Journal of Geography, Environment and Earth Science International

Volume 27, Issue 7, Page 45-56, 2023; Article no.JGEESI.101741
ISSN: 2454-7352

The Delineation of the Langat Basin Aquifer Based on Geological and Hydrogeological Characterization of Three Urban Areas of Malaysia

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Authors' contributions

This work was carried out in collaboration between both authors. Author SJH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SJH and NR managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2023/v27i7695

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/101741

Original Research Article

Received: 19/04/2023
Accepted: 21/06/2023
Published: 07/07/2023

ABSTRACT

Aims: The aim of this study is to find out the hydrogeological settings and aquifer properties of Kajang, Bangi, and Semenyih urban areas to overcome the mismanagement of groundwater.
Study Design: The scarcity of groundwater is one of the major concerns of urbanization in growing populated countries like Malaysia. Lack of knowledge of subsurface geology, hydrogeology and aquifer properties is the main reason for the groundwater mismanagement of the Langat Basin.
Place and Duration of Study: The study targeted three growing urban areas Kajang, Bangi and Semenyih of Malaysia. Data were collected from the Mineral and Geosciences Department,

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Malaysia. Borehole logs, pumping tests and groundwater level monitoring data have been analysed and interpreted for this study.
Methodology: Subsurface logs have been produced by the Strater Demo4 software; Water level analyses have been done by the groundwater level monitoring data, the contour map was plotted by using ArcGIS software with calculated groundwater head values and the Pumping test curve has been prepared by using Excel 2007.
Results: Study areas are situated in Kenny Hill formation. Water is pumped from four types of formations they are; hard rock, weathered sedimentary, shallow sedimentary and a combination of alluvium and hard rock. Groundwater flow direction is controlled by the topography, from the hilly north-eastern side to the low elevated south-western side. The identified aquifer condition of the Kajang area is confined, boundary and consolidated fractured. Water is pumped from the confined fractured aquifer in Bangi town and from the leaky, consolidated fractured and unconfined aquifer in Semenyih town. Transmissivity and Specific capacity of all types of aquifers show a range of 2.35m^2/day to 25.92m^2/day and 2.64 m^2/day to 41.28m^2/day respectively.
Conclusion: This study will help to establish robust policies for the sustainable development of groundwater.

Keywords: Langat basin; hydrogeology; hydraulic properties; aquifer condition; Malaysia; urban area.

1. INTRODUCTION

Groundwater is one of the most precious natural resources, a highly significant and reliable source of water in all climatic regions of all over the world [1]. The high demand for groundwater in Malaysia is the areas where the surface water supply is insufficient and non-exist [2]. Subsurface water is being significantly utilized as a supplement in the water supply systems for public water supply in the state of Selangor. Karim [3], stated that groundwater is also being utilized by various sectors such as factories, estates, farms and the commercial production of mineral water.

The Langat basin in Malaysia contains some major urban centers like Kuala Lumpur, Kajang, Shah Alam, Semenyih and Bangi which are undergoing continuous development and expansion (Fig 1). Cities face scarcity of potable water due to their continuous expansion and increase in population. Some area exploits groundwater for household and industrial uses to overcome the scarcity. For this reason, the detection of subsurface hydrogeology and aquifer properties is very important for the Langat basin to understand the groundwater resource potential. The aim of this study is to delineate subsurface geological and hydrogeological conditions as well as aquifer properties with types of the aquifer of three towns of the Langat basin. Delineation of hydrogeology and aquifer properties has become the basic tool in hydrology [1]. It is very important for the management of groundwater resources and also can be used as a tool to improve a system that required decision-making and policy analysis.

1.1 Description of the Study Area

Langat Basin is located south of Selangor and north of Negeri Sembilan within latitude 2°40′N to 3°20′N and longitude 101°10′E to 102°00′E [4-6] (Fig 1). It is the largest river basin in Selangor, about 200km long and covers an area of 2,423 km^2 [7]. Topographically, the Langat basin can be divided into three geographic regions, i.e. the mountainous area of the north, the undulating land in the centre of the basin and the flat flood plain at the downstream of Langat River [8]. The basin is spread over the state of Selangor, Putrajaya and a small part of Negeri Sembilan [5]. The main study areas (Kajang, Semenyih and Bangi) are situated within the Selangor area. Kajang is a town in the eastern part of Selangor, Malaysia with location 2°59′35″N latitude and 101°47′20″E longitude. It is located about 20 km south of Malaysia's capital, Kuala Lumpur [9]. The location of the Bangi is 2° 54′ 00″ Latitude 101° 47′ 00″ Longitude with an altitude of 30m [10] and the location of the Semenyih is 2° 57' 0" North, 101° 51' 0" East.

1.2 Geology and Climate

Geologically Peninsular Malaysia is divided into three main domains; namely the Western, Central and Eastern Belts. These domains differ in several aspects, including lithology, age, tectonics, structure and paleogeography. Fig. 2. shows the general geological map of the Langat Basin. Bedrock in the mountainous area includes Permian igneous rocks and Pre-Devonian schist and phyllite of the Hawthornden Formation [11,12]. The predominant rock in the foothills is Permo-Carboniferous meta-sandstone, quartzite, slates, phyllites and quartz schist of Kenny Hill Formation [12]. On the coastal plain, quaternary deposits consisting of Palaeocene through Holocene unconsolidated gravel, sand, silt and clay of the Simpang, Kempadang, Gula and Beruas Formations unconformably overlay eroded bedrock, and grow progressively younger and thicker toward the coast [11].

