

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

**"DESIGN OF DRIP IRRIGATION SYSTEM
FOR RECLAIMED LANDS IN EGYPT,
USING COMPUTERS"**

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN CIVIL ENGINEERING

BY

WASEEM MOSTAFA KAMAL AHMED
(B.SC. CIVIL ENGINEERING)

SUPERVISED BY

PROF. DR. SAMEH DAWOOD ARMANIOUS
IRRIGATION AND HYDRAULICS DEPT.,
FACULTY OF ENGINEERING,
AIN SHAMS UNIVERSITY

DR. MOHAMMED M. NOUR EL-DIN
ASSOCIATE PROFESSOR,
IRRIGATION AND HYDRAULICS DEPT.,
FACULTY OF ENGINEERING,
AIN SHAMS UNIVERSITY

DR. KHALED S. EL-KHOLY
LECTURER,
IRRIGATION AND HYDRAULICS DEPT.,
FACULTY OF ENGINEERING,
AIN SHAMS UNIVERSITY

CAIRO, EGYPT

1994

EXAMINERS COMMITTEE

Signature

1- PROF. DR. MONA MOSTAFA EL-KADY *M. El Kady*

Professor, Water Research Centre,
Ministry of Public Works & Water Resources.

2- PROF. DR. GAMAL SADEK EBAID *G. S. Ebaid*

Head of Irrigation and Hydraulics Dept.,
and Professor of Irrigation Designs,
Faculty of Engineering,
Ain Shams University.

3- PROF. DR. SAMEH DAWOOD ARMANIOUS *S. Armanious*

Professor, Irrigation & Hydraulics Dept.,
Faculty of Engineering,
Ain Shams University.

4- DR. MOHMMED MOHMMED NOUR EL-DIN *M. M. Nour El-Din*

Associate Professor, Irrigation and Hydraulics Dept.,
Faculty of Engineering,
Ain Shams University.



STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Civil Engineering.

The work included in this thesis was carried out by the author from October 1986 to Nov. 1994.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institute

Date : 23 /12 /1994

Signature : Waseem

Name : Waseem Mostafa Kamal

ACKNOWLEDGMENT

Firstly, and always, praise to **ALLAH**

To Pof. **Dr. Sameh Dawoud Armanious**, Professor of Irrigation and Hydraulics, Faculty of Engineering, Ain Shams University, I owe more than can be expressed, direct supervision, valuable discussions, continuous encouragement and time he freely gave during this study were behind the accomplishment of this work.

Grateful and sincere acknowledgment to **Associate Prof. Dr. Mohammed M. Nour El-Din**, Irrigation and Hydraulics Dept., Faculty of Engineering, Ain Shams University for his help, direction and useful revision.

I also wish to express my gratitude to **Dr. Khalid El-Kholy**, Lecturer of Irrigation and Hydraulics, Faculty of Engineering, Ain Shams University for his help and cooperation.

I would like to express my profound gratitude to the late **Prof. Dr. Mohammed Wafaie Abdel Salam**, Professor of Irrigation and Hydraulics, Faculty of Engineering, Ain-Shams University for his guidance and beneficial proposals. He has followed up this work up to his regretful death.

I recognize the efforts of **Dr. Moheb Semaika**, Head of the Agronomy Dept. and Technical Office. Director of the Water Distribution and Irrigation Systems Research Institute, Water Research Centre, for his beneficial assistance to use his computer programme and for his useful papers.

Thanks are due to **Dr. Mohammed Bakr**, Drainage Institute, Water Research Centre, for his encouragement and his kind helps.

I wish to express my sincere appreciation to the staff of General Authority of Rehabilitation Projects and Agricultural Development (G.A.R.P.A.D.), Ministry of Agriculture and Land Reclamation, especially **Eng. M. Hassouna El-Nawawy** and **Eng. Hassan Khalil** for their wide guidance and valuable wide helps. Thanks are presented to my friends and colleagues in G.A.R.P.A.D. for their cooperation and assistance.

