



**UNIVERSITI PUTRA MALAYSIA**

**PREDICTION OF PHOSPHORUS CONCENTRATION IN AN  
UNCONFINED AQUIFER USING VISUAL MODFLOW**

**SEYED REZA SAGHRAVANI**

**FK 2009 44**



*To my parents for*

***Encourage and Support***



**PREDICTION OF PHOSPHORUS CONCENTRATION IN AN UNCONFINED  
AQUIFER USING VISUAL MODFLOW**

**By  
SEYED REZA SAGHRAVANI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra  
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Abstract of thesis submitted to the senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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**May 2009**

**Chairman: Associate Professor Sa'ari Bin Mustapha, PhD**

**Faculty: Engineering**

Groundwater as a source of water for municipal, industrial, and agricultural purposes plays a key role in many societies around the world and should be safeguarded against pollution. Nutrients such as phosphorus can be transported to other places by groundwater and has adverse effect on ecosystem of water bodies. Phosphorus causes turbidity in water and eutrophication in surface water and aquatic situation to terrestrial constantly. The objective of this study is to predict groundwater flow direction and spreading of phosphorus in an aquifer located at the Engineering Complex of the Universiti Putra Malaysia. Fertilizers, as main source of phosphorus were used before in study area. Also the fertilizers are currently used at an area located south of the Engineering Complex and it has an adverse effect on quality of groundwater. Visual MODFLOW, is a powerful software package, was used to predict the changes of groundwater flow patterns and concentration of phosphorus for period of 10 and 50 years respectively. These



two periods were selected because adsorption and slow movement of phosphorus in groundwater usually take long time. However, mobility of phosphorus is resumed as the adsorption capacity of phosphorus in the soil is reached.

Data from 11 constructed wells within the study area were collected to determine groundwater level from surface, thickness of geological formation, and concentration of phosphorus. Groundwater movement direction was determined by the triangular linear interpolation and the field data obtained from the observation wells indicate that groundwater flow is from Southeast to Northwest. The concentration of orthophosphorus, as the dominant form of phosphorus was measured in laboratory using spectrophotometer. The results show that concentrations of orthophosphorus in vicinity of the swamp are 0.64 mg/l, and 0.5 mg/l, in the pond is 0.22 mg/l, in western part of the area is 0.13 mg/l and in the center of study area is 0.31 mg/l. These concentrations of phosphorus in the study area show that the highest concentration occurs in the swamp and the concentration decreases with distance from the swamp down to the value of 0.13 mg/l. Visual MODFLOW, which include MODFLOW and MT3DMS, was employed to predict the direction of groundwater flow and concentration of phosphorus for periods of 10 and 50 years. During these periods two types of Constant Head Boundary (CHB) were used. In the first type, the CHB was placed in the northern part of the area and movement of groundwater during the prediction periods was implemented without any



change in hydraulic head. The result shows that phosphorus does not flow to the pond but might be transferred out of the study area due to groundwater flow. In the second type, the CHB was located by the pond to record the fate of phosphorus whenever water depth in the pond drops two meters. The result indicates that the pollutant is directly transferred to the pond from the swamp especially via layer No.2 and this can be related to its high hydraulic conductivity. Prediction of contaminated groundwater shows that the concentration of phosphorus increases at the end of prediction period at the study area and this can be attributed to its migration from the swamp area.



Abstrak tesis ini dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk memperolehi ijazah Master Sains