Lithologically, Bangi and the surrounding area consist of weathered schist. Based on the geological map of the Geological Society of Malaysia (2008) [14], the study area is on the Kajang Schist Formation. Kajang Schist Formation is in the range of Silurian age up to Devonian. The Kajang Formation is composed of schist, limestone and a little phyllite. However, Rosly Mohd Nor [15] put Kajang Formation in the Kenny Hill Formation because of similarities. Kommo [16] estimated that the Bangi area's geological structure consists of three components: alluvium, metasediment and granite.

The climate in the study area is characterized by high average and uniform annual temperatures, high rainfall, and high humidity. This climate directly impacts the hydrology and geomorphology of the study area. Generally, the study area experiences two types of seasons: the wet season in April to November and a relatively drier period from January to March [17,8].

1.3 Hydrogeology

The coarse to very coarse sandy gravel of the Simpang Formation (Palaeocene to Pliocene) at the base of the Quaternary strata is considered the main aquifer of the Langat Basin [12]. The aquifer is typically several meters thick near the foothills and varies from about 50 m to more than 100 m further toward the coast [18].

Almost all alluvial plains have a high potential of groundwater occurrence. Whereas, in steeply mountainous areas underlain by granite with low lineament density, the potential for groundwater is very low. Meanwhile, in hard rock areas, the groundwater potential is high in areas with high lineament density and low drainage density [4]. Highly productive alluvial aquifers of the Langat Basin are the main target for groundwater development. The transmissivity and storativity of the aquifer are shown in Table 1.

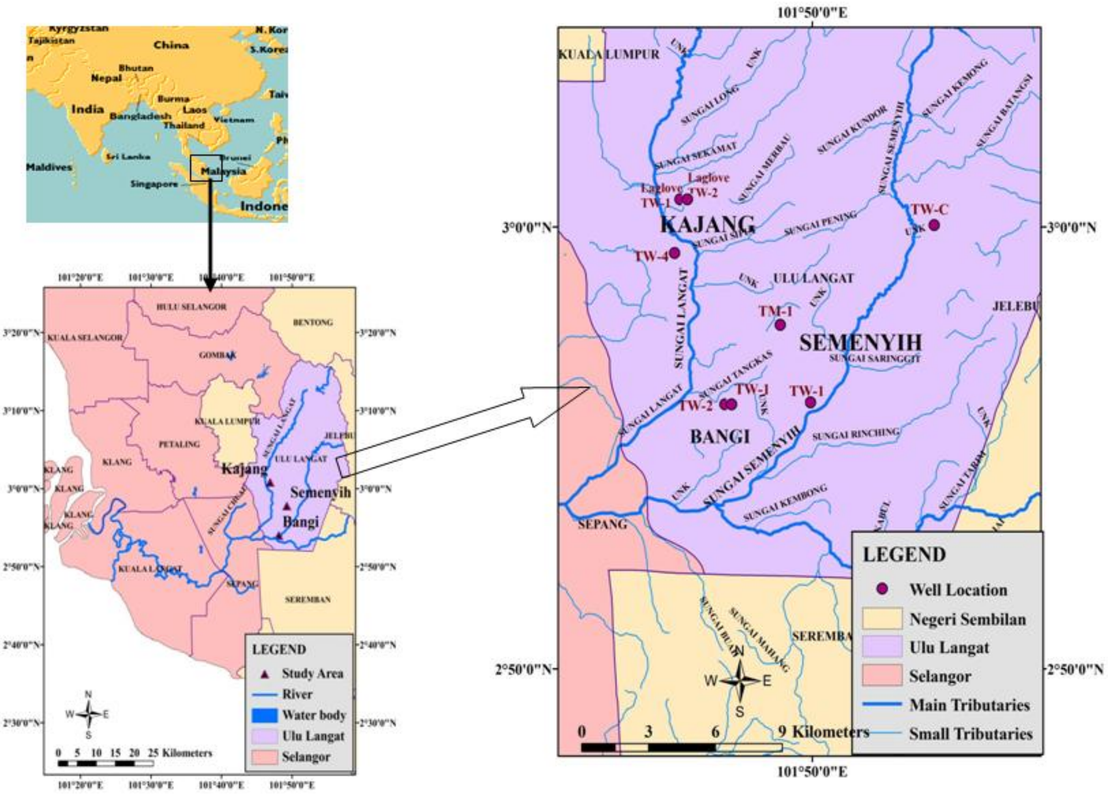


Fig. 1. Location map of the study area with study well locations (Compile from BBC News Asia 2014 & ISCGM 2014)