Finally, deep thanks to the engineers of land reclamation companies, especially **Eng. Shoukry Fadhel**, general manager in the General Company for Land Reclamation, for their kind helps.

VITA

Name : Waseem Mostafa Kamal Ahmed Darweesh

Date of Birth : August 21st, 1961.

Present Position: Civil Engineer, General Authority for Rehabilitation Projects and Agricultural Development (G.A.R.P.A.D.), Ministry of Agriculture and Land Reclamation.

Education :

Al-Nokrashy Primary School from 1967 to 1973

Al-Nokrashy Preparatory School from 1973 to 1976

Al-Nokrashy Secondary School from 1976 to 1979

Faculty of Engineering Ain Shams University,

B.Sc. in Civil Engineering, June 1984

Training Courses :

In Japan : Agricultural Land and Water Resources Development
at J.I.I.D. 1991

In Egypt : Feasibility study of projects 1988

Programming with Basic and Fortran 77 1988-1989

Introduction to SAS 1993

English language courses in AUC (levels
18,19,20) 1993-1994

Date : 23 / 12 / 1994

Name : Waseem M.K. Darweesh

Signature : *Waseem*

ABSTRACT
***DESIGN OF DRIP IRRIGATION SYSTEM
FOR RECLAIMED LANDS IN EGYPT, USING COMPUTERS***

Manual design of drip irrigation system cannot determine the most economic solution and the optimum value of the design parameters. The huge number of parameters may not be included; as this needs several trials and a lot of time and effort. This leads to a reduction of irrigation efficiency, increase of the cost of the drip irrigation system and lowering the benefit - cost ratio. To overcome these defects, two computer programs have been developed:

- The first optimizes the design of drip pipe network for a plot, from the furthest emitter to the hydrant, using the least cost method and taking into account some constraints such as determining the optimum method for computing the reference evapotranspiration, the effect of crop type and soil on specifying the emitter discharge and emitter layout, the effect of emitter type on allowable friction losses in laterals and manifolds, checking the required % of wetted soil area and % of emission uniformity. The output is the optimum diameter, length and material of pipes, the optimum irrigation interval and application time, the pipe network cost, the required energy, the discharge and head at the plot hydrant.
- The second determines the optimum diameter and material for the sections of pressure distribution network, the optimum piezometric head at the pump station, the optimum layout of the pipe network for a certain area, the optimum area allocated for the pump station and the optimum number of pump units. The program is fed with a description table for each layout of pipe network and a table of suitable pipes.

Two examples for the first program and one example for the second program are applied in this study, using the relevant data of a reclamation project on Cairo - Ismaelia road.

CONTENTS

	Page
CHAPTER I INTRODUCTION	1
CHAPTER II REVIEW OF LITERATURE	4
2.1. Drip irrigation system	4
2.1.1. Development of drip irrigation	4
2.1.2. Application of trickle systems	5
2.1.3. Types of trickle irrigation	5
2.2. Components of a trickle system	5
2.2.1. Emitters	8
2.2.1.1. Emitter construction.	8
2.2.1.1a. Performance requirements for emitters . .	8
2.2.1.1b. Modes of operation	8
2.2.1.2. Discharge principles.	9
2.2.1.3. Characterizing hydraulic performance . .	9
2.2.1.4. Emitter types	10
2.2.1.5. Materials.	11
2.2.1.6. Emitters hydraulic performance	12
2.2.2. Pipes	12
2.2.2.1. General	12
2.2.2.1a. Materials for pipes.	12
2.2.2.1b. Pipeline accessories and control equipment	12
2.2.3. Clogging and filtration	13
2.2.3.1. Causes of clogging	13
2.2.3.2. Prevention of clogging	14
2.2.4. Fertilizer applicators	16
2.2.5. The pumping units	16
2.2.5.1. Pump duty	16
2.2.5.2. Power requirement for the pump and engine	17
2.2.5.3. Selection of pump and engine.	18
2.2.6. Automation	18