**PENJANGKAAN KEPEKATAN FOSFORUS DI DALAM AKUIFER TIDAK TERKURUNG DENGAN MENGGUNAKAN VISUAL MODFLOW**

Oleh

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Air bawah tanah sebagai satu sumber air untuk perbandaran, perindustrian, dan pertanian memainkan peranan utama kepada semua masyarakat di seluruh dunia dan ia seharusnya dilindungi daripada pencemaran. Nutrien seperti fosforus boleh diangkut kepelbagai tempat oleh air bawah tanah yang akan memberi kesan buruk ke atas ekosistem jasad air. Fosforus boleh menyebabkan kekeruhan air dan eutrofikasi di dalam air permukaan dan situasi akuatik bagi persekitaran benua. Objektif bagi kajian ini adalah untuk membuat jangkaan arah aliran air bawah tanah dan penumpuan kepekatan fosforus di dalam akuifer yang berada di bawah Kompleks Kejuruteraan, Universiti Putra Malaysia. Baja kimia sebagai punca utama fosforus telah pernah digunakan di dalam kawasan kajian. Pada waktu ini baja kimia digunakan di dalam satu kawasan yang terletak di selatan Kompleks Kejuruteraan tersebut. Penggunaan baja ini memberi kesan buruk terhadap kualiti air bawah tanah. Perisian "Visual MODFLOW", satu perisian yang baik, telah digunakan untuk membuat



jangkaan bagi perubahan aliran bawah tanah dan kepekatan pencemaran dalam tempoh 10 tahun dan 50 tahun yang akan datang. Kedua-dua tempoh ini dipilih kerana proses “adsorption” dan pergerakan fosforus di dalam air bawah tanah adalah perlahan. Walau bagaimana pun, pergerakan fosforus akan terus bermula apabila kapasiti “adsorption” fosforus dicapai.

Data dari 11 telaga yang dibina di dalam kawasan kajian telah digunakan untuk mendapatkan maklumat-maklumat berkenaan kedudukan aras air tanah, ketebalan formasi geologi serta kepekatan fosforus. Arah pergerakan air bawah tanah telah ditentukan dengan kaedah interpolasi linear segi tiga. Data lapangan yang diperolehi dari telaga pemerhatian menunjukkan aliran air bawah tanah adalah dari arah Tenggara menghala ke Barat Laut. Kepekatan orthofosforus sebagai bentuk fosforus yang dominan telah diukur dalam makmal dengan menggunakan spektrofotometer dan menunjukkan kepekatan fosforus di sekitar enapcemar adalah pada 0.64 mg/l, dan 0.5 mg/l, di dalam kolam adalah 0.22 mg/l, di kawasan sebelah barat kawasan kajian adalah 0.13 mg/l dan di kawasan pusat kajian pada 0.31 mg/l. Dengan demikian kepekatan fosforus di dalam kawasan kajian adalah paling tinggi dalam enapcemar dan berkurangan mengikut pertambahan jarak sehingga nilai 0.13 mg/l. Visual MODFLOW yang terdiri dari MODFLOW dan MT3DMS telah digunakan untuk membuat jangkaan aliran air bawah tanah dan keadaan pencemaran pada tempoh 10 dan 50 tahun akan datang. Sepanjang tempoh ini dua jenis had sempadan (Sempadan Tekanan Malar, STM) telah digunakan. Bagi jenis



pertama STM diletakkan di utara dan pemodelan pergerakan air bawah tanah semasa tempoh telah dilaksanakan jangkaan tanpa sebarang perubahan dalam sifat hulu hidraulik kawasan. Hasil pemodelan menunjukkan pencemaran tidak mengalir ke dalam kolam dari kawasan enapcemar tetapi ia mungkin akan dibawa keluar dari kawasan kajian mengikuti arah aliran air bawah tanah. Bagi jenis kedua STM telah ditempatkan di kolam bagi merekodkan keadaan pencemaran apabila kedudukan paras air tanah jatuh dua meter di dalam kolam. Keputusan jangkaan menunjukkan pencemaran berpindah secara langsung ke dalam kolam dari kawasan enapcemar terutama melalui lapisan No.2. Ini adalah disebabkan kekonduksian hidraulik yang tinggi bagi lapisan tersebut. Jangkaan pencemaran air bawah tanah menunjukkan kepekatan fosforus meningkat pada penghujung tempoh jangkaan dalam kawasan kajian. Ini boleh dikaitkan dengan perpindahannya dari kawasan enapcemar.