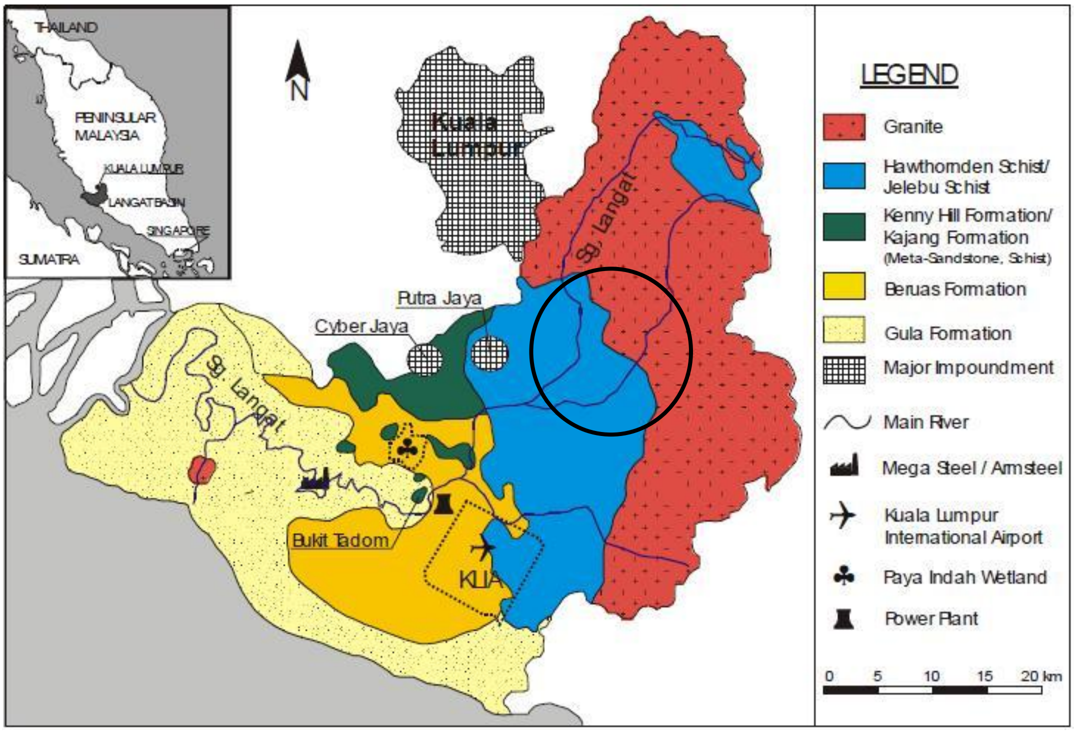


Fig. 2. General geology of the Langat Basin. Circle shows the study area
Source: Bringemeier [13]

Table 1. Aquifer properties of Langat Basin

Properties	Value Range
Transmissivity	450 m^2/day
Storativity	$4x10^{-3}$

(Source: Bringemeier [13])

2. METHODOLOGY

Different literature and other secondary information were collected and reviewed for the selection of the best-fitting area. The materials were collected from the Universiti Kebangsaan Malaysia (The National University of Malaysia) library and different online sources. Considering the findings of the literature review, borehole logs, pumping tests and groundwater level monitoring data were collected from JMG (Jabatan Mineral dan Geosains, Selangor/ Mineral and Geosciences Department). Data sheets of Different wells of the study areas were reviewed; separated into different parts on the basis of types of data. For geological interpretation of the study areas in Malaysia, well log data were collected from geological logging and well design data sheets of JMG. From the compiled data sheets subsurface logs were prepared by using the software Strater Demo4. The position of the well screen of study wells and values of static water levels were collected to identify the location of the water-bearing formation. Water level analyses were done by using the data collected from the groundwater level monitoring data sheet of JMG with elevation data collected from Google Earth. The contour map was prepared by using calculated groundwater head values and the location map of ArcGIS [19]. Well yield and pumping test analysis and interpretation were done by using the data from the well record data sheet, groundwater abstraction data sheet and the pumping test data sheets of JMG. Aquifer properties were calculated by using the available Constant Discharge Pumping test record from the JMG data sheet. Pumping test curves were prepared by using Excel 2007.

3. RESULTS AND DISCUSSION

3.1 Geological Interpretation Using Well Logs

In the Kajang area, two wells in Laglove (M) Sdn Bhd area show the same subsurface lithology (Fig. 3). Tube well 2 is deeper than tube well 1 and both wells collected water from hard rock (granite) formation. The thickness of the water-bearing layer is more than 152 m and both wells contain open hole screens starting from 40 m and 55 m respectively. The upper formation of the logs is stiff clay which is reddish in color (thickness is about 6.80m and 8.70 respectively). Another well of Kajang is located in the Kima Sdn Bhd area which is less deep than the other two wells (Fig. 3). The water-bearing formation is completely weathered dark grey friable shale which is a sedimentary formation and comparatively less hard than the water-bearing formation of the other two wells in Kajang. The thickness of the water-bearing formation is more than 23 m and the screen position is 53.4 m below the subsurface. The uppermost formation is the stiff lateritic clay which is underlain by yellow-brown silty clay. The area is very close to the Langat River so consider as the flood plain area of the river.

In Bangi, both wells show nearly the same subsurface lithology (Fig. 4). The depth of the TW1 is less than TW2 and in both tube well the water-bearing formation is schist. The screen of the TW1 is penetrated from a depth of 17.3m to 41.8m. The thickness of the water-bearing formation is more than 32m. In TW2, the screen penetrates from a depth of 24.7m to 75.5m which are slight to moderately weathered schist formations. The thickness of the water-bearing formation is more than 50m. In TW1 the schist formation is overlain by a thin layer of sandy clay with some gravel and in TW2 the schist formation is overlain by a very thin clayey silt layer (thickness 1m and 2 m respectively)

In Semenyih, collected log data on three areas are drawn by using the software Strater4. The well TM-1 is collected water from the sedimentary rock (Fig. 5). The screen position of the well is within the depth of 14m to 16m. The well is in shallow depth (16.75 m) and the water-bearing formation is a sedimentary rock which is light grey, medium-grained clayey sand. The water-bearing formation is overlain by fine to medium-grained sandy clay and the uppermost formation is stiff clay. The thickness of the water-bearing formation is less than 4 m. The TW1 well also extracts water from soft alluvium formation (Fig. 5). The position of the well screen is within the depth of 15m and 45m. The thickness of the water-bearing formation is nearly 30 m. The screen of the well penetrates both in upper alluvium and lower medium hard bedrock (granite), so it is assumed that the well collects water from both layers. The well Semenyih, C is deeper than the other two wells in that area (Fig. 5). The upper sandy clay layer is nearly 15 m thick which is underlain by slightly fractured granite. The water-bearing formation is weathered and fractured granite with a thickness of more than 65 m. Water-bearing formation is underlain by hard granite bedrock. In the study areas, three wells collected water from sedimentary rocks which are Kajang (TW- 4), Semenyih (TM-1) and Semenyih (TW1).