CHAPTER III ECONOMIC IMPLICATIONS FOR DRIP IRRIGATION	33
3.1. Introduction	33
3.2. The irrigation project costs	33
3.3. Some definitions	35
3.3.1. Investment cost	35
3.3.2. Recurrent cost	35
3.4. Cost for different irrigation systems	36
3.5. Optimization of pipeline diameters by least cost method	37
3.5.1. Number of diameters per section	37
3.5.2. Determination of the optimum diameter	39
CHAPTER IV DESIGN OF THE PLOT DRIP NETWORK	43
4.1. Design principles for the plot drip network	43
4.1.1. Calculation of crop water requirements	43
4.1.2. Crop water requirements related to localized systems	45
4.1.2.1. Influence of ground cover	45
4.1.2.2. Irrigation and crop water requirements	45
4.1.3. Choice of distributors	46
4.1.3.1. Number of distributors per plant	47
4.1.3.2. Layout of distributors	47
4.1.4. Interval between irrigations	49
4.1.4.1. Fixed amount irrigation at variable intervals	49
4.1.4.2. Variable amount irrigation at fixed intervals	50
4.1.5. Duration of each irrigation	50
4.1.6. Discharge per distributor or set of distributors	51
4.1.7. Irrigation uniformity and efficiency	52
4.1.8. Design of pipe network	53
4.1.8.1. Head loss in pipes	54
4.1.8.2a. Laterals	54
4.1.8.2b. Pressure profiles	55
4.1.8.2b. Calculation of lateral head loss	55
4.1.8.2c. Design of manifold and mainline	58
4.1.9. Minimum and maximum discharge ratios	61

4.1.10. Subunit emission uniformity	62
4.1.10.1. Rigorous EU_s computational method	62
4.1.10.2. Shortcut method for computing EU_s	63
4.1.11. Number and shape of subunits	63
4.1.12. Hydraulic design steps	64
4.2. Optimal design of drip plots by computer	66
4.2.1. Objectives of the programme "DRIP"	66
4.2.2. Input parameters and outputs	66
4.2.3. Limitations	67
4.3. Applied examples on design of drip irrigation plots	67
4.3.1. An example for a single - crop plot	67
4.3.1.1. The manual design	68
4.3.1.2. Design using computer	70
4.3.2. An example on a multi-crop plot	71
4.3.2.1. Design using computer	71
CHAPTER V DESIGN AND OPTIMIZATION TECHNIQUES OF PRESSURE DISTRIBUTION NETWORKS	93
5.1. Introduction	93
5.2. Lower envelope curve method	94
5.2.1. Adding sections in derivation	95
5.2.2. Adding sections in series	96
5.2.3. Optimizing the piezometric head of the network.	97
5.3. Linear programming model for designing a pipe system	98
5.4. Optimal design of the pipe network by the program "OIN"	99
5.4.1. Objectives	99
5.4.2. Procedure	100
5.4.3. Implementation	101
5.4.4. Input	101
5.4.4.1. Suitable pipe tables	101
5.4.4.2. Network description data	102
5.4.5. Output	103
5.4.6. Limitations	104

5.5. An example for optimised design of pressure distribution network	104
5.5.1. Data	104
5.5.2. The Manual design	105
5.5.3. The Computer design	106
CHAPTER VI ANALYSIS AND DISCUSSION	139
6.1. Introduction	139
6.2. Design of the plot drip network	139
6.2.1. Case of a single-crop plot	139
6.2.2. Case of a multi-crop plot	143
6.3. Design of pressure distribution network	145
CHAPTER VII CONCLUSIONS AND RECOMMENDATIONS	149
REFERENCES	152
APPENDICES	156
APPENDIX I	156
APPENDIX II	181
ARABIC SUMMARY	202

