DRAINAGE SYSTEM IN FLAT AREA USING GROUNDWATER RECHARGE WELL IN SOLVING FLOODING PROBLEM

by

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Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

January 2015

ACKNOWLEDGEMENT

In the name of Allah S.W.T., the Most Gracious and the Most Merciful

The writing of this thesis has been one of the toughest challenges I have to face throughout my academic career. I would particularly like to thank to supervisor, Prof. Dr. Nor Azazi Zakaria and co-supervisor, Dr. Lau Tze Liang for their guidance. I also would like to express special regards and to acknowledge the financial support from Universiti Sains Malaysia as a research university for continuous support. Special thanks to Universiti Tun Hussein Onn Malaysia for giving me the opportunity to set up my model and for providing me with the facilities. I would like to thank those who assisted me in the preparation of this work including my family, for their tremendous efforts in supporting me. Finally, I would like to thank my friends for their tremendous support and cooperation throughout my study. My special thanks also go to my beloved husband and daughters who are always being there during this invaluable journey to success.

Sabariah Musa

2015

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LIST OF ABBREVIATIONS

ARI	average recurrence interval
ARC	antecedent runoff condition
AQTESOLV	aquifer test software
BAKAJ	Badan Kawalselia Air Johor
BH	bore hole
BRC	bar reinforcement concrete
BOD	biological oxygen demand
CILAS	particle size apparatus
CN	curve number
COD	chemical oxygen demand
DID	Department of Irrigation and Drainage
DO	dissolve oxygen
EW	extra well
FTIR	fourier transform infrared spectroscopy
HSG	hydrologic soil groups
JMG	Jabatan Mineralogi dan Geosains Malaysia
KEMAS	Jabatan Kemajuan Masyarakat
KKTM	Kolej Kemahiran Tinggi Mara
MSMA	Manual Saliran Mesra Alam Malaysia
MW	monitoring well
NDWQS	National Drinking Water Quality Standard

OW	old well
PVC	polyvinyl chloride
RECESS	Research Centre of Soft Soil Malaysia
REWES	Recharge well system
RISDA	Rubber Industry Small Holders Development Authority
RW	recharge well
SEM	scanning electron microscopy
UTHM	Universiti Tun Hussien Onn Malaysia
VES	vertical electrical sounding
XRD	x-ray diffraction
XRF	x-ray fluorescence
1D	one dimension
2D	two dimension
3D	three dimension

LIST OF SYMBOLS

I, i	Intensity of rainfall (mm/hr)
P	depth of rainfall (mm)
F_D	adjustment factor for storm duration (Table 13.3 - MSMA) (dimensionless)
P_{30}, P_{60}	30^{th} minutes and 60^{th} minutes duration rainfall depths respectively (min)
S	maximum amount of water that will be absorbed after runoff begins (mm)
I_a	initial abstraction (dimensionless)
L_i	interception (mm)
P_T	total rainfall depth (mm)
a,b,n	empirical constants (dimensionless)
f	the infiltration capacity (mm/hr) at time t
f_o	the initial rate of infiltration (mm/hr)
f_c	the final constant rate of infiltration (mm/hr)
k	a shape factor (per hr)
t	the time from the start of rainfall (hr)
R	Total runoff (mm)
t_e	time of rainfall excess (min)
Q	rate of injection (m^3/day)
V	average velocity (m/s)
n	Manning's roughness coefficient (dimensionless)
Q_y	*y* year ARI peak flow (m^3/s)
C	runoff coefficient (dimensionless)
${}^{y}I_{t}$	*y* year ARI average rainfall intensity over time of concentration, t_c (mm/hr)
A	Drainage area (m^2)

I Hydraulic gradient causing vertical flow in the gravel pack (dimensionless)

A cross section area (m^2)

P coefficient of permeability of gravel (m/day)

T the transmissivity (m^2/day)

Δs the drawdown difference (m)

S the storativity (dimensionless)

t_o time axis (intersection point, s = 0, t = t_o) (min)

r^2 the effective radius of the single well (m)

S_c the specific capacity (m^3/day/m)

S_A volume of water instantaneously released from storage ($m^3/m^2/m$)

S_y specific yield (dimensionless)

$d_{t\,max}$ depth of trenches (m)

T_s storage time (min)

V_r the porosity of the stone /module fill (%)

T_f the filling time (min)

z the side slope (horizontal over vertical) (%)

W width of trenches (m)

V_c the volume of capture runoff (m^3)

K hydraulic conductivity (m/day)

b aquifer thickness (m)

h_w head above the bottom of aquifer while recharging (m)

H_0 head above the bottom of aquifer when no pumping is taking place (m)

r_0 radius of influence (m)

r_w radius of injection well (m)

R recharge to the aquifer (m^3/day)

GW_{in} influxes from upgradient portion of ground water system (m^3/s)

GW_{out} effluxes to downgardient portion of ground water system (m^3/s)

Q_s discharge to surface water bodies (m^3/s)

Q_w abstractions from ground water system through wells (m^3/s)

$\Delta S / t$ change in ground water storage in the system per unit time (m^3)

r recharge rate (volume per unit surface area) (m^3/m^2)

$\Delta H / t$ rate of seasonal rise in water level in a well (m)

n effective porosity of the aquifer (%)

K_r radial hydraulic conductivity (m/s)

K_z vertical hydraulic conductivity (m/s)

R the soil resistance (ohm-m)

β Neuman parameter (β for a single observation well)

K the coefficient of permeability

D_{15} the soil particle diameter corresponding to 15% passing of the grain size (mm).

