UNIVERSITI PUTRA MALAYSIA

EVALUATION OF GROUNDWATER POTENTIAL FOR IRRIGATION AT THE SEBERANG PERAK AQUIFER, MALAYSIA

MOHD FAUZIE BIN JUSOH

EVALUATION OF GROUNDWATER POTENTIAL FOR IRRIGATION AT THE SEBERANG PERAK AQUIFER, MALAYSIA

By

MOHD FAUZIE BIN JUSOH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

July 2013

DEDICATION

This thesis is dedicated to my beloved father, mother and family who enormously prayed and encouraged me.

The verses in the Holy Koran (year 610 C) are totally true where I realize that:

These verses explained about hydrologic cycle and groundwater existence:

"And We send down water from the sky according to (due) measure, and We cause it to soak in the soil; and We certainly are able to drain it off (with ease)".

[Surah Al-Mu'minun, Verse 18]

"So We opened the gates of heaven, with water pouring forth. And We caused the earth to gush forth with springs, so the waters met (and rose) to the extent decreed".

[Surah Al-Qamar, Verse 11-12]

These verses explained about existence of shallow aquifer:

"Seest thou not that Allah sends down rain from the sky, and leads it through springs in the earth? Then He causes to grow, therewith, produce of various colors: then it withers; thou wilt see it grow yellow; then He makes it dry up and crumble away. Truly, in this, is a message of remembrance to men of understanding".

[Surah Az-Zumar, Verse 21]

"And We produce therein orchard with date-palms and vines, and We cause springs to gush forth therein".

[Surah Yaasin, Verse 34]

This verse explained about existence of deep / fracture rock aquifer:

"Then your hearts became hardened after that, being like stones or even harder. For indeed, there are stones from which rivers burst forth, and there are some of them that split open and water comes out, and there are some of them that fall down for fear of Allah. And Allah is not unaware of what you do."

[Surah Al-Baqarah, Verse 74]

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

EVALUATION OF GROUNDWATER POTENTIAL FOR IRRIGATION AT THE SEBERANG PERAK AQUIFER, MALAYSIA

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July 2013

Chairman : Associate Professor Hasfalina Che Man, PhD

Faculty : Engineering

The pumping well performance and aquifer performance in a quaternary sediment of Gula Formation at Seberang Perak Integrated Agricultural Development Area (Seberang Perak IADA) has been investigated quantitatively. The study was conducted in the years of 2009 and 2010 at a selected rice cultivation area. Aquifer performance test was carried out by conducting 24 hours constant discharge pumping test in a shallow alluvial aquifer.

The time drawdown data were collected at three different wells. The pumping well performance was evaluated by using continuous step-drawdown pumping test. Time-drawdown data was analyzed by using AquiferTest Pro software version 4.2. The aquifer test enabled the values of hydraulic characteristics of

the aquifer material such as transmissivity, hydraulic conductivity, and specific yield to be determined. Well performance was interpreted through well loss coefficient and specific capacity. The predictive analysis of drawdown through multiple pumping well was based on the results of aquifer performance.

The type of the aquifer up to about 10 m depth from ground surface at the research area is unconfined aquifer. The Neuman model and Boulton model have been used to evaluate the hydraulic characteristic of the aquifer. The transmissivity value from observation wells varied from 581 to 940 m^2day^{-1} with the average transmissivity of 761 m^2day^{-1}. This indicates that the aquifer was categorized as having high groundwater potential. The hydraulic conductivity values obtained from observation well 1 and observation well 2 range from 58.1 $mday^{-1}$ to 94.0 $mday^{-1}$. This implies that the aquifer materials are developed from coarse grain sand. The specific yield from observation well 1 and observation well 2 are found to be 0.0041 and 0.0135 respectively. The results of aquifer hydraulic characteristic are in agreement with the recovery test analysis.

In term of well performance, the average specific capacity of the pumping well is found to be 6.1223 m^2hr^{-1}. Specific capacity of the tested well is classified as having moderate potential. The average well efficiency of the tested tube well is found to be 92%. This showed that the well has been well designed and the screen was installed at the suitable location in the aquifer. The coefficient of

aquifer loss and well loss are found to be 0.1513 hrm^{-2} and 0.002 hr^2m^{-5} respectively. In each step, the drawdown inside the pumping well is influenced more by the aquifer loss compared to the well loss.

