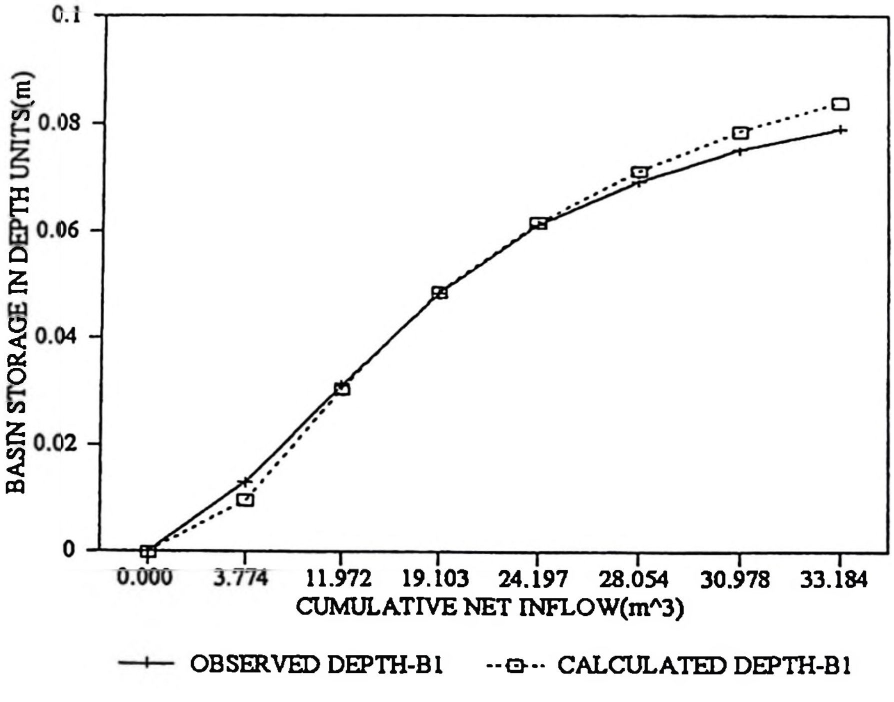

SURFACE STORAGE IN DEPTH UNITS(m)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.000
3.143
9.789
13.043
13.483
14.579
15.805
16.709
17.428
18.360
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-A1
CALCULATED DEPTH-A1

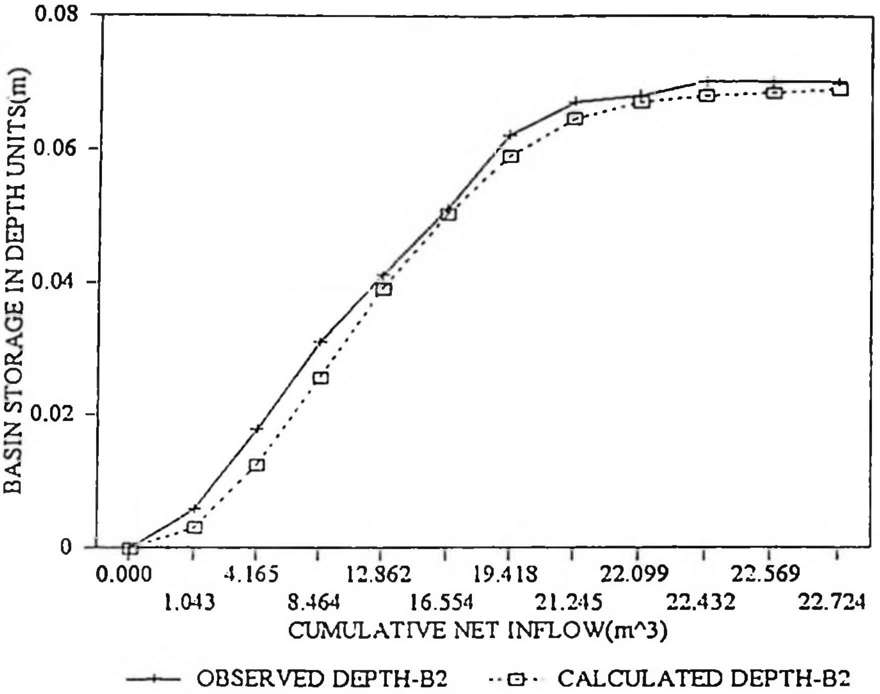

SURFACE STORAGE IN DEPTH UNITS(m)
0.06
0.05
0.04
0.03
0.02
0.01
0
0.000
0.648
2.061
3.991
6.394
9.186
12.179
14.912
17.414
19.527
21.014
22.105
22.988
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-A2
CALCULATED DEPTH-A2

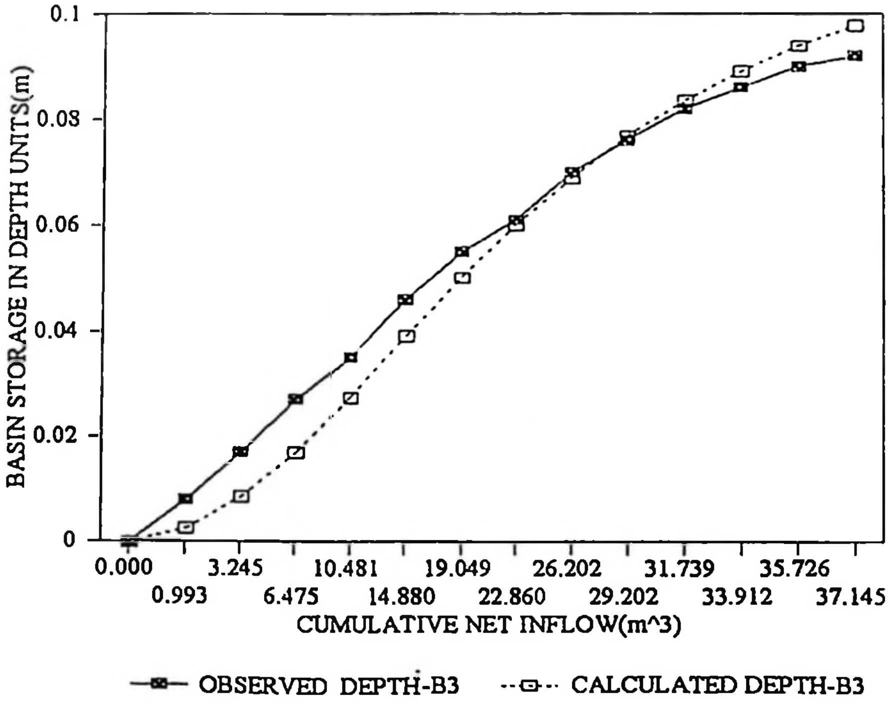

SURFACE STORAGE IN DEPTH UNITS(m)
0.1
0.08
0.06
0.04
0.02
0
0.000
0.520
2.420
5.903
10.399
15.352
19.351
22.363
24.867
26.004
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-A3
CALCULATED DEPTH-A3

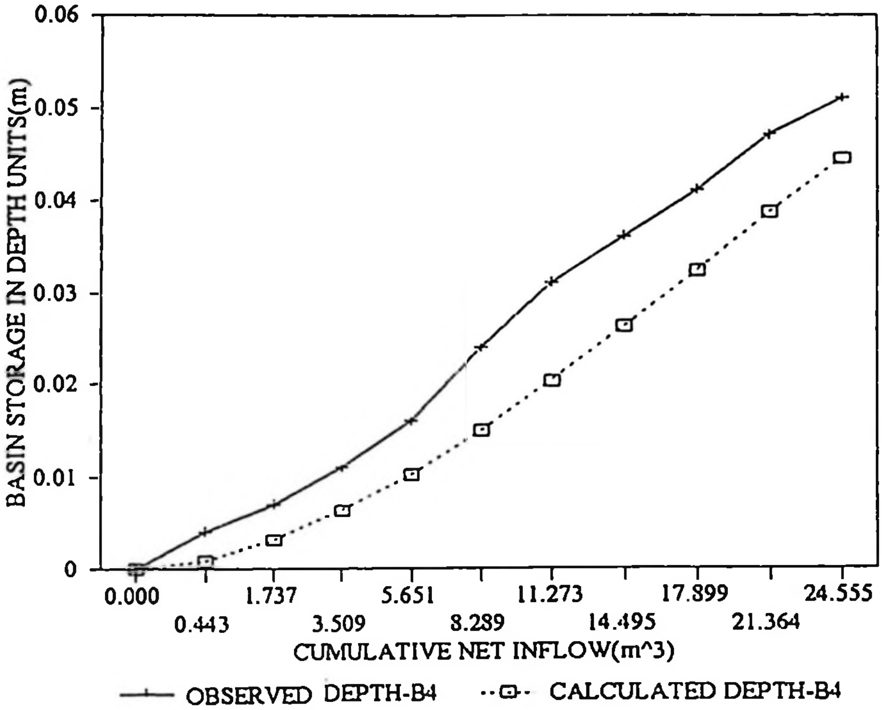

SURFACE STORAGE IN DEPTH UNITS(m)
0.05
0.04
0.03
0.02
0.01
0
-0.01
0.000
-0.055
0.409
1.438
2.752
4.128
5.630
7.260
8.844
10.320
11.630
12.754
13.779
14.647
15.512
16.313
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-A4
CALCULATED DEPTH-A4