C_v coefficient of rate of consolidation (m^2/year or m^2/s)

γ_w unit weight of water (kN/m^3)

m_v coefficient of volume compressibility (m^2/MN)

a_v coefficient of compressibility

e_o initial void ratio

H_s equivalent thickness of solids (m)

W_s dry weight (g)

G_s specific gravity of the solid

π 3.1416

SISTEM SALIRAN DI KAWASAN TANAH RATA MENGGUNAKAN ALIRAN MASUK TELAGA AIR BUMI BAGI MENANGANI MASALAH BANJIR

ABSTRAK

Sri Gading di Johor menghadapi masalah berkaitan air yang disebabkan oleh limpahan air permukaan di kawasan yang rata dan kelemahan penyaliran air semasa musim tengkujuh. Kadar penyusupan tanah yang rendah di Sri Gading disebabkan oleh kebolehtelapan saiz zarah halus yang perlahan yang dikenalpasti sebagai tanah liat berkelodak. Kerja penyiasatan tapak terdiri daripada kajian permukaan dan sub-permukaan telah dijalankan sehingga kedalaman tanah liat 50 m daripada aras purata laut. Kajian permukaan termasuk ujian penyusupan, ujian kerintangan elektrik dan ujian pengepaman dan pemulihan, manakala ujian kebolehtelapan, ujian pengukuhan dan pengkelasan asas tanah telah dijalankan dalam penyiasatan subpermukaan. Kadaralir air bumi kawasan ini dipengaruhi oleh dua sifat lapisan tanah iaitu keliangan dan kebolehtelapan. Daripada ujian lapangan, kebolehtelapan tanah ialah 0.0001 - 0.086 m/hari yang memenuhi julat piawai jenis tanah liat berkelodak. Dengan kata lain, kawasan Sri Gading mengalami masalah bekalan air semasa musim kering. Oleh itu, satu replika *Recharge well system* (REWES) sebagai sistem tadahan bawah tanah telah dicadangkan untuk mengatasi masalah banjir dan bekalan air dengan mengalirkan air larian permukaan terawat ke dalam sistem akuifer. Konsep yang digabungkan dengan pengepaman dan penyaliran masuk air bumi dinilai dapat mengalirkan aliran secara efektif sehingga 31% (12.5m^3/hari – penyaliran masuk piawai 20% -100%) selama 2 jam (tempoh kecemasan) penyaliran. Kajian secara geologi dan mineralogy membuktikan bahawa hubungan kualiti air bumi di antara keaslian air bumi dan kandungan kualiti bahan pencemar bergantung kepada proses pengaliran keluar (kaedah pengepaman) atau penyaliran masuk (kaedah

pencairan). Dengan aliran air yang melalui lapisan tanah, kualitinya akan berubah dan dalam masa yang sama ciri-ciri hidraulik juga boleh dipertingkatkan berdasarkan kesesuaian rekabentuk di tapak dan masalah persekitaran. Akhirnya, aplikasi konsep tadahan ini dapat meningkatkan sistem kitaran air bagi pengurusan air rebut bandar dalam menangani masalah banjir dan bekalan air.

DRAINAGE SYSTEM IN FLAT AREA USING GROUNDWATER RECHARGE WELL IN SOLVING FLOODING PROBLEM

ABSTRACT

Sri Gading in Johor faces water related problems that are caused by excessive surface runoff floods the low areas and ineffective drainage system during wet season. The low infiltration rate of the soil in Sri Gading is caused by low permeability of fine-grained sizes of silty clay. Soil investigation work consisting surface and sub-surface studies were conducted until deep layer clay at 50 m from the mean sea level. The surface studies included infiltration test, resistivity survey, and pumping and recovery tests, while permeability, consolidation, and basic soil classification tests were carried out in subsurface investigation. The flow rate of groundwater in the study area is controlled by two properties of the soil layer, namely porosity and permeability. From the field test, the permeability of the soil is 0.0001–0.086 m/day which falls into the standard range of silty clay. On the other hand, Sri Gading area encounters water supply shortage during dry season. Therefore, the replica of a recharge well system (REWES) as an underground retention system is proposed to solve both flooding and water scarcity problems by recharging treated surface runoff into aquifer system. The combined concept of pumping and recharge was evaluated to effectively capture up to 31% (12.5 m^3/day – recharge standard 20% -100%) throughout 2 hours in (emergency period) of reaches. This geological and mineralogy study establish the groundwater quality relationship between pure groundwater and contamination quality control work during discharge (pumping method) or recharge (dilution method) actions. By letting water pass through the ground, its quality will change, and its geo-hydraulic characteristics will improve the capacity based onsite design and environmental problems. Then, application of retention

concept is integrated with water cycle for urban stormwater in solving flooding problem and water supply management.

CHAPTER 1

INTRODUCTION

1.1 General

Commercial developments in the outskirts of Sri Gading are famous for their local delicacies and textile industries such as Munchy's, Hup Seng, and Hwa Tai biscuits manufacturer, Miaow Miaow Food Products Sdn. Bhd., New Star Food Industries Sdn. Bhd., LY Furniture, Ramatex, and multinational corporations including Fujitsu, Sharp Roxy, and J.R. Courtenay. Sri Gading has a lot of rivers and lakes, and more than 20 bridges are found across this small district. These bridges are rather modest but they have been in this district since the initial development, assuming the heavy responsibility of linking houses and business on both ends.

Parit Raja is a small town in Sri Gading district, Johor, Malaysia. The main population of this town is Javanese and substantial growth has taken place in this region in the past few years. Universiti Tun Hussein Onn Malaysia (UTHM) is located along Jalan Kluang between Fujitsu Sdn. Bhd. and Kolej Kemahiran Tinggi Mara (KKTM). This campus is near to the Parit Raja town and is now a preferred residential location among the upper middle class residents.