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## **DECLARATION**

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

**SEYED REZA SAGHRAVANI**

Date: 25 August 2009



## TABLE OF CONTENTS

		<b>Pages</b>
<b>DEDICATION</b>		i
<b>ABSTRACT</b>		ii
<b>ABSTRAK</b>		v
<b>ACKNOWLEDGEMENTS</b>		viii
<b>APPROVAL SHEETS</b>		ix
<b>DECLARATION FORM</b>		xi
<b>LIST OF TABLES</b>		xiv
<b>LIST OF FIGURES</b>		xv
<b>LIST OF APPENDICES</b>		xvii
<b>LIST OF ABBREVIATIONS</b>		xviii
 <b>CHAPTER</b>		 1
<b>1</b>	<b>INTRODUCTION</b>	1
	OVERVIEW	1
	STATEMENT OF THE PROBLEM	2
	OBJECTIVES OF RESEARCH	3
	SCOPE OF RESEACH	3
	SIGNIFICANCE OF THE STUDY	4
 <b>2</b>	 <b>LITERATURE REVIEW</b>	 6
	POLUTION OF GOUNDWATER	6
	DEFINITIONS	6
	SOURCES OF GROUNDWATER CONTAMINATION	7
	PHOSPHORUS IN GROUNDWATER	12
	PHOSPHORUS CYCLE	19
	FORMS OF PHOSPHORUS	21
	MODELING IN HYDROGEOLOGY	23
	SIMULATION OF GROUNDWATER FLOW AND	
	GROUNDWATER CONTAMINATION	33
	MODFLOW AND VISUAL MODFLOW	34
	SUMMARY	39
 <b>3</b>	 <b>RESEARCH METHODOLOGY</b>	 41
	GENERAL DESCRIPTION OF STUDY AREA	41
	CONSTRUCTION OF OBSERVATION WELLS	46
	INSTALLATION OF PVC INTO WELLS	47
	DETERMINE THE ELEVATION OF OBSERVATION	
	WELLS	47
	AUTOMATIC LEVEL SURVEYING	47
	REAL TIME KINEMATIC GLOBAL POSITIONING	
	SYSTEM	48
	STATISTICAL ANALYSIS	48



MEASUREMENT WATER LEVEL IN WELLS	49
DETERMINATION OF FLOW DIRECTION	49
GROUNDWATER SAMPLING AND ANALYSIS	50
SAMPLE COLLECTION	50
ORTHOPHOSPHORUS MEASUREMENT	51
CALCULATION OF EVAPOTRANSPIRATION	51
MODELING	52
GROUNDWATER FLOW MODEL	52
MODEL CALIBRATION AND VALIDATION	54
INPUT DATA	56
SOIL PROPERTIES OF STUDY AREA	56
DEFINITION OF BOUNDARY CONDITIONS	57
OUTPUT	59
<b>4 RESULTS AND DISCUSSION</b>	<b>61</b>
GENERAL	61
GROUNDWATER FLOW DIRECTION	61
CHEMICAL ANALYSIS	67
SIMULATION BY VISUAL MODFLOW	71
MODEL INPUT DATA	71
SOIL HYDRAULIC PROPERTIES	71
BOUNDARY CONDITIONS	74
MODELING RESULTS	78
VALIDATION OF RESULTS	78
3650-DAYS SIMULATION PERIOD	78
18250-DAYS SIMULATION PERIOD	87
<b>5 CONCLUSIONS AND RECOMMENDATIONS</b>	<b>95</b>
GENERAL	95
SUMMARY OF RESULT	96
RECOMMENDATIONS	98
<b>BIBLIOGRAPHY</b>	<b>99</b>
<b>APPENDICES</b>	<b>107</b>
<b>BIODATA OF STUDENT</b>	<b>154</b>
<b>LIST OF PUBLICATIONS</b>	<b>155</b>