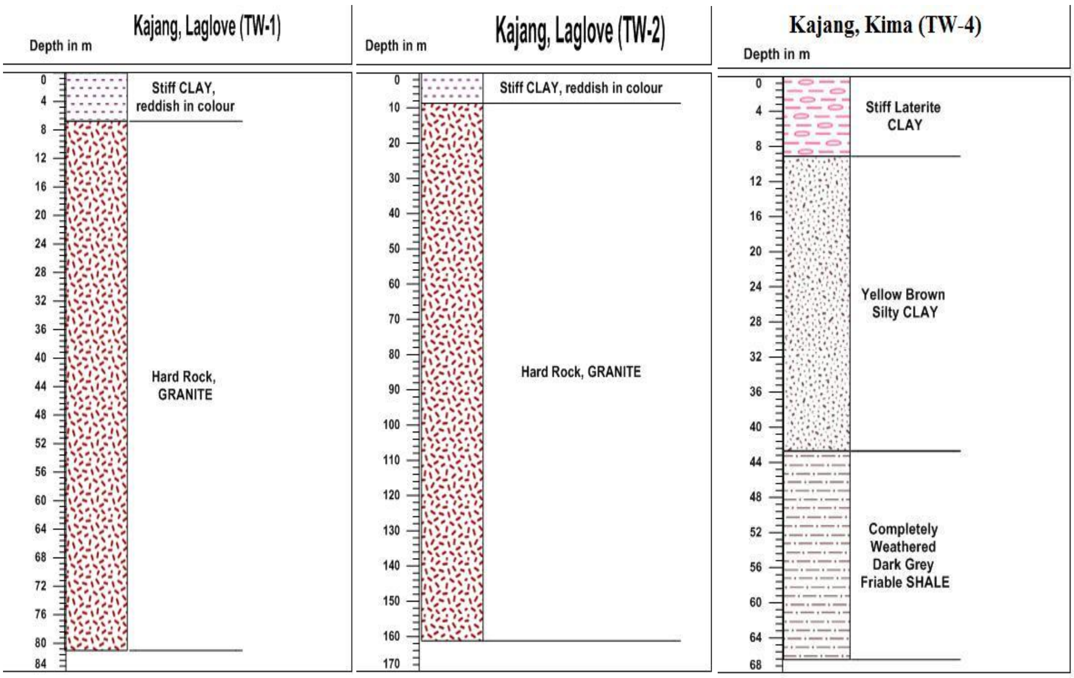


Fig. 3. Subsurface well log diagrams of Kajang town

Fig. 4. Subsurface well log diagrams of Bangi Town

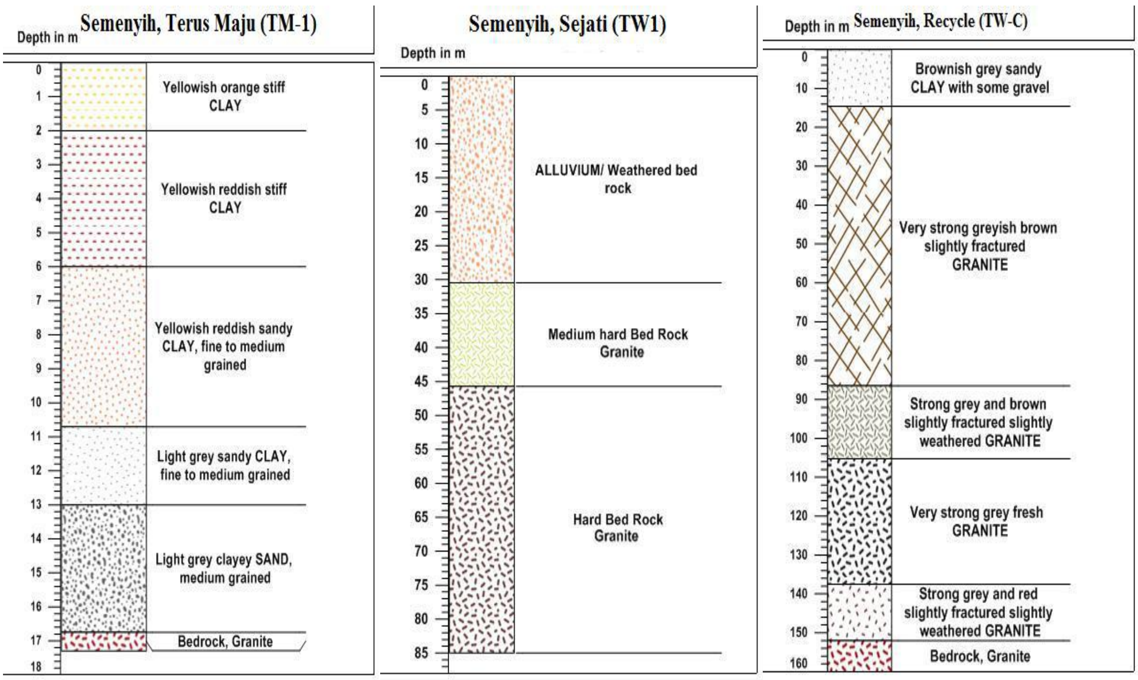


Fig. 5. Subsurface well log diagrams of Semenyih town

According to the description of the literature review, The Kajang Formation is within the Kenny Hill Formation which is consisting of alluvium, metasediment and granite. The logs of the Kajang area contain very thick granite formations with overlain thin stiff clay formations. There is one well containing very dark grey, weathered, friable shale which may be a metasedimentary formation. Logs of the Semenyih area contain very thick, weathered and fractured granite formation which also indicates Kenny Hill Formation.

3.2 Hydrogeology

3.2.1 Water level

The water table map has been prepared with the water head values of the study wells and surrounding wells (Fig. 6). Ground water table of the study area exists within the ranges of 25 m and 51 m (asl). In the Kajang area, TW-4 (Kima sdn bhd) shows a water head of 25.4 m (asl) which is the lowest value of the study area and indicates the deepest water level. In the upstream part of the Sungai Semenyih River (Semenyih area), the groundwater head of TW-C is also very deep from the surface (26.04 m asl). The highest value (51.05 m, asl) of the water head in the study area contains the well TM-1 (Terus Maju Services Sdn Bhd) in the Semenyih area