The study site is new to the Research Centre of Soft Soil Malaysia (RECESS), UTHM which is situated on the typical area of Sri Gading with drainage problems due to the flat terrain. The total area compacted 11,099.93 m^2 consisting of 629.67 m^2 of laboratories, 1284.13 m^2 of pavement, and the remaining area is naturally covered with cow grass. It is also surrounded by concrete and earth channels. Jabatan Kemajuan Masyarakat (KEMAS) area is situated in the south of UTHM and Kolej Kemahiran Tinggi Mara (KKTM) to the west; both areas are located on a higher ground than the study area. The contour ground level is around 1.6 m to 1.9 m with the surrounding boundary of 2.5 m above the mean sea level. Thus, the study area is located in the flat terrain area which does not directly flow the surface water to the discharge point. Figures 1.1 and 1.2 show the distribution of the low lying area (light blue colour) in Sri Gading district (Tjahjanto et al., 2006) and the ground platform at RECESS area respectively. The details of ground level and drainage system are illustrated in Figure A1 (Appendix A).

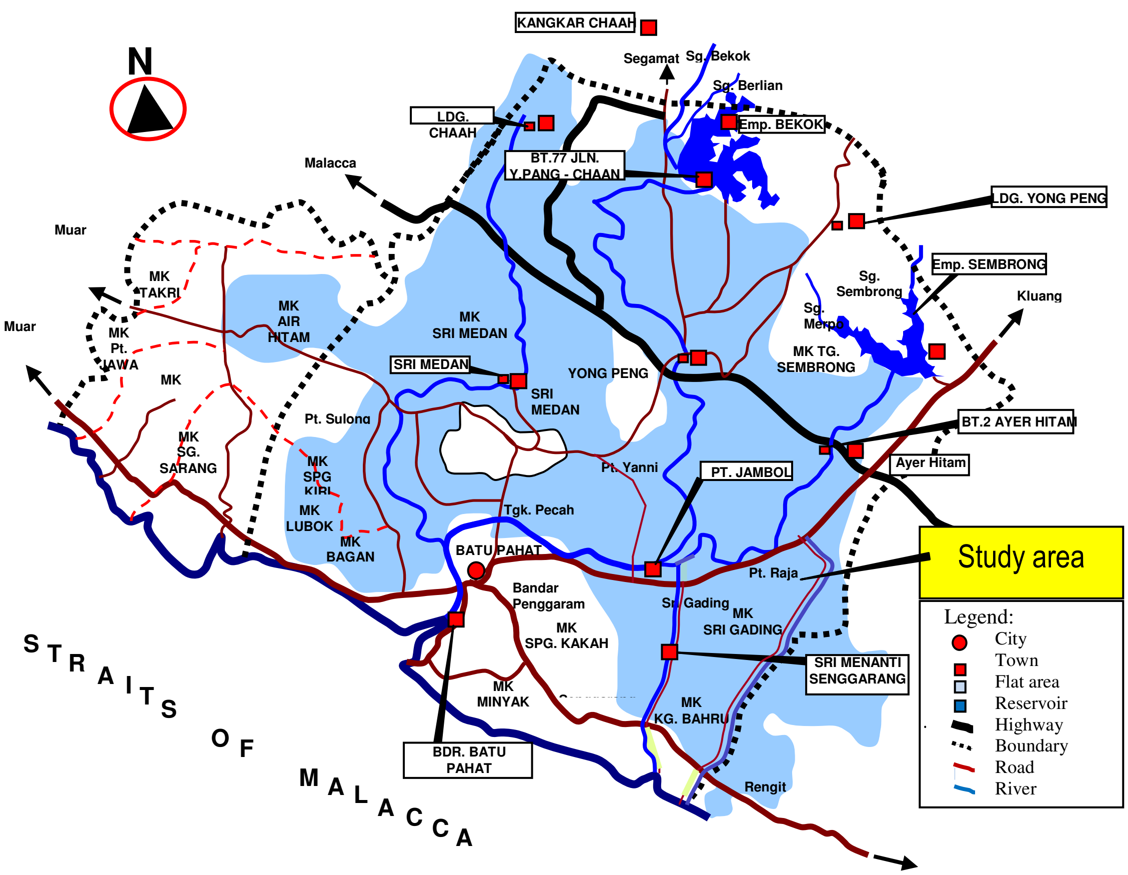

Figure 1.1 Study areas at Sri Gading, Johor (Tajahjanto, 2006)