## LIST OF TABLES

		<b>Page</b>
2.1	Values of phosphorus for Class II and III	18
2.2	Simulations for the Kabong aquifer	38
3.1	Some characteristics of study area	54
3.2	Soil properties measured in study area	55
3.3	Values which reported for similar material	55
4.1	Longitude, latitude, and height of observation wells	63
4.2	Calculating a difference between two measurements	64
4.3	Groundwater level depth in observation wells	65
4.4	Component of soil in first layer	69
4.5	The data and result of monthly evapotranspiration	71
4.6	Thickness of layers which has observed in observation wells	72
4.7	Dispersion of phosphorus in clay loam and limestone	73
4.8	Storage characteristics of clay loam and limestone	74





## LIST OF FIGURES

	<b>Page</b>	
2.1	Distribution of point source of pollution in Malaysia	12
2.2	Simplified phosphorus cycle	20
2.3	The phosphorus cycle, phosphorus movement, and phosphorus-enrichment processes	21
2.4	Finite-element grid for an aquifer	30
2.5	Block-centered finite-difference grid	31
2.6	Mesh-centered finite-difference grid	32
2.7	A discretized Hypothetical aquifer system	35
2.8A	Migration after 1 year	39
2.8B	Migration after 10 years	39
3.1	General View of Study Area	42
3.2	Elevation Contour lines from MSL	43
3.3	Geological map of study area	45
3.4	Location of observation wells	46
3.5	Basic concept of RTK-GPS	48
3.6	Water level indicator	49
3.7	Determination of Groundwater movement direction	50
3.8	Guelph permeameter equipment	58
3.9	Flowchart of research methodology	60
4.1	Locations of observation wells in study area	62
4.2	Illustration of groundwater movement direction	66



4.3	Concentration of phosphorus in the study area (mg/l)	67
4.4	Texture triangle to determine type of soil	70
4.5	Location of Constant Head Boundary (CHB) and wall boundary	76
4.6	CHB in the Northwest of study area and wall boundary	77
4.7	Groundwater pollution concentration in study area after 3650 days in layer No.1 in steady state	80
4.8	Groundwater pollution concentration in study area after 3650 days in layer No.2 in steady state	82
4.9	Groundwater pollution concentration in study area after 3650 days in layer No.1 in transient state	84
4.10	Groundwater pollution concentration in study area after 3650 days in layer No.2 in transient state	86
4.11	Groundwater pollution concentration in study area after 18250 days in layer No.1 in steady state	88
4.12	Cross-sectional views of subsurface phosphorus concentration contours	90
4.13	Groundwater pollution concentration in study area after 18250 days in layer No.2 in steady state	91
4.14	Groundwater pollution concentration in study area after 18250 days in layer No.1 in transient state	93
4.15	Groundwater pollution concentration in study area after 18250 days in layer No.2 in transient state	94



## LIST OF APPENDICES

		<b>Page</b>
A	Variation of phosphorus concentration in layer No.1 and No.2 of the study Area	107
B	Figures of the study area	117
C	Climate parameters obtained from UPM weather station, Serdang, Selangor (2007)	126
D	National water quality standard for Malaysia (2004)	139
E	Graph and simulation results of calibration and validation	142
F	T-test result	145
G	Fan diagrams of aquifer layers within the study area	147
H	Results of Guelph permeameter test	150



## LIST OF ABBREVIATIONS

MODFLOW	Modular Three-dimensional Finite-difference Groundwater Flow
MT3DMS	Modular Three-dimensional Multi Species Transport Model
OTA	Office of Technology Assessment
UNTA	United Nation Technical Aid Assistance
DOE	Malaysian Department of Environment
NGMP	National Groundwater Monitoring Program
USEPA	United Nation Environmental Protection Agency
INWQSM	Interim National Water Quality Standard for Malaysia
GMS	Groundwater Modeling System
USGS	United State Geological Survey
MGO	Modular Groundwater Optimizer
WHO	World Health Organization
RTK	Real-time Kinematic
GPS	Global Positioning System
MSL	Mean Sea Level
CHB	Constant Head Boundary
HFB	Horizontal Flow Barrier



# CHAPTER 1

## INTRODUCTION

### 1.1. Overview

The rapid rate of urbanization and increasing demand for water is the major reason for considering groundwater as an alternative of surface water. Overuse in addition with misuse of water can be prologue to contamination of groundwater with harmful and poisonous substances. Recent studies have indicated that, human activities can alter the natural composition of groundwater through the disposal or distribution of chemicals and microbial matter over the land surface and into the soil, or through injection of wastes directly into groundwater.