The potential yield of the pumping well is calculated as 450 m^3day^{-1}. Based on the crop water requirement and groundwater irrigation on the field, it is estimated that 4 hectares of paddy plot requires 260 m^3day^{-1}. However, the pilot project on groundwater irrigation for rice cultivation on the study site use less than the amount of water calculated from crop water requirement. The result of 24 hours constant discharge pumping test shows that the drawdown at the pumping well is 2.2 m with the total abstraction of 240 m^3day^{-1}. Two pumping wells are required to irrigate 4 hectares of paddy plot. The effect of drawdown on multiple pumping well can be predicted through the result of pumping test directly which can save time and minimize the research cost.

Abstrak thesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN POTENSI AIR BAWAH TANAH UNTUK PENGAIRAN DI AKUIFER SEBERANG PERAK, MALAYSIA

Oleh

MOHD FAUZIE BIN JUSOH

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Penilaian telaga pengepaman dan prestasi telaga pengepaman dalam sedimen kuartenari bagi Formasi Gula di Kawasan Pembangunan Pertanian Bersepadu Seberang Perak (IADA Seberang Perak) telah dikaji secara kuantitatif. Kajian telah dijalankan pada dari tahun 2009 – 2010 di kawasan penanaman padi terpilih. Prestasi akuifer telah dinilai dengan menjalankan ujian pengepaman luahan tetap selama 24 jam dalam lapisan alluvium cetek.

Data surutan-masa telah diperhatikan daripada 3 telaga berlainan di kawasan kajian. Prestasi telaga pengepaman telah dinilai dengan menggunakan ujian pengepaman surutan berperingkat berpanjangan. Data surutan-masa telah dianalisis dengan menggunakan perisian AquiferTest Pro Versi 4.2. Ujian pengepaman membolehkan nilai sifat-sifat hidraulik seperti keterusan,

kekonduksian hidraulik, dan simpanan tentu dikira. Prestasi telaga diinterpretasi melalui pekali kehilangan telaga dan kapasiti tentu. Analisis jangkaan bagi surutan melalui pengepaman telaga berganda berdasarkan keputusan prestasi akuifer.

Jenis akuifer pada kedalaman sehingga 10 m daripada tanah di kawasan kajian adalah akuifer tidak terkekang. Model Neuman dan model Boulton telah digunakan untuk menilai sifat-sifat hidraulik akuifer tersebut . Nilai keterusan daripada telaga pemantauan berjulat antara 581 hingga 940 m^2hari^{-1} dengan purata keterusan 761 m^2hari^{-1}. Ini menunjukkan akuifer dikategorikan mempunyai potensi yang tinggi. Nilai kekonduksian hidraulik yang diperolehi daripada telaga pemantauan 1 and telaga pemantauan 2 berjulat antara 58.1 $mhari^{-1}$ ke 94 $mhari^{-1}$. Ini menunjukkan bahan yang membina akuifer terdiri daripada pasir kasar. Simpanan tentu daripada telaga pemantauan 1 dan telaga pemantauan 2 didapati masing-masing berjulat antara 0.0041 dan 0.0135. Keputusan daripada ujian pemulihan adalah berpadanan dengan sifat-sifat akuifer yang diperolehi daripada ujian pengepaman luahan tetap.

Dari segi prestasi telaga, purata hasil tentu bagi telaga pengepaman adalah 6.1223 m^2jam^{-1}. Hasil tentu bagi telaga yang diuji telah diklasifikasikan sebagai keupayaan pertengahan. Purata kecekapan telaga yang diuji pula adalah 92%. Ini menunjukkan bahawa telaga telah direkabentuk dengan baik dan kedudukan saringan telah diletakkan di kedudukan yang sesuai di dalam akuifer. Pekali

kehilangan akuifer dan pekali kehilangan telaga adalah masing –masing 0.1513 $jamm^{-2}$ and 0.002 $jam^{2}m^{-5}$. Bagi setiap langkah, surutan di dalam telaga pengepaman adalah lebih dipengaruhi oleh kehilagan akuifer berbanding kehilangan telaga.