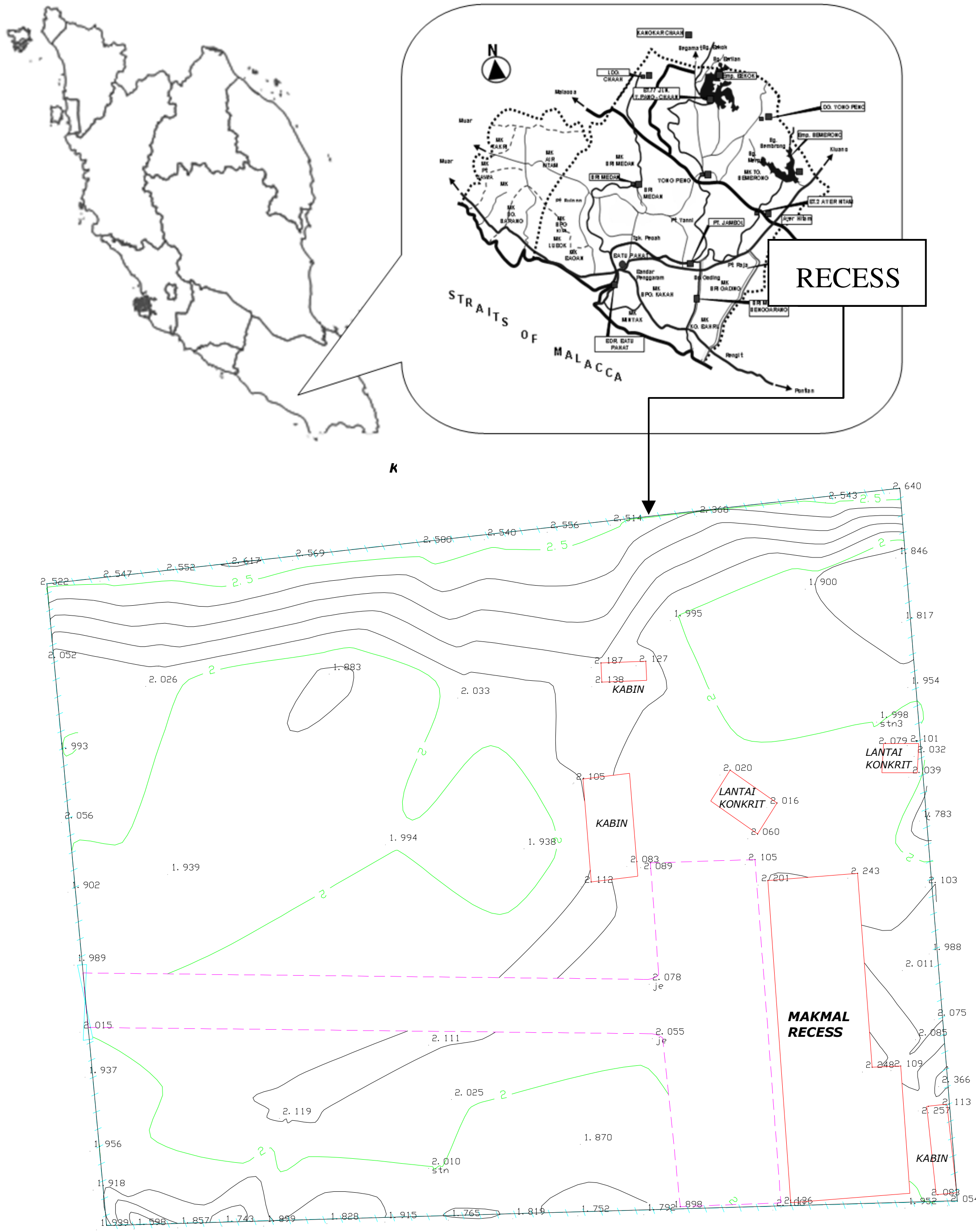

Figure 1.2 Map and contour lines of study area in the Research Centre of Soft Soil Malaysia (RECESS)

The development of the Sri Gading district has caused an increasing number of inhabitants. The population in Parit Raja increases substantially since the establishment of UTHM. Several incidents of flooding occurred in rural and urban areas especially in Parit Raja (Zhou, 2007). Figure 1.3 shows one of the flood occurrence at the UTHM main campus and its surrounding area at the end of December 2006 to January 2007 due to the poor drainage system.

On the other hand, one of the consequences of population increase is high water demand. Study shows that the municipal council is not able to provide sufficient quality water supply due to type of soil affects to groundwater intake (Tjahjanto et al., 2008). Another contributing factor of flood in Sri Gading is the low permeability of soil due to the ground being covered by peat soil on the surface and clay in the deep layer.

Figure 1.3 Flood and inundation in the area of Universiti Tun Hussien Onn Malaysia and its surrounding area of Sri Gading

1.2 Flooding Area

Based on Tjahjanto et al. (2008), Department of Irrigation and Drainage (DID) stated that the area of Batu Pahat experiences a huge flood in every 100 years. The recent event is shown in Figure 1.4. Over 70% of the areas are flooded and roads are damaged. The flooding was a result of the following: (1) excessively high rainfall, where 170 to 247 mm/day was recorded at Bekok Dam, and 181 to 229 mm/day was recorded at Sembrong Dam; (2) insufficient capacity of the available reservoirs to store surface runoff, where the maximum water levels were above the critical levels, i.e., over 17.5 m in Bekok Dam and 12.0 m in Sembrong Dam; (3) the cross section of the river was insufficient to handle the peak flow rate; and (4) most areas of Sri Gading have low infiltration rate and low lying areas (approximately 1.5 m to 2.0 m above mean sea level), making the river incapable to discharge stormwater effectively to the sea.

Figure 1.4 Flooding in Sri Gading area

Figure 1.5 shows an example of flood on 9 July 2013. The recorded rainfall depth within 2 hours 22 minutes is 789 mm (Musa et al., 2013). Indirectly, groundwater discharge also supports water distribution with better water quality compound to the surface runoff in this area.

(a) Study area in wet condition (b) Recharge well system in study area

Figure 1.5 Present study area condition during wet season

Hence, groundwater recharge well need to be studied as an alternative way to enhance the drainage system of a flat area using sub-surface land as water storage and as a source for water supply. This recharge method is considered applicable for flat area with silty clay or clay soil types, deep layer of bedrock, high water table, and low infiltration rate. The application of a vertical groundwater recharge system is possible for the flat area and remediation of these sites generally occur over many years. This vertical groundwater recharge system functions as underground retention basin drainage to store surface runoff and modelling recharge system for future work.

1.3 Problem Statements

The area of Parit Raja faces of flooding and shortage of water supply problems. Flood is a result of Sri Gading and its surrounding areas (about 20 km only from Pantai Rengit) almost flat and low land in area. This condition becomes worst with the low permeability of the top layer of soil covered with silty clay or peat soil. Thus, backwater from the river and the absence of proper stormwater drainage has caused flooding in the study area.

