

8-11-2007

## Continuous simulation of groundwater use and effluent discharge in catfish (*Ictalurus punctatus*) ponds at five locations in the Southeast U.S

Sugeng Triyono

Follow this and additional works at: <https://scholarsjunction.msstate.edu/td>

---

### Recommended Citation

Triyono, Sugeng, "Continuous simulation of groundwater use and effluent discharge in catfish (*Ictalurus punctatus*) ponds at five locations in the Southeast U.S" (2007). *Theses and Dissertations*. 1172.  
<https://scholarsjunction.msstate.edu/td/1172>

This Dissertation - Open Access is brought to you for free and open access by the Theses and Dissertations at Scholars Junction. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of Scholars Junction. For more information, please contact [scholcomm@msstate.libanswers.com](mailto:scholcomm@msstate.libanswers.com).

CONTINUOUS SIMULATION OF GROUNDWATER USE AND EFFLUENT  
DISCHARGE IN CATFISH (*ICTALURUS PUNCTATUS*) PONDS AT FIVE  
LOCATIONS IN THE SOUTHEAST U.S.

By

Sugeng Triyono

A Dissertation  
Submitted to the Faculty of  
Mississippi State University  
in Partial Fulfillment of the Requirements  
for the Degree of Doctor of Philosophy  
in Biological Engineering  
in the Department of Agricultural and Biological Engineering

Mississippi State, Mississippi

August 2007

Copyright By

Sugeng Triyono

2007

CONTINUOUS SIMULATION OF GROUNDWATER USE AND EFFLUENT  
DISCHARGE IN CATFISH (*ICTALURUS PUNCTATUS*) PONDS AT FIVE  
LOCATIONS IN THE SOUTHEASTERN U.S.

By

Sugeng Triyono

Approved:

---

Thomas P. Cathcart  
Professor of Biological and Agricultural  
Engineering  
(Director of Dissertation)

---

Jonathan W. Pote  
Professor of Biological and Agricultural  
Engineering  
(Committee Member)

---

Charles L. Wax  
Professor of Geosciences  
(Committee Member)

---

Janice DuBien  
Associate Professor of Statistics  
(Committee Member)

---

Sandun Fernando  
Graduate Coordinator of the  
Department of Agricultural and  
Biological Engineering

---

Glenn Steele  
Dean, Bagley College of Engineering

Name: Sugeng Triyono

Date of Degree: August 11, 2007

Institution: Mississippi State University

Major Field: Biological Engineering

Major Professor: Dr. Thomas P. Cathcart

Title of Study: CONTINUOUS SIMULATION OF GROUNDWATER USE AND EFFLUENT DISCHARGE IN CATFISH (*ICTALURUS PUNCTATUS*) PONDS AT FIVE LOCATIONS IN THE SOUTHEAST U.S.

Pages in Study: 146

Candidate for Degree of Doctor of Philosophy

Long-term climatological data were used to evaluate the effectiveness of a drop/add management strategy to reduce groundwater use and effluent discharge in catfish ponds in the southeast U.S.. A drop/add approach is based on the creation of a storage volume in the pond for rainfall collection. The storage volume is created by allowing water level in the pond to decrease until some minimum level is reached. When the minimum level is reached, the pond is partly refilled, leaving the remaining volume available to capture incident precipitation. In this way, the role of precipitation in the water budget is increased. In the process, groundwater use and effluent release both become smaller.

The data consisted of 45 year precipitation and evaporation records from Fairhope, AL; Clemson, SC; Stoneville, MS, Stuttgart, AR; and Thomsons, TX. The data were used in a water balance levee pond model that included precipitation, evaporation, infiltration, overflow, groundwater pumping, and draining. The model appeared to

indicate that the drop/add management scheme is an effective strategy to reduce groundwater use and effluent discharge.

The simulated results showed that variation of climate in the southeast U.S. was an important determinant of performance of the drop/add management scheme. At locations with positive P-0.8E, zero groundwater use could be achieved with low drop depths. At location with negative P-0.8E, zero groundwater use could be achieved for about 50% of the 45 simulated years. The model also indicated that effluent discharge cannot be avoided at most locations except at location with very low (negative) P-0.8E. The model also indicated that 65 to 100% of annual precipitation (depending on the P-0.8E's of the locations) can be captured and used in the ponds. Rainwater contribution to the total water budget ranged from 90 to 100%.

The sensitivity analysis showed that model sensitivity to pan coefficient and infiltration rate was affected by infiltration rate and pond water storage capacity (drop depth). The model was more sensitive to pan coefficient rather than to infiltration rate at lower infiltration rates and *vice-versa*. Both sensitivities of the model, however, increased when pond water deeper storage capacity was used.

Key words: aquaculture, pond, model, drop/add scheme

## DEDICATION

I would like to dedicate this research to my parents Harinto Samad and Seruni, and my wife Sri hartatik, my son Afid Fitro Setiawan, and my daughter Vina Dwiayu Wardhani.