Hasil upaya bagi sebuah telaga pengepaman adalah sebanyak 450 $m^{3}hari^{-1}$. Berdasarkan keperluan air tanaman dan pengairan menggunakan air bawah tanah di kawasan kajian, adalah dianggarkan 4 hektar kawasan padi memerlukan sebanyak 260 $m^{3}hari^{-1}$. Walaubagaimanapun, projek perintis menggunakan air bawah tanah untuk pengairan tanaman padi di tapak kajian menunjukkan air bawah tanah yang digunakan adalah kurang daripada jumlah keperluan air tanaman. Keputusan daripada ujian pengepaman luahan tetap menunjukkan surutan yang terhasil selepas 24 jam adalah 2.2 m dengan jumlah luahan adalah sebanyak 240 $m^{3}hari^{-1}$. Dua telaga pengepaman adalah diperlukan untuk mengairi kawasan seluas 4 hektar kawasan padi. Kesan surutan daripada telaga pengepaman berganda boleh dijangka melalui keputusan ujian pengepaman secara terus dimana ia boleh menjimatkan masa dan meminimumkan kos.

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I certify that a Thesis Examination Committee has met on 29 July 2013 to conduct the final examination of Mohd Fauzie Bin Jusoh on his thesis entitled "Evaluation of Groundwater Potential for Irrigation at the Seberang Perak Aquifer, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee commends that the students be awarded the Master of Science (Soil and Water Engineering).

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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MOHD FAUZIE BIN JUSOH

Date: 29 July 2013

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m^3yr^{-1}	: Cubic meter per year
m^3day^{-1}	: Cubic meter per day
m^3hr^{-1}	: Cubic meter per hour
m^2day^{-1}	: Square meter per day
m^2hr^{-1}	: Square meter per hour
$mday^{-1}$	: Meter per day
L	: Liters
m	: Meter
m^3	: Cubic meter
mm	: Millimeter
kW	: Kilo watt
Hz	: Hertz
$mmin^{-1}$	: Meter per minute
$cmday^{-1}$	: Centimeter per day
mg/l	: Milligram per liter
^oC	: Degree celsius
T	: Transmissivity
K	: Hydraulic conductivity
S_y	: Specific yield
S	: Storage coefficient
c	: Hydraulic resistance
L	: Leakage factor

kg	: Kilogram
Kg.	: Kampung
Sg.	: Sungai
IADA	: Integrated Agriculture Development Area
DID	: Department of Irrigation and Drainage
MGDM	: Minerals and Geoscience Department of Malaysia
NWRS	: National Water Resources Study (2000 - 2050)
NEAC	: National Economic Action Council
JICA	: Japan International Cooperation Agency
MOA	: Ministry of Agriculture
DOE	: Department of Environment
AKSB	: Air Kelantan Sdn Bhd

CHAPTER 1

INTRODUCTION

1.1 Background

Water is very important in our life and others living things. Water is needed in human activities for domestic, agriculture, recreation and industrial purposes. Two major water resources are surface water and groundwater. Groundwater is the hidden water source where the quantity of groundwater actually is greater than the amount of available surface water. Fitts (2002) mentioned that fresh groundwater is about 100 times more plentiful than fresh surface water, but surface water is commonly used as it is easy to obtain.

Water is important in agriculture sector for plant and livestock growth. It is estimated that 70% of fresh water worldwide is being used for agriculture where 1,000 L of water are required to produce 1 kg of cereal grain and 43,000 L of water are required to produce 1 kg of beef (Pimentel *et al.*, 2004). Rosegrant *et al.* (2002) reported that worldwide cereal demand will grow by a projected 46% between 1995 and 2025 and for developing countries; it is projected by 65%. The demand worldwide is expected to grow by 56% and for developing countries it is projected to be more than double of 1995 production. The development of groundwater resources can increase agricultural production to meet the food needs of a country (Islam, 2006).

Rice is the staple food for most of the Asian country including Malaysia. More than 90% of global rice is produced and consumed in Asia (Akinbile *et al.*, 2011; Lee *et al.*, 2005a). Malaysia is currently ranked 25th of world paddy production with a production capacity of 2.4 million tonne and cultivable land of about 0.7 million hectares since 1980s (Akinbile *et al.*, 2011). Water is a critical element in rice cultivation and this crop need a large amount of water (Rowshon *et al.*, 2012) during pre-saturation and normal growth (Akinbile *et al.*, 2011; Azwan *et al.*, 2010; Lee *et al.*, 2005b; Rosegrant*et al.*, 2002; Mahmad *et al.*, 2000).

Integrated Agricultural Development Area (IADA) was introduced by Ministry of Agriculture and Agro-Based Industry Malaysia in 1965, focusing on development of granary area in Malaysia (Ministry of Agriculture, MOA, 2011). MOA (2011) highlighted three general objectives of IADA which are; i) to increase the income and productivity of farmers, ii) to increase the paddy yield to 6.5 metric tonne per hectare towards 2010 and iii) to modernize the rice agriculture sector. Therefore, in order to achieve the general objective listed, a reliable and proper management of irrigation water on paddy plantation is very important to be stressed.