For water supply shortage, it is due to the limited source of fresh water caused by pollution in Sembrong River. A study by Rosli (2010) found that the tap water is not clean and its contaminants has 38% odour, 33% silty, 19% colour and 10% salty (Harian Metro, 2012). According to BAKAJ (Badan Kawalselia Air Johor) (2012), Sembrong Dam (West) losses 10 million litres of water per day due to algae bloom as shown in Figure 1.6. The fresh water in Sembrong Dam contains high levels of acid thus making water treatment costly. Pesticide chemicals flowing into Bekok Dam causes 500,000 users vulnerable to cancer and other chronic diseases as a result of continued aggression committed by irresponsible agencies (Harian Metro, 2012).

Figure 1.6 Algae problem since 2010 at Sembrong Dam

Local residents in Sri Gading are not confident with the use of shallow (< 10m) raw groundwater for domestic purposes because the groundwater quality at shallow intake exceeds the standard for water distribution (Musa et al., 2009). Most of the alternative water supplies are obtained from rainwater harvesting to support the water use. Some local residents use rainwater harvesting as an alternative to support the water demand in this area as shown in Figure 1.7. However, the rainwater cannot be used sometimes due to high levels of air pollutants from the industries (Tjahjanto et al., 2006).

Figure 1.7 Rainwater harvesting for non-potable usage (Rosli, 2010)

Based on the local problems is low infiltration rate during heavy rainfall, the vertical drainage using infiltration basin method is supposed to capture the runoff at the top surface, especially during wet condition. The combination between recharge well system (REWES) with pumping method has the potential to collect and channel more surface runoff during wet season or high rainfall intensity.

1.4 Objectives

The objectives of this study are as follows:

1. To determine the characteristics of the aquifer at the study area.

2. To evaluate the effectiveness of innovative system named REWES based on the discharge and recharge actions.
3. To evaluate the water quantity response of REWES and groundwater quality.

This study is conducted to determine the best way to overcome the problems due to the improper drainage system in the Sri Gading area. The drilled well, which is used to integrate with stormwater system, can be a part of vertical drainage system during the wet condition to mitigate flooding. The surface runoff with proper treatment would be suitable for groundwater recharge. Potential use of the urban stormwater runoff for groundwater recharge would be extremely site-specific. Besides, this study aims to identify a method to overcome water supply shortage and flood problems by making use of the groundwater sources and facilities around the area.

1.5 Scope of Study

The scope of works was summarized as follows:

(a) To design an innovative system named REWES based on the mechanism of existing well and geo-hydraulic properties.

(b) To construct REWES as a real-site model for Sri Gading area.

(c) To evaluate the quantity and quality of groundwater cycled through the REWES model.

The particular study was limited to data collection of parameters of aquifer from the existing well. Data collection from pumping test and recovery analysis is conducted to determine parameters of aquifers such as transmissivity (*T*), storativity (*S*), hydraulic conductivity (K), thickness of aquifer (b), specific yield (S_y) and specific capacity (S_c) based on existing well.

The evaluation of surface runoff to aquifer using the existing well as the onsite detention pond consisted of a roof, pipe system, surface runoff, and recharge well was performed. Variable and factor effecting recharge and discharge capacity during pumping and recovery test are determined. Evaluation of the potential aquifer as water quantity intake and storage capacity on existing well defines the contaminations or mineralogy for water quality requirements. The hydrological data was collected to determine the hydrological characteristics such as intensity (i), time of concentration (t_c), catchment area (A), coefficient of runoff (C), and runoff (R) based on the rational method.

Data collection on top surface area was done to determine the type of top soil using the soil classification test (standard method) and the infiltration test (I) using tension infiltrometer apparatus on the study area. Levelling survey also done to mapping the contours area for surface runoff flow and area surface profile. Three line - profile in sub-surface area using SAS 4000 apparatus was conducted by resistivity test along 400 m respectively. Resistivity soil test was carried out to verify that the resistivity survey values at the site can be transformed in determination of the type of soil in the study area.

The construction of a physical model (REWES) that consisted of infiltration basin, well and contact to aquifer were done to verify the results from the analysis. The effectiveness of the system as a vertical drainage was defined. The construction of 2-inch and 4-inch monitoring wells (4 nos) at the study area between 4, 10, 20, and 35 m from the recharge well. In addition, geotechnical tests such soil classification test, permeability test using load track apparatus and falling head, and consolidation tests for every 1.5 m depth on the soil samples were conducted. The variable and factors effecting recharge and discharge capacity during the pumping and recovery test were also determined.

Onsite basic water quality parameters such as pH, DO, turbidity, conductivity, salinity, chlorine, zink, cadmium, manganese, iron, lead, copper, nitrate, BOD, COD, nitrogen ammonia, and total suspended solid according to required water supply standard were investigated. Dry samples passing 300 mm for every layer on the main well were tested using X-Ray Fluorescence (XRF) and X-Ray Diffraction (XRD) analyses to determine the characteristics of mineralogy and nature of groundwater body sources.

1.6 Significance of Study

Although groundwater is available in the area of study, the water supply is still insufficient due to the limitation of water availability on surface. In Johor, the area studied by Musa et al. (2010) is limited for studies on groundwater as potential groundwater and stormwater management. Hence, the availability of groundwater should be enhanced by recharging surface runoff into the ground using the recharge well system, especially in urban area as retention or water storage; it was implemented in the Sri Gading district. Moreover, by using artificial recharge, the volume of water in the retention pond (RECESS area) is reduced, and thus the surface area is able to anticipate the stormwater (flood mitigation). This innovative system acts as discharge and recharge actions for water supply and drainage exchange for groundwater cycle to contribute more benefits for sustainable management and to integrate the channel system.