which indicates a very shallow water level from the surface. The overall water head value of the mapped area ranges from 12.69 m to 58.86 m (asl) which contains the value of study areas and surrounding areas. The water head values of the study wells and surrounding wells indicate that the groundwater flow direction is from the northeast and northwest to the southwest. Topographically the area is hilly on the eastern side and the elevation gradually decreases to the western side (towards the sea). So, the situation also indicates that the groundwater flow direction is controlled by the topography of the area. Water flows from the hilly north-eastern side to the comparatively low elevated south-western side.

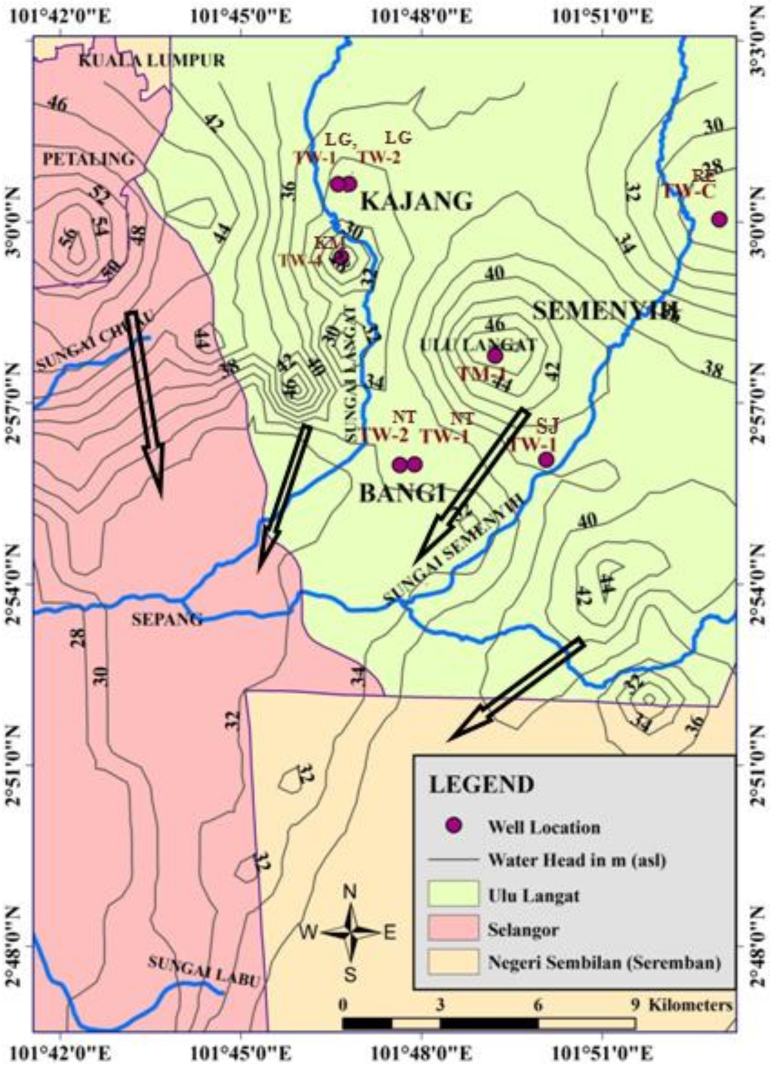


Fig. 6. Groundwater head contour map of the study wells and surrounding wells. ***Arrows*** **indicates groundwater flow direction**

(LG: Laglove; KM: Kima; NT: Naditech; TM: Terus Maju; SJ: Sejati; RE: Recycle)

3.2.2 Well yield

According to Musa *et al.* [4], the groundwater potential of the study area is very low (discharge rate <10 m^3/hour) to low (discharge rate 10-14 m^3/hour/well) because of the mountainous area and low lineament density. Wells of the study area also reflects the same consequence (Table 2). The discharge rates of all wells in the study area are less than 10m^3/hour except Kajang TW-4 (Kima), which yields a comparatively high discharge rate (11m^3/hour).