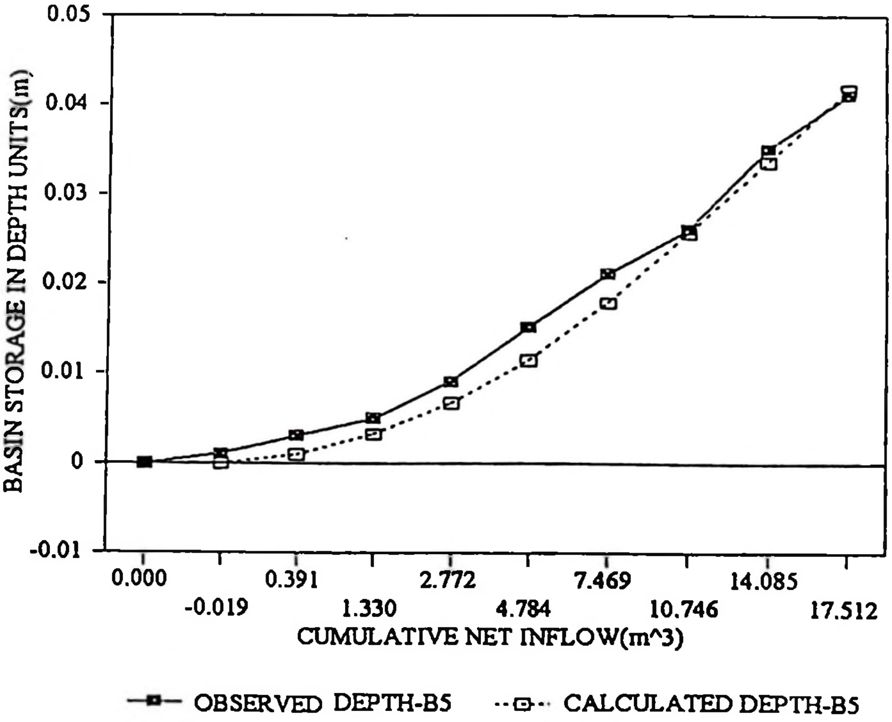

0.05
0.04
0.03
0.02
0.01
0
SURFACE STORAGE IN DEPTH UNITS(m)
0.000
1.249
3.533
6.828
10.672
14.074
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-A5
CALCULATED DEPTH-A5

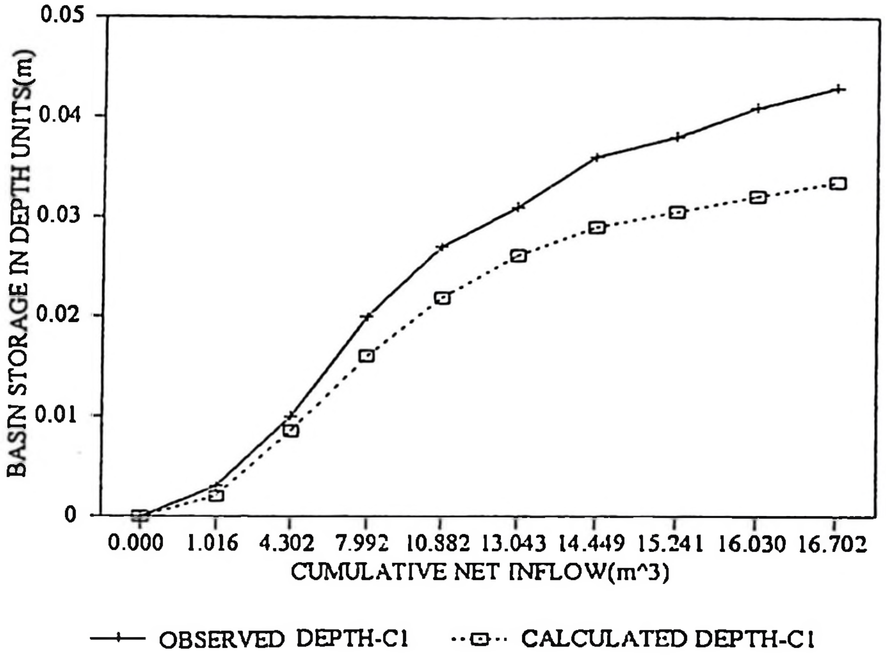

0.1
0.08
0.06
0.04
0.02
0
BASIN STORAGE IN DEPTH UNITS(m)
0.000
3.774
11.972
19.103
24.197
28.054
30.978
33.184
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-B1
CALCULATED DEPTH-B1

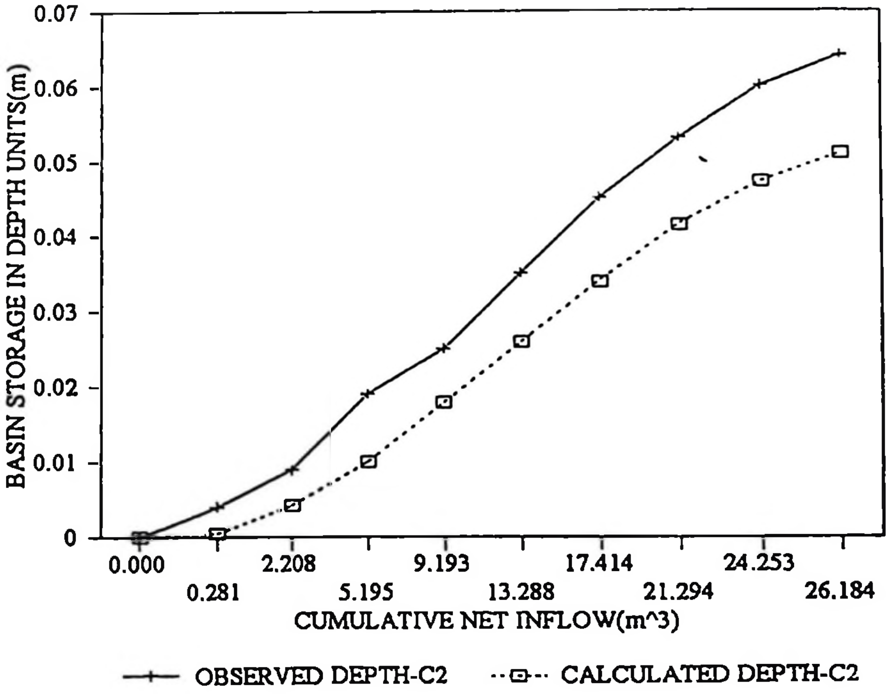

0.08
0.06
0.04
0.02
0
BASIN STORAGE IN DEPTH UNITS(m)
0.000
1.043
4.165
8.464
12.862
16.554
19.418
21.245
22.099
22.432
22.569
22.724
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-B2
CALCULATED DEPTH-B2

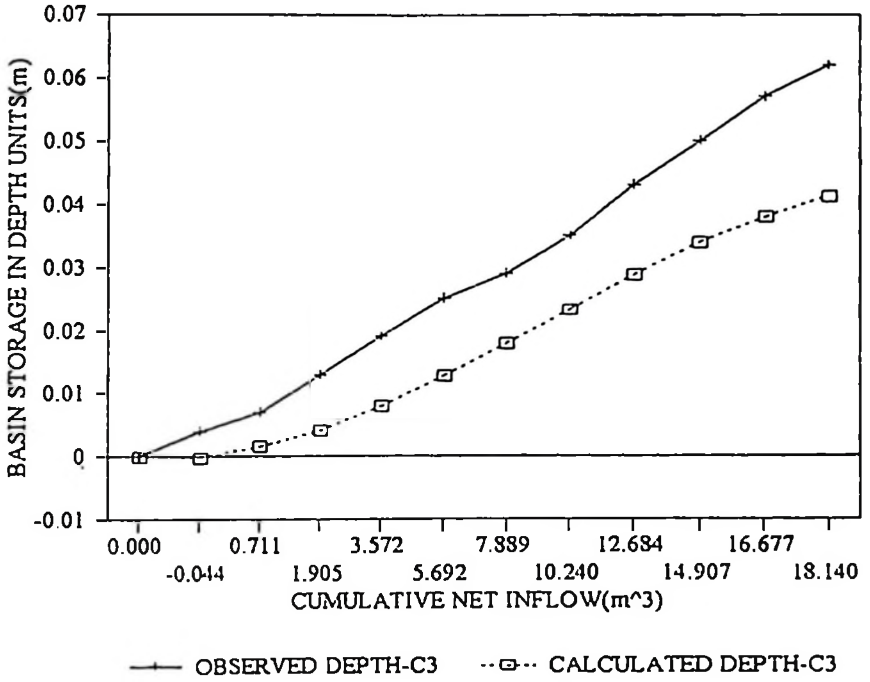

0.1
0.08
0.06
0.04
0.02
0
BASIN STORAGE IN DEPTH UNITS(m)
0.000
0.993
3.245
6.475
10.481
14.880
19.049
22.860
26.202
29.202
31.739
33.912
35.726
37.145
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-B3
CALCULATED DEPTH-B3