1.7 Outline of the Thesis

This thesis comprises of seven chapters as follows:

Chapter 1 begins with the history of the study area and followed by the problem statement, scopes of the research and objectives of the study.

Chapter 2 reviews studies from previous researchers and presents the important findings from past studies. It describes the theoretical applications of surface and sub-surface flow. Groundwater flow estimation and its parameters analysis are also included in this section. This chapter covers the theoretical background of analysis such as Darcy's Law, Rational Method, Nueman method and others solutions.

Chapter 3 describes stages of research methodology in details. The construction of REWES is presented which includes the drilling work of borehole, sampling the soils in layers, installation of pipes and pump, pumping tests for aquifer characteristics and water quantity and quality analysis.

Chapter 4 presents the characteristics of aquifer and its conditions of this study area. The interaction of groundwater activities and their reaction to real conditions are also analyzed. Evaluation of the aquifer characteristics using the well data collection and AQTESOLV software are described. The type of aquifer is then identified.

Chapter 5 describes the verification of the hydraulic conductivity and permeability values for this area based on types of soil. Some theories and methods applied to identify the aquifer characteristics are presented.

Chapter 6 presents the analysis of stormwater and groundwater demand. Both analyses for water quantity and water quality aspects are described. Pumping-recovery and pumping-recharge tests are discussed. The monitoring of water quality is discussed.

Chapter 7 concludes the findings of this study and suggests recommendations for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews available literatures that contribute to the understanding of current research on recharge well system. This study was conducted to evaluate the practical method for solving flooding and water scarcity issues.

Currently, there is no in-depth study or research on the stormwater recharge to underground structure for Sri Gading district area. Most studies focus on the stormwater management in terms of water quantity and quality, enhancement of the surface water and groundwater flow problems and application of the appropriate techniques as summarized in Appendix B.

2.2 Local Conditions

An appraisal of geological logs from exploratory drilling indicates that the subsurface is predominantly clayey in nature. The occurrences of sandy layers very limited both vertically and laterally. Some of the boreholes drilled penetrated an entirely clayey sequence (Logananthan et al., 1987). This investigation on the subsurface lithological and hydrogeological conditions in the area aims to determine the amount of groundwater can be obtained for domestic and/or industrial/agriculture use.

Generally, a top layer of brownish, peaty clay covers most of the area. Below the top covering is a layer of greyey clay, which is frequently mottled and locally contains a lateritic redness. Greenish, shell-bearing clay, probably of marine origin, is also extensive, particularly near the coast. Sand is limited in extent, both vertically and laterally, and is often admixed with a little clay (Logananthan et al., 1987). In the area of Sembrong, Johor, sand occurs as isolated layer within the extensive clay layers and has limited capacity as an aquifer. In addition, some other parts of the investigation area have only a few meters thick sand layers (Musa et al., 2010). This condition affects this study and proper investigation can explore suitable solutions for the problems of this area.

The report in titled Soil Investigation for New Campus at UTHM (Maju Teknik, 2003) also shows the similar result of an average 20 m depth of clay and silt cover the top layer. Only two points of the borehole (BH3 and BH10) show a sandy layer on the top surface as shown in Table 2.1. A total of 48 undisturbed soil samples were obtained from a very soft clayey layer in BH-1, BH-2, BH-4, BH-5, BH-7, BH-8, and BH-9. Nevertheless, this study investigates a deeper recharge well over 40 m deep, which found limestones one of the porous layer at this area as potential groundwater resources (Mohamad, 2010). Therefore, meteorological and geo-hydrological/ geophysical information about the catchment area, the existing water table and its fluctuations, water demand, availability of runoff water, and socio-economic condition are considered as fundamental input for recharge studies (Kamra et al., 2004). The investigation records on the study area were collected to assess the flooding problem and integrate the drainage system according to real conditions of the area.

Table 2.1 Types of soil for boreholes around study area (Musa et al., 2009)

Borehole no.	BH depth (m)	Thickness of layer (m) Clay	Silt	Sand
1	36.3	0-27	27-36.30	-
2	31.93	0-23	23-31.93	-
3	39.15	1.10-25	0-1.10 , 28.2-39.15	25-28.2
4	34.8	0-23.6	23.6-34.8	-
5	34.62	0-22	22-34.62	-
6	34.62	0.8-24.8	0-0.8, 24.8-34.62	-
7	31.87	0-24.4	24.3 - 31.87	-
8	28.65	0-21.8	21.8- 28.65	-
9	37.77	0-23.2	23.2-37.7	-
10	45.3	0.8-11.2 , 13-19	0-0.8 , 19-45.3	11.2 - 13

2.3 Retention Basin

Traditionally, the surface water is commonly used for surface runoff solution in the watershed but groundwater specific deals to the groundwater flow in the aquifer systems (Johnson, 1966). However, surface water and groundwater systems also have watersheds at flow-system divides and limited for area condition. The interaction of surface water and groundwater research by Thomas et al. (2003) studied groundwater movement in small catchment, the water table was not an exact replica of the land surface and the water table contours were not parallel to land surface contours because water table was affected by type of soil, area condition, water flow movement, drainage system and land use (Chuenchooklin et al., 2006).

By recharging the surface water with well system (Akan and Houghtalen, 2003), the configuration of the land surface affects the distribution of recharge areas because for a given permeability, water moving downward through the unsaturated zone reaches the water table sooner where the unsaturated zone is thinner (Al Ajlouni, 2007). If the region is underlain by poorly permeable geologic deposits, such as clayey, fluvial silt and clay, groundwater flow do not underlie surface divides in many settings (Thomas et al., 2003 and Kharal, 2002). However, recharge in the clay aquifer underlies flow divides in smaller region than confined aquifer with limited permeability's (Lerner, 1990). However, the man-made structure (REWES model) was applicable for water inserting to the ground by discharge and recharge methods.