The average yields of paddy at Seberang Perak IADA, Kerian Sungai Manik IADA, Barat Laut Selangor IADA and Pulau Pinang IADA for 2010 were 3.352, 3.344, 4.979, and 5.029 metric tonne per hectare respectively (MOA, 2010). These indicating that paddy production in granary area in Malaysia are not achieving the target of 6.5 metric tonne per hectare for IADA projects. Munit (2010) mentioned that the paddy yields in Sekinchan area has been successfully achieved to 10 metric tonne per hectare whereas it was not obtained in Tanjung Karang granary area. This

situation was probably happened due to inadequate supply of irrigation water and improper monitoring system of water supply. Akinbile *et al.* (2011) and Keizrul (2006) agreed that the water problems being experienced by Malaysia today is not about having too little water to satisfy our needs especially in agriculture but it is a problem of ineffective water management. Haque *et al.* (2006) supported that poor management of available water for irrigation at the system and farm level caused aggravated water availability and further reduced the benefits of irrigation investments.

Global warming causes climate change and the most affected area of the world is South East Asian which located in the tropical region where it cause productivity loss, varying monsoon pattern and water scarcity (Dewi, 2009). Malaysia is blessed because it receives abundant amount of rainfall each year. The average annual rainfall for Peninsular Malaysia, Sabah and Sarawak are 2400 mm, 2360 mm and 3830 mm respectively (Che-Ani *et al.*, 2009). However, Malaysia is experiencing occasional water shortages (David, 2004).

The largest granary area for Malaysia which is Muda Irrigation Scheme was experienced six incidents of drought in the period of 1977 until 1992 (Mon & Chang, 2008). Water supply for irrigation and domestic use in Perlis is mainly supplied from Muda, Pedu and Timah Tasuh dams. However, the recent severe drought have cause the water level in these dams dropped to the critical level (Issa *et al.*, 2012a). The Muda and Pedu dam have experienced critical low water storage in 1978, 1987, 1991 and 1998 that caused paddy farmer forego the off-season planting (Jamalluddin & Sing, 2003). In early 2006, Kedah and Perlis received less rainfall than normal and

consequently, off-season planting was delayed and almost to be cancelled (Keizrul, 2006). The water shortages in Malaysia caused farmers face deficiencies in water deliveries and further reduce the rice yield (Keizrul, 2006; Mon & Chan, 2008) and reduce farmer's income (Haque *et al.*, 2006).

Lee *et al.* (2005a) proposed a new schedule for cropping calendar of Besut irrigation Scheme to overcome water scarcity during off-season planting. During February 2010, Malaysia again faced the drought. It was estimated that 184 hectares of Melaka paddy plantation area was affected because the canal become dry and therefore, water cannot be supplied to the field block (" Kemarau jejas lima kawasan sawah di Melaka ", 2010). Jamalluddin and Sing (2003) expected that frequency and intensity of drought in Malaysia will increase in the future. Chan (2009) caution that there are now increasingly frequent occurrences of drought and water stress in recent years as happen in Malacca, Selangor and parts of East Malaysia.

The surface water resources in Malaysia also become more polluted from year to year. Haliza (2007) supported that the development of urban area, industrial and commercial activities has contributed to river pollution. Consequently, the number of Malaysia's river categorized in Class I and Class II was decreasing while in Class IV and Class V was increasing. According to National Water Resource Study, NWRS (2000a), the river basins that classified as Class III and need extensive advance treatment prior being used as water supply are Sg. Linggi at Kg. Baru Mambau, Sg. Pahang at Bentong, Sg. Perak at Bagan Datok, Sg. Melaka at Alor Gajah and Sg. Selangor at Batang Berjuntai.

Department of Environment, DOE (2009) reported that from 1063 water quality monitoring stations involved 577 rivers monitored, 578 (54%) monitoring stations were classified as clean, 378 (36%) slightly polluted and remaining 107 (10%) were polluted. The report also shows that there was a reduction in river water quality in 2009 compared to 2008 due to increase numbers of polluting sources for instance sewage treatment plant, manufacturing industries and palm oil mills. The river pollution affecting paddy plantation since most of irrigated water is diverted from river.