3.2.3 Pumping test analysis and interpretation

Transmissivity is the rate of water that is transmitted through an aquifer under a unit width and a unit hydraulic gradient. It equals the aquifer's hydraulic conductivity (permeability) times the aquifer thickness. The higher the transmissivity, the more productive the aquifer and the small drawdown observed in the well. The specific capacity of a well is a function of the well construction and the capacity of the aquifer to yield water. Specific capacity is defined as the unit volume of water discharged per unit drawdown of water level in the well. The specific capacity of a well is basically the pumping rate (yield) divided by the drawdown. It is a very valuable number that can be used to present the design pumping rate or maximum yield for the well. It can be used to discover potential well, pump, or aquifer problems, and therefore to develop an appropriate well maintenance program.

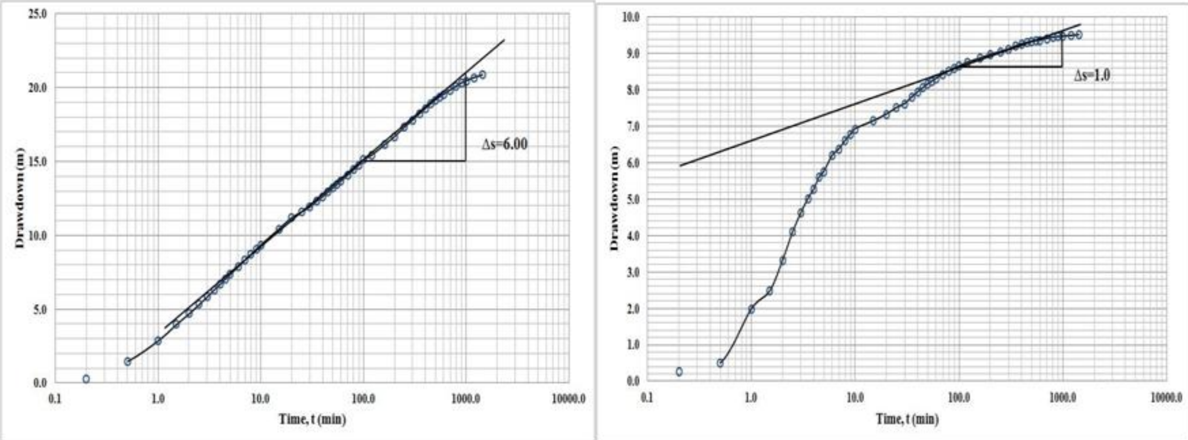
In Kajang town pumping test data of three wells (Laglove TW-1, Laglove TW-2 and TW-4) has been calculated. Laglove TW- 1 shows very low transmissivity (0.098m^2/hr) and specific capacity (0.15m^2/hr). Low transmissivity indicates low productivity of the aquifer. So, the productivity of hard rock aquifer is very low (Fig. 7). The time-drawdown curve of Laglove TW-1 matches the theoretical curve of a confined aquifer (Fig. 7). The geological information also indicates that the upper part of the water bearing formation is confined by stiff clay.

Comparatively high transmissivity is observed in TW-2 and TW-4 of Kajang area which is 0.77m^2/hr and 0.76m^2/hr respectively (Fig. 7 and 8). The TW-2 is within the Laglove (M) Sdn Bhd area which is a hard rock aquifer but the well depth is very deep (more than 160m) to tap entire permeable zone and the screen also enough (150 mm) to yield the maximum amount of water that’s why the specific capacity of the well also high (0.44m^2/hr). Another well is in the Kima Sdn Bhd area which is very near to the river and the aquifer is consisting of Weathered Sedimentary or Metasedimentary rock. The well is in the Langat River flood plain so the transmissivity and as well as specific capacity are also very high (Sc=1.72 m^2/hr). The Laglove TW-2 of the Kajang area shows well with boundary conditions (Fig. 7). The time-drawdown curve of Kima TW-4 in the Kajang area is matched with a consolidated fractured aquifer (Fig. 8)

In the Bangi area, Pumping test analysis has been done on two wells of the same area (Naditech Tenaga Sdn Bhd, TW1 & TW2). Due to the downstream side of Langat River, both wells show high Transmissivity (0.75m^2/hr and 1.08m^2/hr respectively). Specific capacity of both well shows moderate values (0.39m^2/hr and 0.37m^2/hr respectively) (Fig. 9). The time-drawdown curve for both wells are match with the confined fractured aquifer. Both wells are confined by clay layers.

Table 2. Aquifer types with discharge rate of Kajang, Bangi and Semenyih

Well Name	Discharge Rate (m^3/hour)	Rock Types in Aquifer
Kajang, Laglove, TW-1	3.2	Hard Rock
Kajang, Laglove,TW-2	4.2	Hard Rock
Kajang, Kima, TW-4	11	Weathered Sedimentary or Metasedimentary
Bangi, Naditech, TW1	4.5	Hard Rock
Bangi, Naditech, TW2	6.5	Hard Rock
Semenyih, Terus Maju, TM-1	1.5	Completely Shallow Sedimentary
Semenyih, Sejati, TW1	8	Both Alluvium(sedimentary) and Hard rock
Semenyih, Recycle, TW-C	7.5	Hard Rock