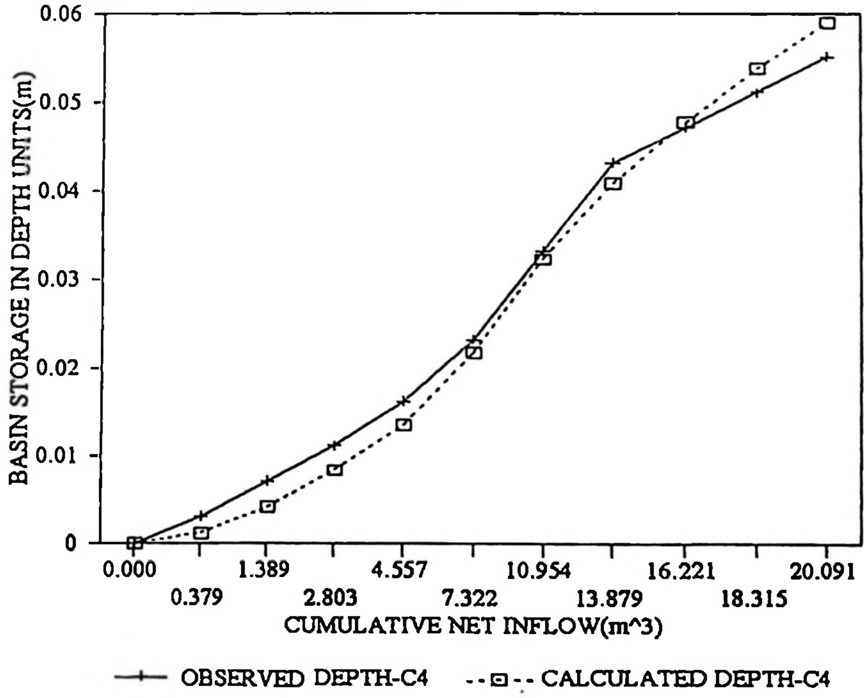

0.06
0.05
0.04
0.03
0.02
0.01
0
BASIN STORAGE IN DEPTH UNITS(m)
0.000
0.443
1.737
3.509
5.651
8.289
11.273
14.495
17.899
21.364
24.555
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-B4
CALCULATED DEPTH-B4

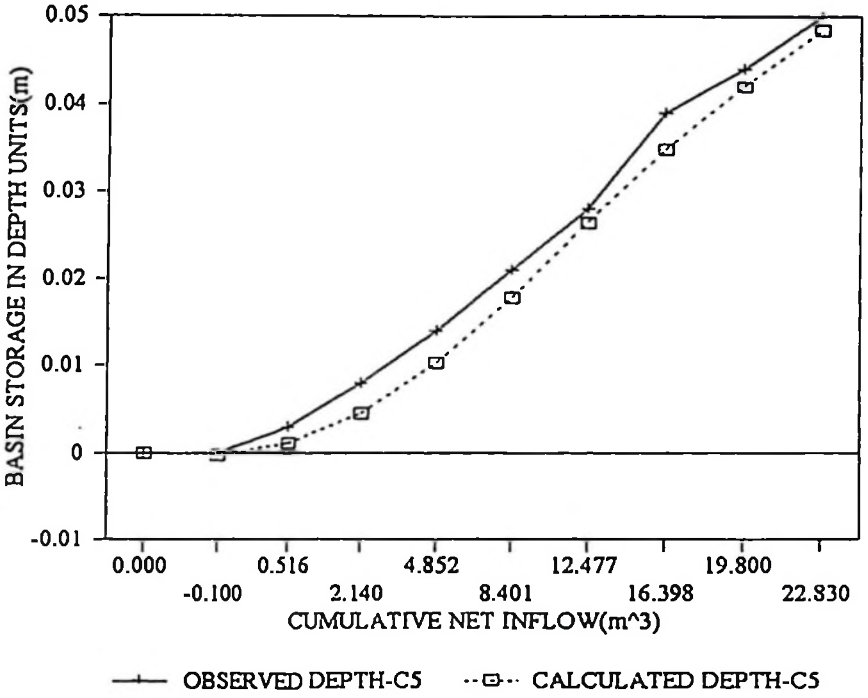

0.05
0.04
0.03
0.02
0.01
0
-0.01
BASIN STORAGE IN DEPTH UNITS(m)
0.000
-0.019
0.391
1.330
2.772
4.784
7.469
10.746
14.085
17.512
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-B5
CALCULATED DEPTH-B5

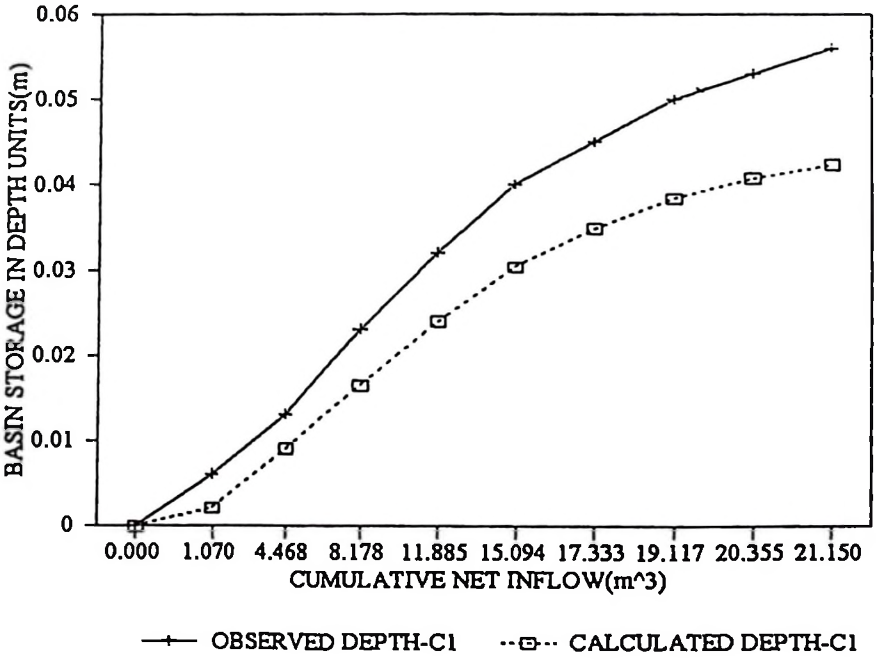

0.05
0.04
0.03
0.02
0.01
0
BASIN STORAGE IN DEPTH UNITS(m)
0.000
1.016
4.302
7.992
10.882
13.043
14.449
15.241
16.030
16.702
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-C1
CALCULATED DEPTH-C1


0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
BASIN STORAGE IN DEPTH UNITS(m)
0.000
0.281
2.208
5.195
9.193
13.288
17.414
21.294
24.253
26.184
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-C2
CALCULATED DEPTH-C2


BASIN STORAGE IN DEPTH UNITS(m)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0.000
-0.044
0.711
1.905
3.572
5.692
7.889
10.240
12.684
14.907
16.677
18.140
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-C3
CALCULATED DEPTH-C3


BASIN STORAGE IN DEPTH UNITS(m)
0.06
0.05
0.04
0.03
0.02
0.01
0
0.000
0.379
1.389
2.803
4.557
7.322
10.954
13.879
16.221
18.315
20.091
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-C4
CALCULATED DEPTH-C4


0.05
0.04
0.03
0.02
0.01
0
-0.01
BASIN STORAGE IN DEPTH UNITS(m)
0.000
-0.100
0.516
2.140
4.852
8.401
12.477
16.398
19.800
22.830
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-C5
CALCULATED DEPTH-C5


0.06
0.05
0.04
0.03
0.02
0.01
0
BASIN STORAGE IN DEPTH UNITS(m)
0.000
1.070
4.468
8.178
11.885
15.094
17.333
19.117
20.355
21.150
CUMULATIVE NET INFLOW(m^3)
OBSERVED DEPTH-C1
CALCULATED DEPTH-C1

APPENDIX F

Computer program testing input data and output

Appendix F-1 Input data

Field characteristics

Number of fields	1
Number of basins	5
Acceleration due to gravity	9.81m/s^2
Saturated hydraulic conductivity(k_{sat})	1.1239160566126E-06 m/s
Horizontal hydraulic conductivity(k_h)	3.182560082E-07 m/s

Meteorological data

Pan : Colorado Sunken Pan

- Windward side distance from green crop = 10m
- Round in shape, painted black inside, use cup to add water, placed 4 inch from the ground surface.