Research by Donald (2003), are often conducted within smaller watersheds, either to focus on a more homogeneous watershed or to reduce costs. This study was conducted on a local condition by scaled retention basin to evaluate in small basin analysis to reduce the cost and specific study to local properties, specifically sub-catchment categories, to explore the vicinity properties of the recharge system at the site conditions (Musa et al., 2013). Then, the fluxes of infiltration surface runoff will be treated and collected before let it channeled to the ground by gravity (Mishra and Fahimuddin, 2005, and Tjahjanto and Kassim, 2004).

2.4 Soil Type

This study area is generally covered by clay that makes up more than 60% of the total layers up to 35 m depth (Musa et al., 2009). Sandy layer is limited in the extent both vertically and laterally in layers and it is often admixed with sandy clay. A survey on the sub-surface profile using the resistivity technique at the UTHM campus shows that the sand exists as isolated lenses within the extensive clay layers and is therefore of limited capacity as aquifers (Musa et al. 2009). Thus, this study location indicates that the sand presents as layers only a few meters thick and does not appear to have extensive lateral continuity in layer.

Research on soil permeability has been conducted in the area of UTHM (Tjahjanto et al., 2006). The top layer of soil in this area mostly consists of silty clay with very low rate of infiltration (Figure 2.1). The infiltration tests also results in no natural recharge from surface water to the sub-soil system or aquifer. Thus, this condition has potential to exchange the poor drainage system to recharge well as integrated drainage system, whereby the rainwater runoff is not reduced by process of infiltration. Study by Tjahjanto et al., (2008) shows that most parts in the Sri Gading area are flat (low laying area) and around 1.0 m to 1.5 m above mean sea level. This topography condition has resulted in the river being incapable of discharging stormwater directly to the downstream or sea. Certain drainage areas like the drainage area of the campus of UTHM and surrounding lowland area face floods every year due to backwater from the river.

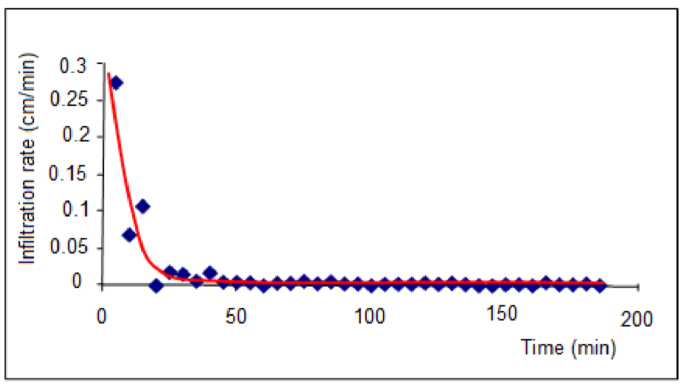

Figure 2.1 Infiltration rate of top layer of soil distribution at the study area

Ab. Hamidhad (2002) conducted a study on the requirement of drainage system for Parit Raja town, Batu Pahat using urban stormwater management manual. The area is 849.84 hectares, located at newly planned Parit Raja township between UTHM to Taman Robena. This study was conducted to design a flood prevention system in Parit Raja town that complies with the urban stormwater management manual. This study also established a baseline against the conventional system in order to integrate and improve the conventional system for long term uses. Based on this study by Ab. Hamidhad, 2002, the application urban stormwater management and recharge well system (REWES) useful for any types of soil and condition is possible.

The present study aims to examine the stormwater potential of artificial drainage as retention system where the water is channelled to surface infiltration or vertically spread to the recharge well system. The well-recharging process is helpful to improve groundwater quality because the raw groundwater is studied by Mohd Yusof (2009) contained iron. The quality of groundwater can be diluted by the rainwater that can be recharged into the well.

The potential groundwater recharge well in Sri Gading district was chosen because it is expected to gain popularity in the near future due to the rapid expansion of Parit Raja town into a centre of education in the southern part of Johor, Malaysia.

2.5 Resistivity Exploration

As preliminary record to survey the location and area conditions, a simple survey for profiling the layer needs to be conducted before the selection of any drilling well. According to Edward (1966), the best way to learn the character of the formations beneath the Earth's surface is to drill through the formations, obtain samples while drilling, and record a log of the borehole. The best point as well as installation of well logging consists of recording the characteristic properties of the various strata in terms of depth. However, an electric log and other kinds of geophysical logs may also be obtained under certain conditions. This method is the most popular technique for both regional and detailed groundwater explorations because of its wide range of applicability and low cost (Kumar et al., 2001).

Almost all of the resistivity studies conducted by researchers in Malaysia show that resistivity survey using geophysical techniques presented good results in subsurface profiles. Therefore, this method was used to delineate aquifer geometry, and to estimate hydraulic parameters such as hydraulic conductivity (*K*), transmissivity (*T*) and thickness (*b*) of aquifer. Then, groundwater contaminations also found by Kumar et al. (2001) imply that geo-electrical techniques offer an alternative approach of alluvial aquifer.

This technique is not limited for soil characteristics determination but Ibrahim et al. (2003) showed that the capability of resistivity imaging is effective for delineating the groundwater aquifer boundary and for mapping bedrock in the Banting area. The interpretation clearly shows that the thickness of the aquifer varies between 10 m to 30 m, and in some areas up to 45 m depending on length of line used. The depth of the bedrock estimated using 2-D resistivity imaging generally varies from 30 m to 65 m. The results of the resistivity imaging show that the interpretation is similar when compared to the reference well logs. The accuracy this method was chose to use this sub surface survey layer at the study area for three lines in layers.