LIST OF FIGURES

<u>Fig. No.</u>	<u>Description</u>	<u>Page</u>
Fig.2.1	Components of a drip system	20
Fig.2.2	Layout of drip irrigation systems	21
Fig.2.3	Laminar (long path) emitters	22
Fig.2.4	Turbulent emitters	22
Fig.2.5	Orifice emitters	23
Fig.2.6	Operation curves for some emitters	24
Fig.2.7	Pressure differential applicator	25
Fig.2.8	Sequential hydraulically operated system	25
Fig.3.1	Selection of irrigation method based on land quality (after Caswell et al., 1984).	40
Fig.3.2	Rising energy prices and dropping water tables	40
Fig.3.3	Minimum cost of a compound section	40
Fig.3.4	Least cost method	41
Fig.4.1	Layouts of distributors	72
Fig.4.2	Pressure profiles along a lateral line for different $\Delta H^1/\Delta H$ values	72
Fig.4.3	Minimum lateral discharge ratio as a function of head loss for uniform pipe size laterals on flat fields.	73
Fig.4.4	Maximum lateral discharge ratio as a function of head loss for uniform pipe size laterals on flat fields	73
Fig.4.5	Minimum lateral discharge as a function of head loss for tapered pipe size laterals on flat fields ..	74
Fig.4.6	Lateral inlet pressure heads along a sloping manifold with the water input near the middle ..	74
Fig.4.7	Relation between lateral line discharge exponents and head loss ratios for various emitter discharge exponents.	74
Fig.4.8	Flow chart of "DRIP"	75

Fig.4.9	Layout no. (1) of a typical plot	83
Fig.4.10	Losses of PE pipes	84
Fig.4.11	Losses of PVC pipes	85
Fig.4.12	Relationship between irrigation time and total costs	169
Fig.4.13	Relationship between irrigation time and pipe cost	169
Fig.4.14	Relationship between irrigation time and required energy	170
Fig.4.15	Relationship between irrigation time and emission uniformity of subunit%	170
Fig.4.16	Layout no. (2) of a multi-crop plot	86
Fig.4.17	Relationship between manifold discharge and manifold diam. for various allowed friction loss	180
Fig.4.18	Relationship between manifold discharge and EU%	180
Fig.5.1	The lower envelope curve	107
Fig.5.2	An example for addition in derivation	107
Fig.5.3	An example for addition in derivation of terminal sections	107
Fig.5.4	Addition in derivation of sections	108
Fig.5.5	Addition in derivation when a single diameter only is allowed	108
Fig.5.6	An example for addition in series	109
Fig.5.7	An example for addition in series in terminal sections	109
Fig.5.8	Addition in series	109
Fig.5.9	Addition in series when only one diameter is allowed	109
Fig.5.10	Optimization of direct supply	110
Fig.5.11	Optimization of supply with elevated tank	110
Fig.5.12	Optimization of supply with peak demand shedding	110
Fig.5.13a	Scheme of a sprinkler system pipe network	111

Fig.5.13b	Scheme of pipe-section (i) with j pipe size . . .	111
Fig.5.14	Flow chart of "OIN"	112
Fig.5.15	Head loss nomograph for Asbestos pipes	120
Fig.5.16	Layout No. (300-1)	121
Fig.5.17	Layout No. (400-1)	122
Fig.5.18	Layout No. (500-1)	123
Fig.5.19	Layout No. (500-2)	124
Fig.5.20	Layout No. (500-3)	125
Fig.5.21	Layout No. (500-4)	126
Fig.5.22	Layout No. (600-1)	127
Fig.5.23	Layout No. (600-2)	128
Fig.5.24	Layout No. (700-1)	129
Fig.5.25	Layout No. (700-2)	130
Fig.5.26	Layout No. (800-1)	131
Fig.5.27	Layout No. (800-2)	132
Fig.5.28	Layout No. (880-1)	133
Fig.5.29	Relationship between area served and HP/fed .	199
Fig.5.30	Relation between area served and cost/fed. . .	200
Fig.5.31	Relation bet. area served and annual costs/fed	201