Wind speed : 0.5km/hr(12km/day)

Humidity : 74%

Pan evaporation : 3.744 mm/day

BASIN	WEIR WIDTH (cm)		WEIR COEFFICIENT		BASE LEVEL DIFFERENCE (cm)			
	IN	OUT	IN	OUT	SIDE A	SIDE B	SIDEC	SIDE D
A1	39.3	39.6	1.078	1.143	10.0	19.3	7.0	14.3
A2	39.6	40.0	1.143	1.314	-7.0	14.3	14.0	0.3
A3	40.0	38.9	1.314	1.493	-14.0	31.0	21.0	0.0
A4	38.9	39.0	1.493	1.214	-21.0	38.0	19.0	0.0
A5	39.0	39.5	1.214	1.635	-19.0	31.3	7.0	0.0

BASIN	AREA	BUND WIDTH(cm)				BUND LENGTH(cm)				No. OF STEP MEASUREMENTS
		SIDE A	SIDE B	SIDE C	SIDE D	SIDE A	SIDE B	SIDE C	SIDE D	
A1	275.97	42	75	42	42	29.9	13.1	26.7	5.4	10
A2	433.23	42	75	42	42	26.7	16.0	27.3	16.6	14
A3	314.96	42	60	42	42	27.3	10.3	27.8	12.9	9
A4	342.01	42	60	42	42	27.8	13.1	27.2	11.9	11
A5	348.04	42	90	50	42	27.2	13.4	26.7	12.5	6

Water measurement data

PLOT	CHANGE IN TIME,Δt (min)	SURFACE FLOW AT INFLOW WEIR Weir	SURFACE FLOW AT INFLOW WEIR Yel ΔZa (cm)	SURFACE FLOW AT OUTFLOW WEIR Weir	SURFACE FLOW AT OUTFLOW WEIR Yel-ΔZa (cm)	Rainfall (mm)	WATER LEVEL IN PLOT(cm) Staff reading	WATER LEVEL IN PLOT(cm) Water depth	AVERAGE WATER LEVEL IN ADJUCENT PLOT/DRAIN(cm) Staff reading A	B	C	D	Water depth A	B	C	D	REMARKS
A1	0.000	1	0.0	2	0.0	0.0	9.8	2.6	21.7	19.0	12.6	6.2	21.7	19.0	4.2	6.2	Inflow into A1 at 8.50am
A1	10.000	1	3.8	2	0.0	0.0	10.3	3.1	21.7	19.0	12.6	6.2	21.7	19.0	4.2	6.2	
A1	10.000	1	4.9	2	0.0	0.0	12.2	5.0	21.7	19.0	12.6	6.2	21.7	19.0	4.2	6.2	
A1	10.000	1	5.0	2	0.0	0.0	13.6	6.4	21.7	19.0	12.6	6.2	21.7	19.0	4.2	6.2	
A1	10.000	1	5.3	2	0.0	0.0	15.0	7.8	21.7	19.0	12.6	6.2	21.7	19.0	4.2	6.2	Fill and spill into A2 at 9.30am
A1	10.000	1	5.9	2	1.9	0.0	16.5	9.3	21.7	19.0	12.8	6.2	21.7	19.0	4.4	6.2	
A1	10.000	1	6.3	2	3.4	0.0	17.9	10.7	21.7	19.0	13.3	6.2	21.7	19.0	4.9	6.2	
A1	10.000	1	6.4	2	4.1	0.0	18.8	11.6	21.7	19.0	13.9	6.2	21.7	19.0	5.5	6.2	
A1	10.000	1	6.3	2	4.6	0.0	19.5	12.3	21.7	19.0	14.9	6.2	21.7	19.0	6.5	6.2	
A1	10.000	1	6.3	2	4.8	0.0	19.8	12.6	21.7	19.0	15.9	6.2	21.7	19.0	7.5	6.2	
A2	0.000	2	0.0	3	0.0	0.0	12.1	3.7	15.3	12.0	11.8	7.4	8.1	12.0	2.9	7.4	Spill into A2 at 9.33am
A2	15.000	2	2.3	3	0.0	0.0	12.3	3.9	16.2	12.0	11.8	7.4	9.0	12.0	2.9	7.4	
A2	10.000	2	2.8	3	0.0	0.0	12.5	4.1	17.0	12.0	11.8	7.4	9.8	12.0	2.9	7.4	
A2	10.000	2	3.3	3	0.0	0.0	13.0	4.6	17.5	12.0	11.8	7.4	10.3	12.0	2.9	7.4	
A2	10.000	2	3.3	3	0.0	0.0	13.5	5.1	17.8	12.0	11.8	7.4	10.6	12.0	2.9	7.4	
A2	10.000	2	3.7	3	0.0	0.0	14.1	5.7	17.9	12.0	11.8	7.4	10.7	12.0	2.9	7.4	Fill and spill into A3 at 10.25am
A2	10.000	2	3.8	3	0.8	0.0	14.7	6.3	18.2	12.0	12.0	7.4	11.0	12.0	3.1	7.4	
A2	10.000	2	3.9	3	1.3	0.0	15.3	6.9	18.2	12.0	12.0	7.4	11.0	12.0	3.1	7.4	
A2	10.000	2	4.2	3	1.8	0.0	15.7	7.3	18.2	12.0	12.3	7.4	11.0	12.0	3.4	7.4	
A2	10.000	2	4.2	3	2.1	0.0	16.3	7.9	18.2	12.0	12.7	7.4	11.0	12.0	3.8	7.4	
A2	10.000	2	4.3	3	2.4	0.0	16.6	8.2	18.2	12.0	13.2	7.4	11.0	12.0	4.3	7.4	
A2	10.000	2	4.3	3	2.8	0.0	17.0	8.6	18.2	12.0	13.8	7.4	11.0	12.0	4.9	7.4	
A2	10.000	2	4.3	3	3.3	0.0	17.2	8.8	18.2	12.0	14.3	7.4	11.0	12.0	5.4	7.4	
A2	10.000	2	4.3	3	3.3	0.0	17.5	9.1	18.2	12.0	14.9	7.4	11.0	12.0	6.0	7.4	
A3	0.000	3	0.0	4	0.0	0.0	14.3	5.4	17.2	15.0	16.1	9.5	8.8	15.0	5.0	9.5	Spill into A3 at 10.25am
A3	40.000	3	2.7	4	0.0	0.0	15.9	7.0	19.1	15.0	16.1	9.5	10.7	15.0	5.0	9.5	
A3	10.000	3	3.3	4	0.0	0.0	16.7	7.8	19.8	15.0	16.1	9.5	11.4	15.0	5.0	9.5	Fill and spill into A4 at 11.15am
A3	10.000	3	3.8	4	1.1	0.0	17.7	8.8	20.3	15.0	16.1	9.5	11.5	15.0	5.6	9.5	
A3	10.000	3	4.3	4	2.1	0.0	18.2	9.3	20.8	15.0	16.8	9.5	12.4	15.0	6.3	9.5	
A3	10.000	3	4.3	4	2.8	0.0	19.1	10.2	20.8	15.0	17.4	9.5	12.4	15.0	6.9	9.5	
A3	10.000	3	4.8	4	3.4	0.0	19.8	10.9	20.8	15.0	18.2	9.5	12.4	15.0	7.7	9.5	
A3	10.000	3	4.9	4	3.8	0.0	20.3	11.4	20.8	15.0	19.0	9.5	12.4	15.0	8.5	9.5	
A3	10.000	3	5.2	4	4.2	0.0	20.7	11.8	20.8	15.0	19.9	9.5	12.4	15.0	9.4	9.5	
A4	0.000	4	0.0	5	0.0	0.0	15.4	4.9	20.5	21.0	13.7	13.7	11.6	21.0	4.1	13.7	Spill into A4 at 11.15am
A4	20.000	4	2.3	5	0.0	0.0	16.2	5.7	20.5	21.0	13.7	13.7	11.6	21.0	4.1	13.7	
A4	10.000	4	2.7	5	0.0	0.0	16.9	6.4	20.5	21.0	13.7	13.7	11.6	21.0	4.1	13.7	
A4	10.000	4	3.3	5	0.0	0.0	18.0	7.5	20.5	21.0	13.7	13.7	11.6	21.0	4.1	13.7	Fill and spill into A5 at 12.05pm
A4	10.000	4	3.7	5	0.0	0.0	18.8	8.3	20.5	21.0	13.7	13.7	11.6	21.0	4.1	13.7	
A4	10.000	4	3.8	5	1.1	0.0	19.5	9.9	20.5	21.0	13.7	13.7	11.6	21.0	4.1	13.7	
A4	10.000	4	3.8	5	2.2	0.0	20.0	9.5	20.5	21.0	14.4	13.7	11.6	21.0	4.8	13.7	
A4	10.000	4	4.2	5	2.8	0.0	20.7	10.2	20.5	21.0	15.0	13.7	11.6	21.0	5.4	13.7	
A4	10.000	4	4.3	5	3.3	0.0	21.3	10.8	20.5	21.0	15.7	13.7	11.6	21.0	6.1	13.7	
A4	10.000	4	4.4	5	3.8	0.0	21.8	11.3	20.5	21.0	16.6	13.7	11.6	21.0	7.0	13.7	Start raining
A4	10.000	4	4.8	5	4.5	1.5	22.4	11.9	20.5	21.0	18.1	13.7	11.6	21.0	8.5	13.7	
A5	0.000	5	0.0	6	0.0	0.0	13.1	3.5	18.3	22.7	8.5	11.7	7.8	22.7	8.5	11.7	Spill into A5 at 12.05pm
A5	20.000	5	2.5	6	0.0	0.0	13.8	4.2	20.1	22.7	8.5	11.7	9.6	22.7	8.5	11.7	
A5	10.000	5	3.4	6	0.0	0.0	14.4	4.8	20.6	22.7	8.5	11.7	10.1	22.7	8.5	11.7	
A5	10.000	5	3.9	6	0.0	0.0	15.2	5.6	21.6	22.7	8.5	11.7	11.1	22.7	8.5	11.7	
A5	10.000	5	4.3	6	0.0	0.0	16.3	6.7	22.1	22.7	8.5	11.7	11.6	22.7	8.5	11.7	Leakage into A5
A5	10.000	5	4.5	6	1.9	0.0	16.8	7.2	22.1	22.7	8.5	11.7	11.6	22.7	8.3	11.7	Fill and spill out of A5 at 12.55pm