Occasionally, the analysis of the result of resistivity does not match the existing values. Musa et al. (2013) proved that the moisture content, types of soil, temperature, and salt content influence the value of soil resistances. It also found that it is mainly influenced by the type of soil (clay, shale, and others), moisture content, the amount of electrolytes (minerals and dissolved salts), and finally, temperature. The soil resistivity result shows the real subsurface condition and at the same time indicates that the four point's method on undisturbed soil samples is correct (Musa et al., 2012).

Dhakate and Singh (2005) had almost the same findings using vertical electrical sounding (VES) to interpret the sub surface layer as shows in Table 2.2. Therefore, the interpreted results of these sounding curves useful to impliment before any costly projects are undertaken.

Table 2.2 Values of vertical electrical sounding method for groundwater exploration

Type of soil	Interpretation sub surface condition
Clay	< 10 ohm-m
Sandy Clay/ Clayey sand/ Clay and Kankar (aquifer)	10-25 ohm-m
Weathered Dunite/ Peridotite/ Metabasalt/ Pyroxenite (aquifer)	>25 – 160 ohm-m
Hard and massive bed rock	> 160 ohm -m

Source: Dhakate and Singh (2005)

2.5.1 Soil Resistance at the Real Site

Surface geophysical measurements and well log geophysics offer a higher resolution power in this sense (Ortege and Miranda, 2000 and 2004). Most researchers use the latest techniques such as to survey the subsurface condition (resistivity or VES test). These surveys are more efficient than conventional methods (borelog). However, the data analysis sometimes refers to bore log records or have a similar record with others area.

An important method for sampling and testing is used to verify the resistivity survey. Traditionally, direct drilling is a conventional method for exploring the subsurface in underground layers, but today, it is considered to be unsuitable. Nowadays, geophysical methods using resistivity survey are used to achieve accurate results. The most popular method for groundwater exploration is VES (Dhakate and Singh, 2005). However, to interpret the best results of these sounding curves, one must refer to the standardized values based on location and conditions. The soil resistivity test is widely used for simple interpretation type of soil through sub surface results. Therefore, soil resistance was recorded at this area for verification and interpretation analysis of other future works for unconfined case.

Area conditions and soil contaminations affect soil resistances. A study by Ozcep et al. (2009) analyzed the relationships between electrical resistivity and soil-water content in the context of electrical properties of coarse-grained soils and developed a practical and applicable relation for the determination of soil water content from geo-electrical measurements. The presence of moisture and saltwater content in the ground also causes the ions to dissolve in the moisture, resulting in a low resistivity of the soil.

The study on soil resistances at Sri Gading area can be potentially used for comparable results in research in real conditions. Interpretation result based on soil resistancy by Tjahjanto et al. (2006,) indicated that the layers of this area had very soft and very stiff clay with less sandy layer as an aquifer (Tan et al., 2009). This prediction result also indicated that Sri Gading is limited aquifer layer for stormwater management purpose.

Although, Musa et al. (2009) suggested using the groundwater as an alternative water supply at dry and wet conditions and control stormwater runoff in the wet condition by groundwater recharge and discharge well system.

2.6 Groundwater Recharge

Groundwater recharge is applied in a low laying area with a high water table which is used as underground retention of stormwater storage. When recharging the water to deep layers, this potential aquifer provides alternative flow channels during the wet condition and discharges groundwater by pumping method as needed. However, Sunjoto (2008) suggested an applicable infiltration method using a recharge well for water conservation and supply in urban areas due to limited space.

Several methods of groundwater recharge like spreading, pit, induced recharge and well methods are practiced. When the well method is used, recharge is fast and has no transit losses or evaporation losses (Khaledhonkar et al., 2003). Then, the groundwater recharge system is a better alternative that supports the open channel system, capturing surface water through infiltration, seepage, leaking, or recharge to the ground by gravity. This groundwater recharge technique is in balance with the climatic cycle because recharge and discharge must increase or decrease to readjust to the changed situation (Edward, 1966).

Well testing or evaluating aquifer transmissivity (Ortege et al., 1999) and permeability (Ortege et al., 2000) using geophysical well log and hydrodynamic parameters by longitudinal conductance is the best predictor of aquifer transmissivity. The pumping test or well test by Pech (2002), was found that the skin factor affected the well bore storage in a single well and capable to estimate aquifer parameters. Although, the pumping tests do not make it possible to study aquifer structural variability, which is necessary to efficiently solve many hydrology problems (Ortege and Miranda, 2004).

The investigation of groundwater recharge involves a variety of approaches, including soil moisture budgeting, well hydrograph analysis, numerical modeling, and water balance solution (Misstear at al., 2009). Lewandowski et al. (2009) found that groundwater recharge depends on factors such as temperature, vegetation, soil water saturation, and the thickness of the unsaturated zone. When the river and the oxbow are blocked, groundwater recharge does not occur since precipitating rainwater may flow directly into the surface water bodies as surface runoff. The dampening and delay of fluctuations of the river gauge spreading into the aquifer caused 70% of fluctuations, and 20% of groundwater recharge was due to precipitation events. According to Majumdar et al. (2009), topography causes a constant ratio of interflow and overland flow quantity to recharge the shallow aquifer. This relied on hydraulic conductivity, thickness, and the surface slope. Most rainfall runoff studies in the mountainous watershed focused on a single aquifer being recharged from the surface soil layer. Very often, multiple aquifers, not just a single aquifer, receive the interflow from the soil cover.

The use of injection wells to funnel stormwater to the underground aquifer has been practiced in Florida for years. In central Florida, up to 40 percent of the aquifer recharge is estimated to occur through drainage wells. A permit may be required if the department finds that a well is affecting primary drinking water standards or public health. An existing well may require alteration apart from routine maintenance, or repair work to restore a well to its