GROUNDWATER MODELLING FOR DETERMINATION OF OPTIMUM PUMPING RATE AT KUBANG KERIAN OF KELANTAN

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ABSTARK

Kelantan adalah salah sebuah negeri di Malaysia yang 40% daripada penggunaan air datand dari air bawah tanah. Populasi dan ekonomi di Kelantan meningkat seperti negeri-negeri lain di Malaysia. Peningkatan populasi manuasia dan pembangunan ekonomi menyebabkan peningkatan permintaan air bersih di Kelantan. Air bawah tanah memainkan faktor utama dalam menghadapi permintaan air terutama di Kota Bharu. Oleh sebab itu, pengambilan air bawah tanah perlu diuruskan untuk mengelakkan masalah kepada sistem air bawah tanah. Untuk pengurusan air bawah tanah yang baik, Ia memerlukan simulasi air bawah tanah dengan menggunakan berbeza-beza kadar pengepaman. Objektif utama kajian ini adalah melakukan simulasi pergerakan air bawah tanah di kota bharu, Kelantan dengan menggunakan tiga dimensi model simulasi air bawah tanah dalam menentukan kadar pemgepaman optimum. Air bawah tanah mengunakan air hujan dan air sungai berdekatan untuk menambah jumlah air bawah tanah. Oleh sebab itu, impak daripada pengambilan air bawah tanah dari air sungai terutamanya semasa musim kering diutamakan. Pergerakan air bawah tanah dan budget pemgaliran boleh ditentukan melalui simulasi menggunakan keadaan statik dan keadaan bergerak dalam aliran air bawah tanah. Hasil kajian menyatakan bahawa 30 juta liter sehari air boleh dipam daripada air bawah tanah. Ia tidak memberikan kesan negatif kepada sumber air bawah tanah dan ekosistem.

ABSTRACT

Kelantan is the only state of Malaysia where about 40% of water supply comes from groundwater. Population of Kelantan is increasing and economy is growing like other parts of Malaysia. The increased population and developing economy will certainly increase water demand. Groundwater has to play an important role to meet the growing demand in the state. Therefore, abstraction of groundwater should be managed properly to avoid overexploitation. For proper management of groundwater resources, it is required to simulate groundwater status under different pumping situations. The major objective of the present research is to simulate groundwater flow at Kubang Kerian located in Kota Bahru of Kelantan by using a three-dimensional groundwater simulation model in order to determine the optimum pumping rate. The groundwater in the study area is recharged by rainfall and nearby river system. Therefore, the impact of groundwater abstraction on the river system especially during dry season is also assessed. Finally, the groundwater flow pattern and flow budget are determined by simulating both steady state and transient conditions of groundwater flow. The study reveals that maximum 30 MLD of water can be withdrawn in the study area without any negative impact on groundwater resources and surrounding ecosystem.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOL

K	Hydraulic Conductivities
P	Precipitation
Ea	Evapotranspiration
Q	Flow Rate
ΔS	Storage
Ss	Specific Storage
Sy	Specific Yield
n	Porosity
T	Transmissivity
b	Layer Depth
W	River Width
L	Length of the River
M	Thickness of Riverbed
Φriv	Head on the River side of the Riverbed
φaquifer	Head on the Aquifer Side of the Riverbed

LIST OF ABBREVIATIONS

JPS	Department of Irrigation and Drainage
JKR	Public Works Department
JMG	Minerals and Geo Science Department
DOE	Department of Environment
AKSB	Kelantan Water Authority
DID	Department of Irrigation and Drainage Malaysia
GIS	Geographic Information System
UTM	University Technology Malaysia

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Kelantan, situated at northeast of peninsular Malaysia is the only state of Malaysia where a major portion (40%) of total water supply comes from groundwater. Groundwater is main source of water supply in Kota Bharu, the capital state of Kelantan. Groundwater supplies more than 90% of the total water demand in Kota Bharu. Groundwater exploration in Kota Bharu has increased drastically in the last decade because of increasing water demand in residential, industrial and agriculture sectors.

The population in Kelantan is increasing and the economy also growing rapidly like other states of Malaysia. Irrigation based agriculture is also growing to feed the growing population with sufficient food. Increased population and consequent growth of water demand will certainly increase groundwater demand in Kota Bharu. Therefore, the likely increase of groundwater abstraction to meet the growing demand will certainly affect the groundwater resources as well as the ecology of the river system as it plays a major role in groundwater recharge.