Processed inflows and outflows (from spreadsheet computation)

INFLOW		OUTFLOW							
Surface inflow (m^3/s) (Eqn 2 33)	Rainfall amount after time,Δt (mm)	Surface outflow (m^3/s) (Eqn 2 33)	ETc (mm/min)	SEAPAGE(m^3/s) (Eqn 3 13) A	B	C	D	Net seapage across bunds, HS(m^3/s)	Percolation losses,VS (m^3/s)
0.0000	0.0	0.0000	0.0026	-5.361E-08	4.191E-09	2.841E-08	1.138E-08	-9.625E-09	3.102E-04
0.0053	0.0	0.0000	0.0026	-6.040E-08	5.859E-09	3.700E-08	1.421E-08	-3.333E-09	3.102E-04
0.0078	0.0	0.0000	0.0026	-7.590E-08	1.473E-08	7.890E-08	2.680E-08	4.454E-08	3.102E-04
0.0081	0.0	0.0000	0.0026	-7.685E-08	2.384E-08	1.191E-07	3.797E-08	1.041E-07	3.102E-04
0.0083	0.0	0.0000	0.0026	-6.892E-08	3.512E-08	1.673E-07	5.075E-08	1.842E-07	3.102E-04
0.0103	0.0	0.0020	0.0026	-5.057E-08	4.953E-08	2.239E-07	6.621E-08	2.892E-07	3.102E-04
0.0114	0.0	0.0043	0.0026	-2.424E-08	6.543E-08	2.771E-07	8.231E-08	4.006E-07	3.102E-04
0.0117	0.0	0.0064	0.0026	-2.628E-09	7.673E-08	3.074E-07	9.351E-08	4.751E-07	3.102E-04
0.0114	0.0	0.0076	0.0026	1.672E-08	8.615E-08	3.185E-07	1.027E-07	5.241E-07	3.102E-04
0.0114	0.0	0.0031	0.0026	2.569E-08	9.035E-08	3.085E-07	1.057E-07	5.312E-07	3.102E-04
0.0000	0.0	0.0000	0.0026	-3.534E-08	1.507E-08	1.133E-07	-1.582E-08	2.719E-08	4.869E-04
0.0025	0.0	0.0000	0.0026	-9.547E-08	1.642E-08	1.210E-07	-1.570E-08	2.626E-08	4.869E-04
0.0036	0.0	0.0000	0.0026	-1.053E-07	1.782E-08	1.239E-07	-1.547E-08	2.591E-08	4.869E-04
0.0044	0.0	0.0000	0.0026	-1.182E-07	2.155E-08	1.494E-07	-1.447E-08	3.829E-08	4.869E-04
0.0045	0.0	0.0000	0.0026	-1.290E-07	2.562E-08	1.709E-07	-1.283E-08	5.473E-08	4.869E-04
0.0055	0.0	0.0000	0.0026	-1.384E-07	3.096E-08	1.981E-07	-1.004E-08	8.063E-08	4.869E-04
0.0057	0.0	0.0006	0.0026	-1.491E-07	3.679E-08	2.242E-07	-6.340E-09	1.055E-07	4.869E-04
0.0057	0.0	0.0013	0.0026	-1.550E-07	4.310E-08	2.541E-07	-1.736E-09	1.405E-07	4.869E-04
0.0056	0.0	0.0022	0.0026	-1.580E-07	4.758E-08	2.703E-07	1.836E-09	1.617E-07	4.869E-04
0.0066	0.0	0.0027	0.0026	-1.614E-07	5.471E-08	2.958E-07	7.950E-09	1.970E-07	4.869E-04
0.0069	0.0	0.0033	0.0026	-1.626E-07	5.846E-08	3.036E-07	1.135E-08	2.109E-07	4.869E-04
0.0069	0.0	0.0042	0.0026	-1.636E-07	6.364E-08	3.149E-07	1.623E-08	2.312E-07	4.869E-04
0.0069	0.0	0.0054	0.0026	-1.638E-07	6.632E-08	3.168E-07	1.882E-08	2.381E-07	4.869E-04
0.0069	0.0	0.0054	0.0026	-1.639E-07	7.043E-08	3.219E-07	2.289E-08	2.514E-07	4.869E-04
0.0000	0.0	0.0000	0.0026	-1.944E-07	6.313E-08	2.366E-07	-2.164E-08	8.373E-08	3.540E-04
0.0040	0.0	0.0000	0.0026	-2.563E-07	8.796E-08	3.303E-07	-1.711E-08	1.449E-07	3.540E-04
0.0054	0.0	0.0000	0.0026	-2.840E-07	1.014E-07	3.812E-07	-1.296E-08	1.857E-07	3.540E-04
0.0066	0.0	0.0011	0.0026	-3.113E-07	1.192E-07	4.436E-07	-6.021E-09	2.505E-07	3.540E-04
0.0080	0.0	0.0030	0.0026	-3.290E-07	1.285E-07	4.702E-07	-1.818E-09	2.679E-07	3.540E-04
0.0080	0.0	0.0046	0.0026	-3.418E-07	1.460E-07	5.221E-07	6.979E-09	3.333E-07	3.540E-04
0.0094	0.0	0.0062	0.0026	-3.495E-07	1.602E-07	5.557E-07	1.492E-08	3.813E-07	3.540E-04
0.0097	0.0	0.0073	0.0026	-3.537E-07	1.707E-07	5.740E-07	2.117E-08	4.120E-07	3.540E-04
0.0106	0.0	0.0085	0.0026	-3.564E-07	1.792E-07	5.817E-07	2.653E-08	4.310E-07	3.540E-04
0.0000	0.0	0.0000	0.0026	-2.859E-07	7.457E-08	2.000E-07	-3.888E-08	-5.027E-08	3.844E-04
0.0032	0.0	0.0000	0.0026	-3.230E-07	8.991E-08	2.420E-07	-4.112E-08	-3.220E-08	3.844E-04
0.0044	0.0	0.0000	0.0026	-3.532E-07	1.041E-07	2.810E-07	-4.213E-08	-1.033E-08	3.844E-04
0.0059	0.0	0.0000	0.0026	-3.966E-07	1.277E-07	3.463E-07	-4.193E-08	3.545E-08	3.844E-04
0.0070	0.0	0.0000	0.0026	-4.249E-07	1.459E-07	3.969E-07	-4.042E-08	7.751E-08	3.844E-04
0.0073	0.0	0.0009	0.0026	-4.474E-07	1.626E-07	4.433E-07	-3.814E-08	1.204E-07	3.844E-04
0.0073	0.0	0.0026	0.0026	-4.623E-07	1.749E-07	4.641E-07	-3.598E-08	1.407E-07	3.844E-04
0.0085	0.0	0.0038	0.0026	-4.813E-07	1.928E-07	5.003E-07	-3.219E-08	1.796E-07	3.844E-04
0.0088	0.0	0.0048	0.0026	-4.960E-07	2.086E-07	5.276E-07	-2.824E-08	2.120E-07	3.844E-04
0.0091	0.0	0.0055	0.0026	-5.070E-07	2.222E-07	5.427E-07	-2.445E-08	2.334E-07	3.844E-04
0.0104	1.5	0.0077	0.0026	-5.189E-07	2.390E-07	5.494E-07	-1.931E-08	2.502E-07	3.844E-04
0.0000	0.0	0.0000	0.0026	-1.681E-07	2.007E-08	1.190E-08	-2.718E-08	-1.633E-07	3.912E-04
0.0032	0.0	0.0000	0.0026	-2.112E-07	2.547E-08	1.927E-08	-2.984E-08	-1.963E-07	3.912E-04
0.0051	0.0	0.0000	0.0026	-2.404E-07	3.048E-08	2.692E-08	-3.137E-08	-2.144E-07	3.912E-04
0.0062	0.0	0.0000	0.0026	-2.828E-07	3.768E-08	3.902E-08	-3.236E-08	-2.384E-07	3.912E-04
0.0072	0.0	0.0000	0.0026	-3.300E-07	4.857E-08	5.921E-08	-3.173E-08	-2.540E-07	3.912E-04
0.0077	0.0	0.0029	0.0026	-3.473E-07	5.390E-08	6.975E-08	-3.069E-08	-2.543E-07	3.912E-04