## ACKNOWLEDGMENTS

The author expresses his sincere gratitude to Dr. Thomas P. Cathcart, as the major professor, for his magnanimity in expending energy and time to guide and assist me throughout this research and dissertation process with patience. Expressed appreciation is also due to the other members of my dissertation committee, Dr. Jonathan W. Pote, Dr. Charles L. Wax, and Dr. Janice DuBien for the invaluable aid and direction.



## TABLE OF CONTENTS

	Page
DEDICATION .....	ii
ACKNOWLEDGMENTS .....	iii
LIST OF TABLES .....	vii
LIST OF FIGURES .....	ix
CHAPTER	
I. INTRODUCTION .....	1
II. LITERATURE REVIEW .....	8
2.1 Problems of Groundwater Overexploitation .....	8
2.2 Impacts of Eutrophication .....	12
2.3 Water Quality of Embankment Catfish Ponds .....	18
2.4 Drop-Add Management Strategy .....	21
2.5 Simulation Modeling in Aquaculture Ponds .....	25
III. METHODOLOGY .....	30
3.1 Data Processing and Site Selection .....	30
3.2 Pond Water Balance Model .....	32
3.3 Simulation .....	36
3.4 Scenarios and Analysis .....	37
3.4.1 Climate Characteristics .....	37
3.4.2 Pond Performance .....	38
3.4.3 Sensitivity Analysis .....	39
3.4.4 Effect of Intentional Harvest Discharge .....	40
3.4.5 Mass Discharge of Water Constituents .....	41
3.4.6 Linked Pond System .....	42

IV.	RESULTS AND DISCUSSION .....	43
4.1	Climate Characteristics .....	43
4.1.1	Annual Records .....	43
4.1.2	Seasonal Records .....	49
4.1.3	Monthly Records .....	53
4.1.4	Evaluation of P-0.8E in 15-Year Blocks.....	56
4.2.	Pond Performances .....	61
4.2.1	Effect of Climate on Pond Performance .....	61
4.2.2	Seasonal Evaluation .....	66
4.2.3	Effect of Infiltration Rates .....	71
4.2.4	Summary .....	80
4.3	Effect of Deeper Fill Depths .....	82
4.4	Sensitivity Analysis .....	84
4.4.1	Relative Sensitivity to Pan Coefficient .....	86
4.4.2	Relative Sensitivity to Infiltration Rate .....	90
4.5	Effect of Intentional Harvest Discharge .....	93
4.6	Mass Discharge of Water Constituents .....	100
4.7	Linked Pond System .....	106
4.7.1	Groundwater Use .....	107
4.7.2	Effluent Discharge .....	109
4.7.3	Rainwater Stored .....	111
4.7.4	Summary .....	113
V.	CONCLUSION .....	115
	REFERENCES .....	118
APPENDIX		
A.	SAS OUTPUTS OF ONE WAY CLASSIFICATION ANALYSIS OF VARIANCE AND LSD MULTIPLE COMPARISONS FOR ANNUAL PRECIPITATION AMONG LOCATIONS .....	127
B.	SAS OUTPUTS OF ONE WAY CLASSIFICATION ANALYSIS OF VARIANCE AND LSD MULTIPLE COMPARISONS FOR ANNUAL P-0.8E AMONG LOCATIONS .....	130
C.	SAS OUTPUTS OF TWO-WAY CLASSIFICATION ANALYSIS OF VARIANCE AND LSD MULTIPLE COMPARISONS FOR SEASONAL PRECIPITATION .....	133

D. SAS OUTPUTS OF TWO-WAY CLASSIFICATION ANALYSIS OF VARIANCE AND LSD MULTIPLE COMPARISONS FOR SEASONAL P-0.8E .....138

E. SAS OUTPUT OF THREE-WAY CLASSIFICATION ANALYSIS OF VARIANCE FOR P-0.8E'S OF 15-YEAR BLOCKS .....143

## LIST OF TABLES

TABLE	Page
1. World Availability of Water Resources .....	9
2. Annual Precipitation .....	43
3. Annual Accumulation of P-0.8E .....	46
4. Seasonal Average of 45 Year Precipitations .....	49
5. Seasonal Average of 45 Year P-0.8E .....	50
6. Seasonal Accumulation of P-0.8E's among 15-Year Blocks at Fairhope .....	57
7. Seasonal Accumulation of P-0.8E's among 15-Year Blocks at Clemson .....	57
8. Seasonal Accumulation of P-0.8E's among 15-Year Blocks at Stoneville .....	57
9. Seasonal Accumulation of P-0.8E's among 15-Year Blocks at Stuttgart .....	58
10. Seasonal Accumulation of P-0.8E's among 15-Year Blocks at Thomsons .....	58
11. Annual P-0.8E's among 15-Year Blocks at Each Location.....	58
12. Groundwater Use and Effluent Discharge of 15/7.5 and 45/7.5 Management Schemes Using Pan Coefficient=0.8 at 0.1 cm/day and 0.4 cm/day Infiltration Rates, as Base Sets for Sensitivity Analysis .....	85
13. Relative Sensitivity of Groundwater Use to Pan Coefficient .....	89
14. Relative Sensitivity of Effluent Discharge to Pan Coefficient .....	89
15. Relative Sensitivity of Groundwater Use to Infiltration .....	92
16. Relative Sensitivity of Effluent Discharge to Infiltration .....	92