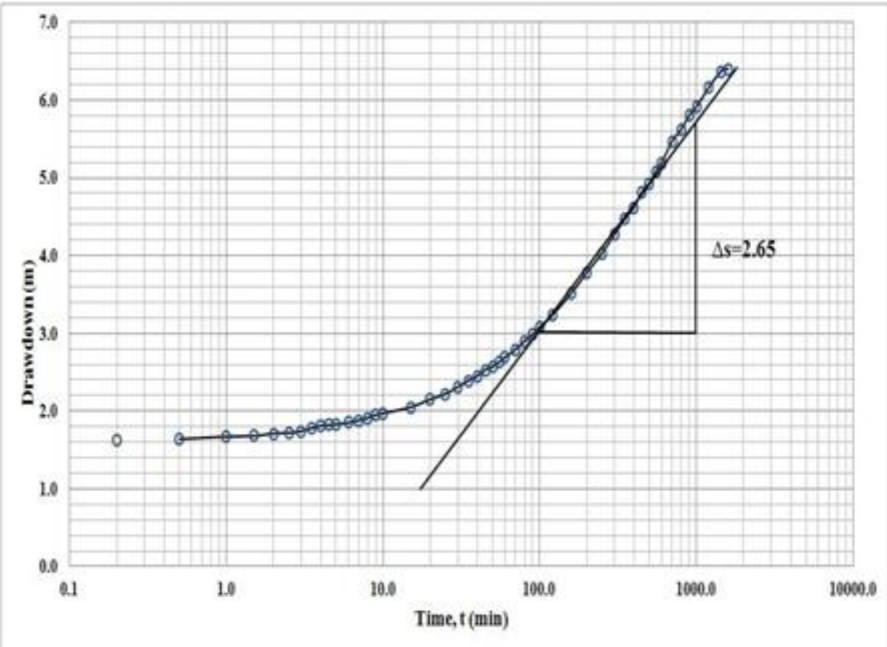
Kajang, Laglove (TW-1):

Transmissivity, T: 0.098m²/hr
Specific capacity, (Sc): 0.15m²/hr

Kajang, Laglove (TW-2):

Transmissivity, T: 0.77m²/hr
Specific capacity, (Sc): 0.44m²/hr

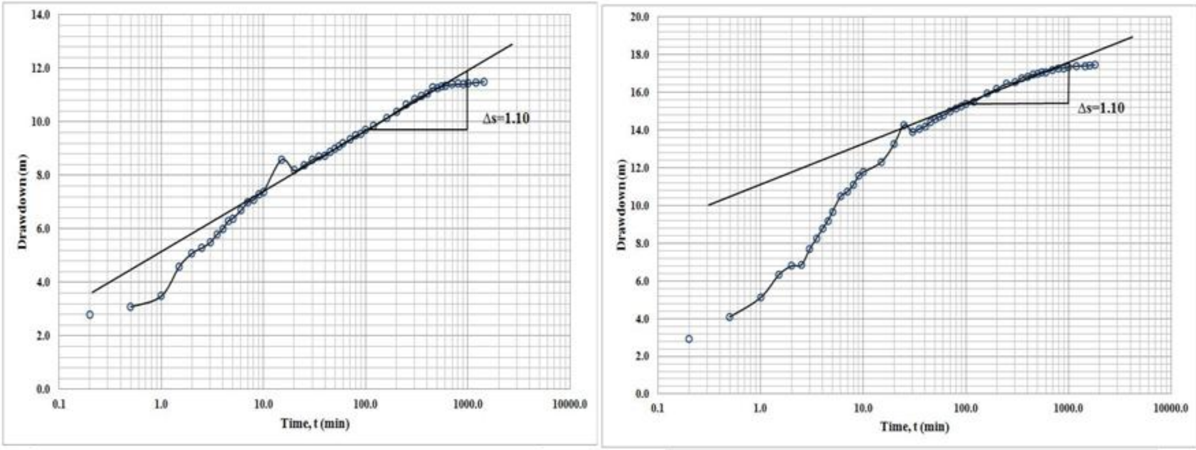
Fig. 7. Aquifer properties of Kajang, Laglove TW-1 and TW-2 (Malaysia)



Kajang, Kima (TW-4):

Transmissivity, T: 0.76m²/hr
Specific capacity, (Sc): 1.72m²/hr

Fig. 8. Aquifer properties of Kajang, Kima TW-4 (Malaysia)



Bangi, Naditech (TW1):

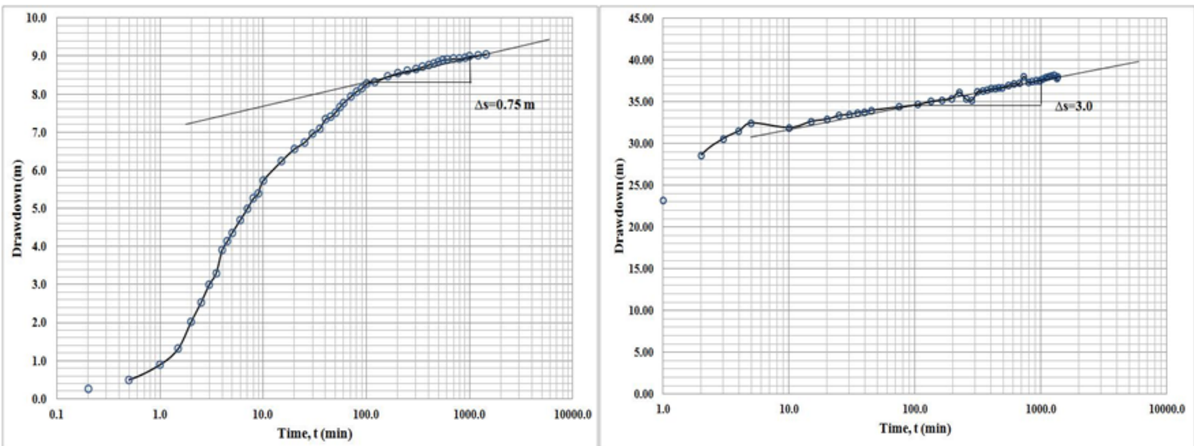
Transmissivity, T: 0.75m²/hr
Specific capacity, (Sc): 0.39m²/hr