Results from spreadsheet computation

OBSERVED CHANGE IN DEPTH, Δh(m)	OBSERVED DEPTH (m)	CALCULATED CHANGE IN DEPTH, Δh(m) (Eqn 3 3)	CALCULATED DEPTH (m)	NET INFLOW VOLUME IN TIMEΔt (m^3) (Eqn 3 4)	CUMMULATIVE NET INFLOW VOLUME IN (m^3)	CALCULATED CHANGE IN TIME t(min) USING CALCULATED Δh (Eqn 3 5)
-	0.026	0.000	0.026	0.000	0.000	-
0.005	0.031	0.005	0.031	1.409	1.409	10.000
0.019	0.050	0.014	0.045	3.755	5.164	10.000
0.014	0.064	0.017	0.061	4.571	9.736	10.000
0.014	0.078	0.018	0.079	4.864	14.600	10.000
0.015	0.093	0.018	0.097	4.940	19.540	10.000
0.014	0.107	0.015	0.112	4.271	23.811	10.000
0.009	0.116	0.012	0.124	3.359	27.170	10.000
0.007	0.123	0.009	0.133	2.527	29.697	10.000
0.003	0.126	0.007	0.140	1.933	31.630	10.000
-	0.037	0.000	0.037	0.000	0.000	-
0.002	0.039	0.002	0.039	0.677	0.677	15.000
0.002	0.041	0.004	0.042	1.535	2.212	10.000
0.005	0.046	0.005	0.047	2.104	4.317	10.000
0.005	0.051	0.006	0.052	2.407	6.724	10.000
0.006	0.057	0.006	0.059	2.729	9.453	10.000
0.006	0.063	0.007	0.065	2.864	12.317	10.000
0.006	0.069	0.006	0.071	2.533	14.850	10.000
0.004	0.073	0.005	0.077	2.353	17.203	10.000
0.006	0.079	0.005	0.082	2.211	19.414	10.000
0.003	0.082	0.004	0.086	1.933	21.347	10.000
0.004	0.086	0.004	0.090	1.563	22.910	10.000
0.002	0.088	0.002	0.092	0.951	23.861	10.000
0.003	0.091	0.001	0.093	0.599	24.459	10.000
-	0.054	0.000	0.054	0.000	0.000	-
0.016	0.070	0.012	0.066	3.887	3.887	40.000
0.008	0.078	0.008	0.074	2.583	6.470	10.000
0.010	0.088	0.010	0.084	3.039	9.510	10.000
0.005	0.093	0.009	0.093	2.922	12.432	10.000
0.009	0.102	0.007	0.101	2.280	14.712	10.000
0.007	0.109	0.006	0.106	1.754	16.466	10.000
0.005	0.114	0.005	0.111	1.465	17.931	10.000
0.004	0.118	0.004	0.114	1.132	19.063	10.000
-	0.049	0.000	0.049	0.000	0.000	-
0.008	0.057	0.004	0.053	1.456	1.456	20.000
0.007	0.064	0.006	0.059	2.044	3.500	10.000
0.011	0.075	0.008	0.068	2.854	6.355	10.000
0.008	0.083	0.011	0.078	3.649	10.004	10.000
0.007	0.090	0.011	0.089	3.789	13.792	10.000
0.005	0.095	0.009	0.098	3.084	16.876	10.000
0.007	0.102	0.008	0.106	2.584	19.461	10.000
0.006	0.108	0.007	0.113	2.370	21.831	10.000
0.005	0.113	0.006	0.119	2.035	23.866	10.000
0.006	0.119	0.006	0.125	2.162	26.028	10.000
-	0.035	0.000	0.035	0.000	0.000	-
0.007	0.042	0.004	0.039	1.428	1.428	20.000
0.006	0.048	0.006	0.046	2.233	3.661	10.000
0.008	0.056	0.009	0.055	3.141	6.802	10.000
0.011	0.067	0.011	0.066	3.782	10.584	10.000
0.005	0.072	0.010	0.075	3.364	13.948	10.000

COMPUTER PROGRAM OUTPUT

Input data

```
                    CROP DATA
                    ~~~~~~~~~

CROP TYPE                   :  RICE
DEVELOPMENT STAGE           :  CROP DEVELOPMENT
CROP COEFFICIENT            :  1.3
CROP EVAPOTRANSPIRATION     :  4.8672   mm/day   ( 0.0034mm/min)




                    SOIL DATA
                    ~~~~~~~~~
     FIELD  1            BASIN  1
     ~~~~~~~~            ~~~~~~~~

SATURATED VERTICAL HYDRAULIC CONDUCTIVITY(Ksat): 1.123916E-06 m/s
HORIZONTAL HYDRAULIC CONDUCTIVITY(Kh)          : 3.18256E-07 m/s

                    SOIL DATA
                    ~~~~~~~~~
     FIELD  1            BASIN  2
     ~~~~~~~~            ~~~~~~~~

SATURATED VERTICAL HYDRAULIC CONDUCTIVITY(Ksat): 1.123916E-06 m/s
HORIZONTAL HYDRAULIC CONDUCTIVITY(Kh)          : 3.18256E-07 m/s

                    SOIL DATA
                    ~~~~~~~~~
     FIELD  1            BASIN  3
     ~~~~~~~~            ~~~~~~~~

SATURATED VERTICAL HYDRAULIC CONDUCTIVITY(Ksat): 1.123916E-06 m/s
HORIZONTAL HYDRAULIC CONDUCTIVITY(Kh)          : 3.18256E-07 m/s

                    SOIL DATA
                    ~~~~~~~~~~
     FIELD  1            BASIN  4
     ~~~~~~~~            ~~~~~~~~

SATURATED VERTICAL HYDRAULIC CONDUCTIVITY(Ksat): 1.123916E-06 m/s
HORIZONTAL HYDRAULIC CONDUCTIVITY(Kh)          : 3.18256E-07 m/s

                    SOIL DATA
                    ~~~~~~~~~~
     FIELD  1            BASIN  5
     ~~~~~~~~            ~~~~~~~~

SATURATED VERTICAL HYDRAULIC CONDUCTIVITY(Ksat): 1.123916E-06 m/s
HORIZONTAL HYDRAULIC CONDUCTIVITY(Kh)          : 3.18256E-07 m/s
```

METEOROLOGICAL DATA

RELATIVE HUMIDITY : 74 %
WIND : .5 km/day
PAN LOCATION : Short green cropped area
PAN TYPE : Colorado Sunken Pan
WINDWARD SIDE DISTANCE OF SHORT GREEN CROPPED AREA : 10 m

PAN EVAPORATION : 3.744 mm/day

PAN COEFFICIENT : 1

FIELD CHARACTERISTICS DATA

FIELD 1 BASIN 1

BASIN AREA = 275.97 m^2

	BUND WIDTH(cm)	BUND LENGTH(m)	LEVEL DIFFERENCE(cm)
SIDE A	42	29.9	10
SIDE B	75	13.1	19.3
SIDE C	42	26.7	7
SIDE D	42	5.4	14.3

FIELD CHARACTERISTICS DATA

FIELD 1 BASIN 2

BASIN AREA = 433.23 m^2

	BUND WIDTH(cm)	BUND LENGTH(m)	LEVEL DIFFERENCE(cm)
SIDE A	42	26.7	-7
SIDE B	75	16	14.3
SIDE C	42	27.3	14
SIDE D	42	16.6	.3

FIELD CHARACTERISTICS DATA

FIELD 1 **BASIN 3**

BASIN AREA = 314.96 m^2

	BUND WIDTH(cm)	BUND LENGTH(m)	LEVEL DIFFERENCE(cm)
SIDE A	42	27.3	-14
SIDE B	60	10.3	31
SIDE C	42	27.8	21
SIDE D	42	12.9	0

FIELD CHARACTERISTICS DATA

FIELD 1 **BASIN 4**

BASIN AREA = 342.01 m^2

	BUND WIDTH(cm)	BUND LENGTH(m)	LEVEL DIFFERENCE(cm)
SIDE A	42	27.8	-21
SIDE B	60	13.1	38
SIDE C	42	27.2	19
SIDE D	42	11.9	0

FIELD CHARACTERISTICS DATA

FIELD 1 **BASIN 5**

BASIN AREA = 348.04 m^2

	BUND WIDTH(cm)	BUND LENGTH(m)	LEVEL DIFFERENCE(cm)
SIDE A	42	27.2	-19
SIDE B	90	13.4	31.3
SIDE C	50	26.7	7
SIDE D	42	12.5	0