It is required to understand how increased groundwater exploitation will affect groundwater resources and river water flow in Kota Bahru if groundwater exploitation is increase. Kubang Kerian is a small area located in Kota Bahru. The area under investigation covers 33 km^2. Groundwater is the only sources of water to meet the

demand in the area. The location has only one well field that is still on production to abstract water from shallow aquifer. The area has good potential for groundwater. The present study is carried out in Kubang Kerian area to understand the impacts of groundwater pumping using three-dimensional groundwater modelling technique.

This study presents groundwater flow using Groundwater modelling system (GMS) version 7.1. Groundwater modelling system (GMS) is a computer software package that can be used in modelling the aquifer. MODFLOW is one of groundwater computer code that has flexible modelling program which can simulate groundwater flow, both steady state and transient, under varying assumptions about the geology and hydraulic characteristics of aquifer and external stresses such as extraction wells, recharge, evaporation, drainage and river.

1.2 Problem Statement

Water demand in Kelantan has increased in recent years because of the growth of population, industry and agriculture. More than 90% of domestic water supply in Kelantan comes from groundwater (Wan Mohd Zamri W. Ismail, Ismail Yusoff, 2013). Water demand projected by local authorities reveals that water demand of the state will continue to increase very sharply in the coming years. Figure 1.1 shows the water demand projection by local authorities for designing water supply system in Kota Bharu from 2000 until 2050 (SMHB, Ranhill, and Perunding Zaaba., 2000).

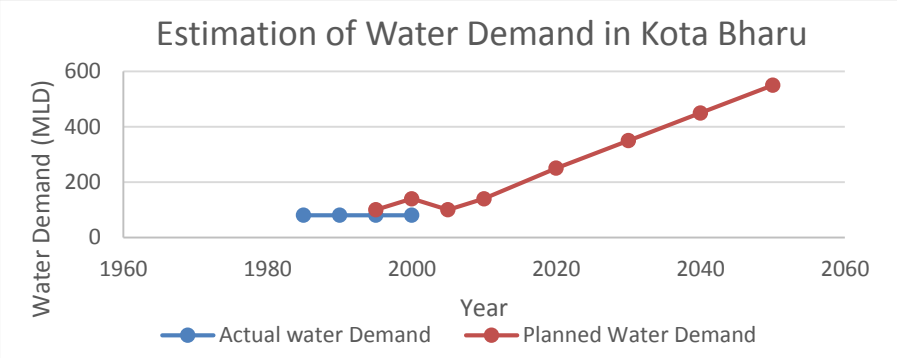

Figure 1.1 Estimation of Water Supply Demand in Kota Bharu (2000- 2050) (SMHB, Ranhill, and Perunding Zaaba., 2000)

Kubang Kerian water well was developed at the centre of Kubang kerian area. This location is not suitable places to increase water pumping because of limitation of available space, potential of contaminant effect from surrounding area and limitation of pumping rate for each well due to types of pump used. Because of that, new location of well field must be selected to increase the supply of raw water.

Groundwater modelling software named as Groundwater Modelling System (GMS) version 7.1 is selected for the modelling of aquifer in Kubang Kerian in order to develop understanding of the groundwater system in the area. Modelling is an attempt to replicate the behaviour of natural groundwater or hydraulics system by defining the essential features of the system in some control physical or mathematical manner. The movement of groundwater in the study area is important to model the groundwater flow and understand the hydrologic characteristics or conditions on the study area.

1.3 Objective of Study

The major objective of this study is to simulate the groundwater flow using a three-dimension groundwater flow model for the determination of optimum pumping in Kubang Kerian of Kelantan. The detail objectives are:

1. To develop a three dimensional (3D) groundwater flow model for the aquifer located in Kubang Kerian of Kelantan
2. To assess the impacts of different groundwater abstraction scenarios on river system
3. To estimate the optimum rate of groundwater withdrawal in the area

1.4 Scope of Study

This study focuses on simulation of groundwater flow in the aquifer located in Kubang Kerian, Kelantan. The computer package of groundwater modelling system (GMS) version 7.1 was employed for the study. The GMS package uses USGS groundwater flow model known as MODFLOW for the simulation of three dimensional flow of groundwater using finite different techniques. The simulation is carried out for both steady state and transient conditions to determine groundwater movement.