Bangi, Naditech (TW2):

Transmissivity, T: 1.08m²/hr
Specific capacity, (Sc): 0.37m²/hr

Fig. 9. Aquifer properties of Bangi, Naditech TW1 and TW2 (Malaysia)

Three wells in Semenyih (TM-1, TW1 & C) indicate moderate to low transmissivity and very low specific capacity (Fig. 10 & 11) which may be due to the upstream side location, mountainous area and low lineament density. In this area Transmissivity of three wells are 0.37m^2/hr, 0.25m^2/hr and 0.22m^2/hr respectively along with specific capacity are 0.17m^2/hr, 0.11m^2/hr and 0.22m^2/hr respectively. The Time-drawdown curve of the well Terus Maju TM-1 shows leaky aquifer condition because of the shallow unconsolidated sedimentary formation (Fig 10). The Sejati TW1 shows a consolidated fractured aquifer and the well Recycle TW-C of the Semenyih area shows unconfined aquifer condition (Fig. 10 and 11). The water-bearing formation of the well TW-C is overlain by a slightly permeable sandy clay formation.



Semenyih, Terus Maju (TM-1):

Transmissivity, T: 0.37m²/hr
Specific capacity, (Sc): 0.17m²/hr

Semenyih, Sejati (TW1):

Transmissivity, T: 0.25m²/hr
Specific capacity, (Sc): 0.11m²/hr

Fig. 10. Aquifer properties of Semenyih, Terus Maju TM-1 and Sejati TW1 (Malaysia)

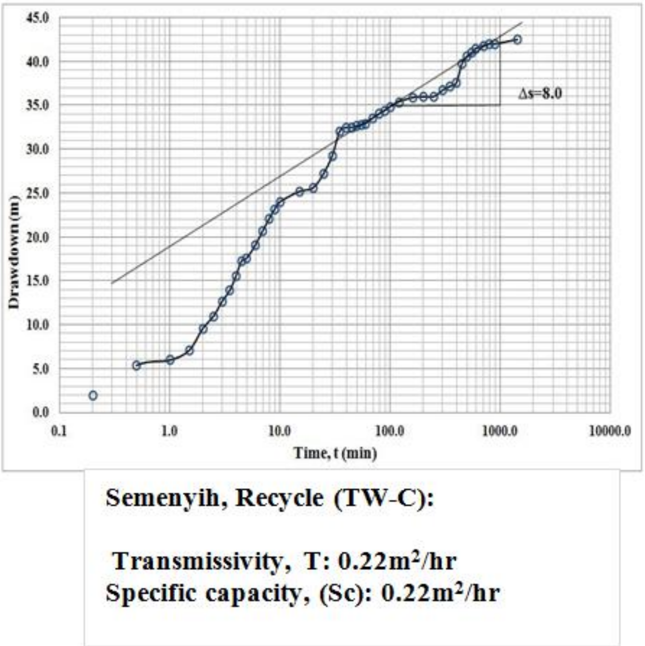


Fig. 11. Aquifer properties of Semenyih, Recycle TW-C (Malaysia)

4. CONCLUSION AND RECOMMENDATION

The study tries to identify the hydrogeological characteristics and aquifer properties and the trend of the Langat basin aquifer with an emphasis on the three towns in Malaysia (Kajang, Bangi and Semenyih). After interpretation of well log information from the Jabatan Mineral and Geosains (JMG) data sheet it is clear that the study wells collected water from four different types of aquifer material that are, hard rock, weathered sedimentary, or metasedimentary, shallow sedimentary and combination of alluvium (sedimentary) and hard rock. The geology of the area is Kenny Hill Formation which contains Schist and Granite. The groundwater flows from the northeast and northwest to the southwest direction. The potentiality of groundwater of the study area in Malaysia is very low to low. Calculated Transmissivity and Specific capacity of all types of aquifer material show very low to low values with a range of 2.35m^2/day to 25.92m^2/day and 2.64 m^2/day to 41.28m^2/day respectively. Study wells show different types of aquifer conditions, these are, confined, consolidated fractured, confined fractured, leaky, fractured and unconfined conditions.

Regional analysis of this study gives a pathway for water planners to formulate proper policies and directives. Systematic identification of hydrogeology and aquifer properties in addition to groundwater levels is essential for suitable water policy planning. Intensive management should require for the solution to the depletion of groundwater storage.

ACKNOWLEDGEMENTS

The authors would like to thank Mineral and Geoscience Department, Selangor (JMG) particularly Ms. Mazatul Akmar binti Aros, Geological officer, for providing necessary water quality data. Special thanks go to the Government of People’s Republic of Bangladesh for providing S.J. Haque’s fund and approving study leave to study in Universiti Kebangsaan Malaysia.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/101741