WATER MEASUREMENTS DATA FIELD 1 BASIN 1

No.	Time (min)	Weir Measurements Inflow Bo (cm)	Inflow Coef	Outflow Bo (cm)	Outflow Coef	Water depth(cm) over weir In	Out	Approach velocity (m/s) In	Out	Rain fall (mm)	Basin water depth (cm)	Depth in adj. basin or canal (mm) A	B	C	D
1	0	39.3	1.078	39.6	1.143	0.0	0.0	0.0	0.0	0.0	2.6	21.7	19.0	4.2	6.2
2	10	39.3	1.078	39.6	1.143	3.8	0.0	0.0	0.0	0.0	3.1	21.7	19.0	4.2	6.2
3	20	39.3	1.078	39.6	1.143	4.9	0.0	0.0	0.0	0.0	5.0	21.7	19.0	4.2	6.2
4	30	39.3	1.078	39.6	1.143	5.0	0.0	0.0	0.0	0.0	6.4	21.7	19.0	4.2	6.2
5	40	39.3	1.078	39.6	1.143	5.3	0.0	0.0	0.0	0.0	7.8	21.7	19.0	4.2	6.2
6	50	39.3	1.078	39.6	1.143	5.9	1.9	0.0	0.0	0.0	9.3	21.7	19.0	4.4	6.2
7	60	39.3	1.078	39.6	1.143	6.3	3.4	0.0	0.0	0.0	10.7	21.7	19.0	4.9	6.2
8	70	39.3	1.078	39.6	1.143	6.4	4.1	0.0	0.0	0.0	11.6	21.7	19.0	5.5	6.2
9	80	39.3	1.078	39.6	1.143	6.3	4.6	0.0	0.0	0.0	12.3	21.7	19.0	6.5	6.2
10	90	39.3	1.078	39.6	1.143	6.3	4.8	0.0	0.0	0.0	12.6	21.7	19.0	7.5	6.2

WATER MEASUREMENTS DATA FIELD 1 BASIN 2

No.	Time (min)	Weir Measurements Inflow Bo (cm)	Inflow Coef	Outflow Bo (cm)	Outflow Coef	Water depth(cm) over weir In	Out	Approach velocity (m/s) In	Out	Rain fall (mm)	Basin water depth (cm)	Depth in adj. basin or canal (mm) A	B	C	D
1	0	39.6	1.143	40.0	1.314	0.0	0.0	0.0	0.0	0.0	3.7	8.1	12.0	2.9	7.4
2	15	39.6	1.143	40.0	1.314	2.2	0.0	0.0	0.0	0.0	3.9	9.0	12.0	2.9	7.4
3	25	39.6	1.143	40.0	1.314	2.8	0.0	0.0	0.0	0.0	4.1	9.8	12.0	2.9	7.4
4	35	39.6	1.143	40.0	1.314	3.2	0.0	0.0	0.0	0.0	4.6	10.3	12.0	2.9	7.4
5	45	39.6	1.143	40.0	1.314	3.3	0.0	0.0	0.0	0.0	5.1	10.6	12.0	2.9	7.4
6	55	39.6	1.143	40.0	1.314	3.7	0.0	0.0	0.0	0.0	5.7	10.7	12.0	2.9	7.4
7	65	39.6	1.143	40.0	1.314	3.8	0.8	0.0	0.0	0.0	6.3	11.0	12.0	3.1	7.4
8	75	39.6	1.143	40.0	1.314	3.8	1.3	0.0	0.0	0.0	6.9	11.0	12.0	3.1	7.4
9	85	39.6	1.143	40.0	1.314	4.2	1.8	0.0	0.0	0.0	7.3	11.0	12.0	3.4	7.4
10	95	39.6	1.143	40.0	1.314	4.2	2.1	0.0	0.0	0.0	7.9	11.0	12.0	3.8	7.4
11	105	39.6	1.143	40.0	1.314	4.3	2.4	0.0	0.0	0.0	8.2	11.0	12.0	4.3	7.4
12	115	39.6	1.143	40.0	1.314	4.3	2.8	0.0	0.0	0.0	8.6	11.0	12.0	4.9	7.4
13	125	39.6	1.143	40.0	1.314	4.3	3.3	0.0	0.0	0.0	8.8	11.0	12.0	5.4	7.4
14	135	39.6	1.143	40.0	1.314	4.3	3.3	0.0	0.0	0.0	9.1	11.0	12.0	6.0	7.4

WATER MEASUREMENTS DATA FIELD 1 BASIN 3

No.	Time	Weir Measurements				Water		Approach		Rain	Basin	Depth in adj.			
		Inflow		Outflow		depth(cm)		velocity		fall	water	basin or canal			
		Bo	Coef	Bo	Coef	over weir		(m/s)		(mm)	depth	(mm)			
	(min)	(cm)		(cm)		In	Out	In	Out		(cm)	A	B	C	D
1	0	40.0	1.314	38.9	1.493	0.0	0.0	0.0	0.0	0.0	5.4	8.8	15.0	5.6	9.5
2	40	40.0	1.314	38.9	1.493	2.7	0.0	0.0	0.0	0.0	7.0	10.7	15.0	5.6	9.5
3	50	40.0	1.314	38.9	1.493	3.3	0.0	0.0	0.0	0.0	7.8	11.4	15.0	5.6	9.5
4	60	40.0	1.314	38.9	1.493	3.8	1.1	0.0	0.0	0.0	8.8	11.9	15.0	5.6	9.5
5	70	40.0	1.314	38.9	1.493	4.3	2.1	0.0	0.0	0.0	9.3	12.4	15.0	6.3	9.5
6	80	40.0	1.314	38.9	1.493	4.3	2.8	0.0	0.0	0.0	10.2	12.4	15.0	6.9	9.5
7	90	40.0	1.314	38.9	1.493	4.8	3.4	0.0	0.0	0.0	10.9	12.4	15.0	7.7	9.5
8	100	40.0	1.314	38.9	1.493	4.9	3.8	0.0	0.0	0.0	11.4	12.4	15.0	8.5	9.5
9	110	40.0	1.314	38.9	1.493	5.2	4.2	0.0	0.0	0.0	11.8	12.4	15.0	9.4	9.5

WATER MEASUREMENTS DATA FIELD 1 BASIN 4

No.	Time	Weir Measurements				Water		Approach		Rain	Basin	Depth in adj.			
		Inflow		Outflow		depth(cm)		velocity		fall	water	basin or canal			
		Bo	Coef	Bo	Coef	over weir		(m/s)		(mm)	depth	(mm)			
	(min)	(cm)		(cm)		In	Out	In	Out		(cm)	A	B	C	D
1	0	38.9	1.493	39.0	1.214	0.0	0.0	0.0	0.0	0.0	4.9	11.6	21.0	4.1	13.7
2	20	38.9	1.493	39.0	1.214	2.2	0.0	0.0	0.0	0.0	5.7	11.6	21.0	4.1	13.7
3	30	38.9	1.493	39.0	1.214	2.7	0.0	0.0	0.0	0.0	6.4	11.6	21.0	4.1	13.7
4	40	38.9	1.493	39.0	1.214	3.3	0.0	0.0	0.0	0.0	7.5	11.6	21.0	4.1	13.7
5	50	38.9	1.493	39.0	1.214	3.7	0.0	0.0	0.0	0.0	8.3	11.6	21.0	4.1	13.7
6	60	38.9	1.493	39.0	1.214	3.8	1.1	0.0	0.0	0.0	9.0	11.6	21.0	4.1	13.7
7	70	38.9	1.493	39.0	1.214	3.8	2.2	0.0	0.0	0.0	9.5	11.6	21.0	4.8	13.7
8	80	38.9	1.493	39.0	1.214	4.2	2.8	0.0	0.0	0.0	10.2	11.6	21.0	5.4	13.7
9	90	38.9	1.493	39.0	1.214	4.3	3.3	0.0	0.0	0.0	10.8	11.6	21.0	6.1	13.7
10	100	38.9	1.493	39.0	1.214	4.4	3.6	0.0	0.0	0.0	11.3	11.6	21.0	7.0	13.7
11	110	38.9	1.493	39.0	1.214	4.8	4.5	0.0	0.0	1.5	11.9	11.6	21.0	8.5	13.7

WATER MEASUREMENTS DATA FIELD 1 BASIN 5

No.	Time	Weir Measurements				Water		Approach		Rain	Basin	Depth in adj.			
		Inflow		Outflow		depth(cm)		velocity		fall	water	basin or canal			
		Bo	Coef	Bo	Coef	over weir		(m/s)		(mm)	depth	(mm)			
	(min)	(cm)		(cm)		In	Out	In	Out		(cm)	A	B	C	D
1	0	39.0	1.214	39.5	1.635	0.0	0.0	0.0	0.0	0.0	3.5	7.8	22.7	8.5	11.7
2	20	39.0	1.214	39.5	1.635	2.5	0.0	0.0	0.0	0.0	4.2	9.6	22.7	8.5	11.7
3	30	39.0	1.214	39.5	1.635	3.4	0.0	0.0	0.0	0.0	4.8	10.1	22.7	8.5	11.7
4	40	39.0	1.214	39.5	1.635	3.9	0.0	0.0	0.0	0.0	5.6	11.1	22.7	8.5	11.7
5	50	39.0	1.214	39.5	1.635	4.3	0.0	0.0	0.0	0.0	6.7	11.6	22.7	8.5	11.7
6	60	39.0	1.214	39.5	1.635	4.5	1.9	0.0	0.0	0.0	7.2	11.6	22.7	8.5	11.7