The National Economic Action Council (NEAC) has identified groundwater as one of the alternative water resources for Malaysia that has the good potential to be developed (Heng, 2004) including the dry areas like Perlis (Issa *et al.*, 2012b). Mazlin *et al.* (2008) agreed that groundwater resources need to be explored and sustainably developed especially in water stressed and isolated areas. Khardzir (2006) stated that the development of groundwater as alternatives water supply is the right action to satisfy the increasing water demand. Groundwater irrigation is better compared to traditional surface water irrigation in terms of more reliable supplies, less influence by drought and ready accessibility for individual users (Garrido *et al.*, 2006; Lloyd, 1981).

1.2 Problem Statement

Water is very important for agriculture especially for rice cultivation in tropical region. A large amount of water is required for land preparation and growing stage of rice cultivation. Groundwater has been identified as alternative water sources for irrigation in rice cultivation areas during drought and off-season planting. However, studies need to be made in advance to assess the aquifer potential and it hydraulic characteristics. Seberang Perak, Perak, Malaysia is located at the Teluk Intan district. Based on Quaternary Geology Study of Teluk Intan Area, Perak Darul Ridzuan by Hoong (1992), Seberang Perak shallow aquifer has a good potential to be developed and used for irrigation due to existence of available freshwater at the upper part of the aquifer and low water table at this area. However, there is no detail study and systematic study on the shallow aquifer hydraulic characteristics at this area.

The present study was conducted to evaluate the storage and transmissive property of Seberang Perak shallow aquifer by conducting pumping test. Currently, the farmers use surface water as the main water resources for rice cultivation. The study on well performance evaluation as well as simulation approach to investigate the effects of the multiple pumping well on drawdown at the study area was also conducted. The tube well developed can act as point water source near cultivation plot and at the same time, it is suitable to be developed for the plot which is located far away from main canal in order to supply enough water and save irrigation time. The data on aquifer hydraulic characteristics and potential well yield are vital in groundwater monitoring and planning for the future groundwater development.

1.3 Objectives of the Study

The main objective of this research is to evaluate the groundwater potential of Seberang Perak aquifer, Perak, Malaysia. This quantitative study was conducted to meet the demand of groundwater as source of irrigation for paddy cultivation at Seberang Perak Integrated Agricultural Development Area (IADA Seberang Perak). The specific objectives of this research are:

i. To determine hydraulic characteristics of the aquifer from pumping test based on constant discharge pumping test.
ii. To evaluate the performance of the pumping well by using step-drawdown pumping test.
iii. To predict the effect of water table drawdown pattern from different scenarios of abstracting rate for rice cultivation.

1.4 Scope of the Study

i. This study will focus on evaluating groundwater potential at Seberang Perak aquifer for rice cultivation by conducting pumping test.
ii. The pumping test consists of two components which are constant discharge pumping test and step-drawdown pumping test. Constant discharge pumping test was carried out to evaluate aquifer performance of the research area. The step drawdown pumping test was carried out to determine the performance or efficiency of the tube well that have been constructed.
iii. The results of pumping test data can be used to analyze the effects of groundwater abstraction from multiple pumping well by using AquiferTest Pro V4.2 software.

1.5 Limitations of the Study

Evaluation of groundwater potential is one of the in-situ tests for estimating hydraulic characteristics of the aquifer for irrigation of the paddy crop. The area of study limited to the Seberang Perak area with the shallow aquifer type (less than ten meter depth). This research was only focusing on shallow aquifer only because of the limited tube well at the research area as well as high costing in developing new tube well. The result of pumping test was obtained during off season in order to reduce the dependence on rain water along the season during rice cultivation and to avoid direct recharge to the aquifer system.

1.6 Organization of the Thesis

Five chapters are presented in this thesis. The chapters will include the theoretical part of the study, methodology, result and discussion. Chapter one roughly explains about background of the study, the problem statement, the objectives of the study, the scope as well as the limitation of the study. Chapter two of the thesis is concerned mostly with the role of groundwater in the hydrologic cycle, the utilization of groundwater in Malaysia, parameter of hydraulic characteristic of the aquifer and the method of analyzing pumping test data. Chapter three covers general geology and hydrogeology of the research area, execution of constant discharge pumping test, execution of step drawdown pumping test and drawdown prediction from multiple pumping well. Chapter four describes the analysis of aquifer performance by using AquiferTest Pro V4.2 software, well performance analysis, and estimation of groundwater abstraction from four different selected scenarios. The last chapter contains conclusions and the recommendations for the future research.

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