Finding the new techniques to protect, prevent from pollution, and finding the sources of contamination for polluted groundwater are of major environmental concerns of modern societies. These subjects are the modern issues in hydrology and hydrogeology. Groundwater flow and contamination transport models are supplementary tools for the assessment and decision making about the fate of groundwater pollution. Reliable and adequate data is needed for modeling the hydrologic systems. The data and models are used for estimation of potential impacts of contamination and leachability of soil body and land



surface sources on the groundwater. The data also enables one to estimate the transportation of contaminants by the groundwater.

## **1.2. Statement of the Problem**

Groundwater as a source of potable water supply is often polluted due to human activity. Through widespread use of fertilizers and disposal of sewage into the groundwater in most parts of the country, it has been noted that accumulation as well as transportation of some nutrient such as phosphorus has been increased in some groundwater. This research is designed to deal with the identification of phosphorus transport in groundwater and a selected area is used as a case study.

The present research was conducted to evaluate the current stage of the groundwater contamination by phosphorus at the Engineering Complex of the Universiti Putra Malaysia in terms of the degree of pollution with phosphorus. The Engineering Complex used to be a paddy field before construction of current Engineering Complex. Currently fertilizers are being used at the south of this area where the Faculty of Architecture and Landscape is located. Since the aquifer slope down toward Northwest, groundwater flow is suspected to carry the pollutants into the study area.

Although the phosphorus in the groundwater did not show a significant threat to public health yet, but some alarming signs such as accelerated growth of

aquatic vegetation and algae have been observed. With the current phase of increased phosphorus concentration in the groundwater, this substance may affect the aquatic system through eutrophication in the long term. The excess in the use of fertilizers containing phosphorus accelerates the generation of the consequence problems.

### **1.3. Objectives of Research**

The objectives of this research are:

- a) To determine groundwater flow direction at the Engineering Complex, Universiti Putra Malaysia.
- b) To measure the concentration of phosphorus in the groundwater at the Engineering Complex.
- c) To predict direction of groundwater flow and phosphorus concentration in groundwater at area of the Engineering Complex.

### **1.4. Scope of Research**

- a) Determining the groundwater table in observation wells by RTK-GPS from Mean Sea Level (MSL) and consequently finding the local groundwater flow direction by interpolation.
- b) Measurement of the orthophosphorus as a dominant form of phosphorus by ascorbic acid method (Hach, 1988) in the study area.

- c) Obtaining the required data for two layers from field work and literature to employ Visual MODFLOW as a computational tool for this research.

### **1.5. Significance of the Study**

Simulation by computer for analyzing flow and fate of solute in groundwater systems has played an effective role in approaches to groundwater remediation and environmental management. It will be essential to have proper software to assess all part of the hydrological cycle which will help to manage water ecosystem and forecasting future events for decision making.

Visual MODFLOW is one of the powerful groundwater modeling softwares, which is able to simulate groundwater flow in a wide range of natural systems. The programs can combine proprietary extension, such as MODFLOW surfactant, MT3DMS, and a 3D model explorer to find the impacts of contamination in both surface and subsurface. It is interesting to note that Visual MODFLOW is used widely throughout the world and it can be applied to many modeling applications extensively.

In the research area, Visual MODFLOW is used to determine the groundwater behavior in connection with the pond and swamp as well as estimation of phosphorus migration which is increased progressively and loading for a long period of time. Result of this simulation will be useful for environmental





management of groundwater in the faculty of engineering Complex, University  
Putra Malaysia.