Results

```
                     RESULTS        FIELD  1        BASIN  1
                     -------        --------        --------
Time   Surface Rain- Surface ETc       Net HS       S&P        Calc.   Basin    Net

       Inflow  fall  outflow (mm       across       (VS)       change  water    inflow,

(min)  (m^3/s) (mm)  (m^3/s) per       bund         (m^3/s)    (depth) depth    Qn

                             min)      (m^3/s)                  (m)     (m)     (m^3)
------------------------------------------------------------------------------------


  0    0.0000   0.0  0.0000  0.0034 -9.625E-09  3.102E-04  0.000   0.026   0.000
 10    0.0054   0.0  0.0000  0.0034 -3.333E-09  3.102E-04  0.005   0.031   1.410
 20    0.0078   0.0  0.0000  0.0034  4.454E-08  3.102E-04  0.014   0.045   3.760
 30    0.0081   0.0  0.0000  0.0034  1.041E-07  3.102E-04  0.017   0.061   4.577
 40    0.0088   0.0  0.0000  0.0034  1.842E-07  3.102E-04  0.018   0.079   4.871
 50    0.0104   0.0  0.0020  0.0034  2.892E-07  3.102E-04  0.018   0.097   4.947
 60    0.0114   0.0  0.0048  0.0034  4.006E-07  3.102E-04  0.016   0.112   4.278
 70    0.0117   0.0  0.0064  0.0034  4.751E-07  3.102E-04  0.012   0.125   3.366
 80    0.0114   0.0  0.0076  0.0034  5.241E-07  3.102E-04  0.009   0.134   2.533
 90    0.0114   0.0  0.0081  0.0034  5.312E-07  3.102E-04  0.007   0.141   1.939
```

```
                     RESULTS        FIELD  1        BASIN  2
                     -------        --------        --------
Time   Surface Rain- Surface ETc       Net HS       S&P        Calc.   Basin    Net

       Inflow  fall  outflow (mm       across       (VS)       change  water    inflow,

(min)  (m^3/s) (mm)  (m^3/s) per       bund         (m^3/s)    (depth) depth    Qn

                             min)      (m^3/s)                  (m)     (m)     (m^3)
------------------------------------------------------------------------------------


  0    0.0000   0.0  0.0000  0.0034  2.719E-08  4.869E-04  0.000   0.037   0.000
 15    0.0025   0.0  0.0000  0.0034  2.626E-08  4.869E-04  0.002   0.039   0.673
 25    0.0036   0.0  0.0000  0.0034  2.591E-08  4.869E-04  0.004   0.042   1.533
 35    0.0044   0.0  0.0000  0.0034  3.829E-08  4.869E-04  0.005   0.047   2.103
 45    0.0046   0.0  0.0000  0.0034  5.473E-08  4.869E-04  0.006   0.053   2.406
 55    0.0055   0.0  0.0000  0.0034  8.063E-08  4.869E-04  0.006   0.059   2.729
 65    0.0057   0.0  0.0006  0.0034  1.055E-07  4.869E-04  0.007   0.065   2.863
 75    0.0057   0.0  0.0013  0.0034  1.405E-07  4.869E-04  0.006   0.071   2.532
 85    0.0066   0.0  0.0022  0.0034  1.617E-07  4.869E-04  0.005   0.077   2.353
 95    0.0066   0.0  0.0027  0.0034  1.970E-07  4.869E-04  0.005   0.082   2.211
105    0.0069   0.0  0.0033  0.0034  2.109E-07  4.869E-04  0.004   0.086   1.932
115    0.0069   0.0  0.0042  0.0034  2.312E-07  4.869E-04  0.004   0.090   1.563
125    0.0069   0.0  0.0054  0.0034  2.381E-07  4.869E-04  0.002   0.092   0.950
135    0.0069   0.0  0.0054  0.0034  2.514E-07  4.869E-04  0.001   0.093   0.598
```

```
                         RESULTS          FIELD  1        BASIN  3
                         -------          --------        --------
 Time    Surface  Rain-  Surface  ETc       Net HS        S&P        Calc.     Basin    Net

         Inflow   fall   outflow  (mm       across        (VS)       change    water    inflow

 (min)   (m^3/s)  (mm)   (m^3/s)  per       bund          (m^3/s)    (depth)   depth    Qn

                                  min)      (m^3/s)                   (m)       (m)     (m^3)
-------------------------------------------------------------------------------------------------

   0     0.0000    0.0   0.0000   0.0034   8.373E-08    3.540E-04    0.000    0.054    0.000
  40     0.0040    0.0   0.0000   0.0034   1.449E-07    3.540E-04    0.012    0.066    3.878
  50     0.0054    0.0   0.0000   0.0034   1.857E-07    3.540E-04    0.008    0.075    2.581
  60     0.0066    0.0   0.0011   0.0034   2.505E-07    3.540E-04    0.010    0.084    3.037
  70     0.0080    0.0   0.0030   0.0034   2.679E-07    3.540E-04    0.009    0.093    2.919
  80     0.0080    0.0   0.0046   0.0034   3.333E-07    3.540E-04    0.007    0.101    2.275
  90     0.0094    0.0   0.0062   0.0034   3.813E-07    3.540E-04    0.006    0.106    1.747
 100     0.0097    0.0   0.0073   0.0034   4.120E-07    3.540E-04    0.005    0.111    1.457
 110     0.0106    0.0   0.0085   0.0034   4.310E-07    3.540E-04    0.004    0.114    1.123
```

```
                         RESULTS          FIELD  1        BASIN  4
                         -------          --------        --------
 Time    Surface  Rain-  Surface  ETc       Net HS        S&P        Calc.     Basin    Net

         Inflow   fall   outflow  (mm       across        (VS)       change    water    inflow

 (min)   (m^3/s)  (mm)   (m^3/s)  per       bund          (m^3/s)    (depth)   depth    Qn

                                  min)      (m^3/s)                   (m)       (m)     (m^3)
-------------------------------------------------------------------------------------------------

   0     0.0000    0.0   0.0000   0.0034  -5.027E-08    3.844E-04    0.000    0.049    0.000
  20     0.0032    0.0   0.0000   0.0034  -3.220E-08    3.844E-04    0.004    0.053    1.454
  30     0.0044    0.0   0.0000   0.0034  -1.033E-08    3.844E-04    0.006    0.059    2.045
  40     0.0059    0.0   0.0000   0.0034   3.545E-08    3.844E-04    0.008    0.068    2.856
  50     0.0070    0.0   0.0000   0.0034   7.751E-08    3.844E-04    0.011    0.078    3.653
  60     0.0073    0.0   0.0009   0.0034   1.204E-07    3.844E-04    0.011    0.089    3.793
  70     0.0073    0.0   0.0026   0.0034   1.407E-07    3.844E-04    0.009    0.098    3.089
  80     0.0085    0.0   0.0038   0.0034   1.796E-07    3.844E-04    0.008    0.106    2.590
  90     0.0088    0.0   0.0048   0.0034   2.120E-07    3.844E-04    0.007    0.113    2.377
 100     0.0091    0.0   0.0055   0.0034   2.334E-07    3.844E-04    0.006    0.119    2.042
 110     0.0104    1.5   0.0077   0.0034   2.502E-07    3.844E-04    0.006    0.125    2.170
```

```
                        RESULTS           FIELD  1         BASIN  5
                        ~~~~~~~          ~~~~~~~~~         ~~~~~~~~
Time    Surface Rain-  Surface ETc       Net HS        S&P        Calc.    Basin    Net

        Inflow  fall   outflow (mm       across        (VS)       change   water    inflow

(min)   (m^3/s) (mm)   (m^3/s) per       bund          (m^3/s)    (depth)  depth    Qn

                               min)      (m^3/s)                   (m)      (m)     (m^3)
-------------------------------------------------------------------------------------------


  0     0.0000   0.0   0.0000  0.0034  -1.633E-07    3.912E-04    0.000    0.035    0.000
 20     0.0032   0.0   0.0000  0.0034  -1.963E-07    3.912E-04    0.004    0.039    1.422
 30     0.0051   0.0   0.0000  0.0034  -2.144E-07    3.912E-04    0.006    0.045    2.229
 40     0.0062   0.0   0.0000  0.0034  -2.384E-07    3.912E-04    0.009    0.055    3.137
 50     0.0072   0.0   0.0000  0.0034  -2.540E-07    3.912E-04    0.011    0.065    3.778
 60     0.0077   0.0   0.0029  0.0034  -2.543E-07    3.912E-04    0.010    0.075    3.359
```