17.	Concentrations of Selected Water Quality Variables (Means and Ranges) in Potential Overflow Effluents from 20 Commercial Channel Catfish Ponds in Northwest Mississippi Sampled over 2 Years. TSS = Total Suspended Solids; TN = Total Nitrogen; TP = Total Phosphorus; BOD5 = 5 Day Biochemical Oxygen Demand .....	100
18.	Mass Discharge (kg/ha/year) of Selected Water Quality Variables Using Schemes 15/7.5 and 45/7.5 at Infiltration Rate of 0.1 cm/day at Fairhope .....	101
19.	Mass Discharge of Selected Water Quality Variables Using Schemes 15/7.5 and 45/7.5 at Infiltration Rate of 0.1 cm/day at Clemson .....	102
20.	Mass Discharge of Selected Water Quality Variables Using Schemes 15/7.5 and 45/7.5 at Infiltration Rate of 0.1 cm/day at Stoneville .....	102
21.	Mass Discharge of Selected Water Quality Variables Using Schemes 15/7.5 and 45/7.5 at Infiltration Rate of 0.1 cm/day at Stuttgart .....	103
22.	Mass Discharge of Selected Water Quality Variables Using 15/7.5 and 45/7.5 Schemes at Infiltration Rate of 0.1 cm/day at Thomsons .....	104

## LIST OF FIGURES

FIGURE	Page
1. Locations and P-0.8E values for the locations used in this study .....	31
2. Histogram of Annual Precipitation at Each Location .....	45
3. Histogram of Annual P-0.8E at Each Location .....	48
4. Histogram of Seasonal P-0.8E at Each Location .....	52
5. Monthly Precipitation and Pond Evaporation at Each Location .....	54
6. Cumulative P-0.8E's in One Year Cycle for Each of 15-Year Blocks.....	60
7. Pond Performance of Schemes with Various Drop Depths and 7.5 cm Fill Depth at Zero Infiltration .....	65
8. Seasonal Groundwater Use of Schemes with Various Drop Depths and 7.5 cm Fill Depth at Zero Infiltration .....	68
9. Seasonal Effluent Discharge of Schemes with Various Drop Depths and 7.5 cm Fill Depth at Zero Infiltration .....	69
10. Average of Pond Water Level for a 45/7.5 Management Scheme at Zero Infiltration .....	70
11. Effect of Infiltration Rates on Pond Performance of Schemes with Various Drop Depths and 7.5 cm Fill Depth at Fairhope.....	73
12. Effect of Infiltration Rates on Pond Performance of Schemes with Various Drop Depths and 7.5 cm Fill Depth at Clemson .....	75
13. Effect of Infiltration Rates on Pond Performance of Schemes with Various Drop Depths and 7.5 cm Fill Depth at Stoneville .....	76
14. Effect of Infiltration Rates on Pond Performance of Schemes with Various Drop Depths and 7.5 cm Fill Depth at Stuttgart .....	77

15.	Effect of Infiltration Rates on Pond Performance of Schemes with Various Drop Depths and 7.5 cm Fill Depth Thomsons .....	79
16.	Pond Water Level for a 45/7.5 Scheme and 0.1 cm/day Infiltration Rate .....	81
17.	Groundwater Use and Effluent Discharge of Schemes with a 45 cm Drop Depth and Various Fill Depths from 2.5 to 45 cm at Each Location .....	83
18.	Increase of Effluent Discharge from One Time Harvest per Year of a 45/7.5 Management Scheme at 0.1 cm/day Infiltration .....	95
19.	Increase of Effluent Discharge from Two Time Harvests per Year of a 45/7.5 Management Scheme at 0.1 cm/day Infiltration .....	96
20.	Increases of Effluent Discharge from One Time Harvest per Year of a 45/7.5 Management Scheme at 0.1 cm/day Infiltration if Water is Transferred to Adjacent Pond .....	99
21.	Effect of Infiltration Rate on Groundwater Use of Production/Storage Ponds with Various Drop Depths and a 7.5 cm Fill Depth.....	108
22.	Effect of Infiltration Rate on Effluent Discharge of Production/Storage Ponds with Various Drop Depths and a 7.5 cm Fill Depth .....	110
23.	Effect of Infiltration Rate on Rainwater Stored of Production/Storage Ponds with Various Drop Depths and a 7.5 cm Fill Depth .....	112
24.	Pond Water Level of Production/Storage Pond at 0.1 cm/day Infiltration Rate at Each Location .....	114