Published data available in journal articles, previously done research project reports, and government reports are gathered. Data of water level, river conductance, hydraulic conductivities, rainfall, well discharge, specific storage and specific yield are gathered and used in the present study for simulation. Groundwater level and rainfall data from January 2008 until December 2008 are used. Model is calibrated and validate with groundwater level data for both steady state model and transient conditions. The development model is also used to study drawdown of groundwater table and groundwater flow during wet and dry periods using three scenarios of groundwater pumping rates. The results obtained are analyzed for the determination of the optimum pumping rate for the study area.

1.5 Important of Study

Conducting detail hydro-geological investigation at the site is very costly and time consuming especially conducting studies by construction of observation wells and pumping test. Computer simulation modelling is one of alternative method that can help the responsible parties to view behavior of groundwater system quickly and cost effectively. The model can be used to assess the water flow pattern of an aquifer which is can provide adequate information for groundwater management.

The abstraction of groundwater is increase in the area every year. New location of well should be built to meet the increased demand of water from different stakeholders. Even through it is anticipated that the area has abound groundwater resources for abstract, optimized pumping must be carried out to avoid any negative implications to the groundwater as well as ecosystem especially to the river systems of the area.

References

Mohd. Badruddin Mohd. Yusof. (1997). *Environmental management : an overview of water resources management in Malaysia.* Johor bharu: UTM.

Bob Booth and Andy Mitchell. (1991). *Getting Started with ArcGIS.* USA: ESRI.

D.G. Fredlund. (1994). Equation for the Soil Water Characteristic Curve. *Canada Geotech, J. 31*, PP. 521-532.

Ismail C. Mohamad. (2012). *Groundwater Monitoring in Malaysia.* Ipoh: Department of Mineral and Geoscience of Malaysia.

Jacques W. Delluer. (1999). *Handbook of Groundwater Enginering.* USA: CRC Press LLC.

Luay. J. Froukh. (2002). Groundwater Modelling in aquifer with Highly Karstic and Heterogeneous Characteristics (KHC) in Palestine. *Water Resources Management*, PP. 367-379.

Mohamad Faizal Tajul Baharuddin. (2002). *Pengurusan Airbumi untuk Akuifer Cetek Pesisir (Tesis).* Johor Bharu: UTM.`

Mohd Faizal TB. (2002). *Groundwater Management for Shallow Aquifer in Coastal Area of Kota Bharu* . Johor: UTM.

Nassir Bsher Madi. (2002). *Groundwater Study for Shallow Alluvium Aquifer at Kota Bharu, Kelantan.* Johor Bharu: UTM.

N.K. Ang. (1978). *Hydrogeological Investigation – Proposed DID Water Management Centre, Kg. Panji, Kota Bharu, Kelantan.* Kuala Lumpur: Geological Survey of Malaysia.

R. Rejani, Madan K. Jha. (2008). Simulation Modelling for Efficient Groundwater Management in Balasore Coastal basin, India. *Water Resources management 22*, PP. 23-50.

R. Sravanan, R. Balamrurugan. (2011). Groundwater Modelling and demarcation of groundwater Protection Zones for Tirupur Basin - A Case Study. *Journal of Hydro-environment Research*, PP. 197-212.

Siti Nur Zulaijah. (2012). *spreadsheet optimizing for evalauting Soil Water Retention Curve (SWRC) by Using Van Genucten Model* . Johor Bharu: UTM.

SMHB, Ranhill, and Perunding Zaaba. (2000). *National Water Resources Study 2000-2050.* Kota Bharu: Kelantan .

Victor M. Ponce. (2007). *SUSTAINABLE YIELD OF GROUNDWATER.* California: California Department of Water Resources.

Umar Hamzah, Abdul Rahim Samsudin. (2007). Groundwater investigation in Kuala Selangor using Vertical Electrical Sounding (VES) Survey. *Environment Geology 51*, PP. 1349-1359.

W.M Nawang. (1989). River Aquifer Interaction in North Kelantan, Malaysia. *Hydraulic and water Resources*, PP.310-313.

Wan Mohd Zamri W Ismail. (2011). *Groundwater Management System Using Hydrogeological Model in Sg. Kelantan River Basin.* Kuala Lumpur: University of Malaya.

Wan Mohd Zamri W. Ismail, Ismail Yusoff. (2013). Simulation of Horizontal Well Performance using Visual Modflow. *Environment earth Science (68),* PP. 1119-1126.