

INTEGRATION OF GEOINFORMATION WITH GEOLOGICAL AND  
GEOPHYSICAL APPROACHES FOR POTENTIAL GROUNDWATER  
EXPLORATION

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INTEGRATION OF GEOINFORMATION WITH GEOLOGICAL AND  
GEOPHYSICAL APPROACHES FOR POTENTIAL GROUNDWATER  
EXPLORATION

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## **DEDICATION**

This research is dedicated to all those who help essentially:

Special to Ayah and Ibu and not to forget to Arwah Ibu

**I REALLY MISS THEM**

And

**Also you,**

Nur Shahkilah Binti Madom....

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## ABSTRACT

Groundwater is one of the most important water source alternatives to meet daily needs especially for a clean drinking water supply. However, the major concern in groundwater exploration is to determine the precise location of the groundwater source zone. This study aimed to integrate the geoinformation approaches into the potential area of groundwater exploration area at Universiti Teknologi Malaysia (UTM), Johor. Aerial images were captured using a photogrammetry approach incorporated with precise Global Positioning System (GPS) ground control points to generate topographic map for the study area, which form as the primary data source. It was found that the positional accuracy of the horizontal and vertical components for this topographic information was 9.1 cm and 10.3 cm respectively, at 95% confidence level. Meanwhile, the secondary data source consists of geological and geophysical data. Existing geological maps were extracted, and the rock samples were collected through field geological investigations. After that, two types of geophysical data collection were implemented in the study area, namely resistivity and seismic refraction with four resistivity lines (R1-R4) and one seismic line (S1). Then, the subsurface geological information such as lithology and geological structure were combined together to evaluate the subsurface profile. The subsurface profile model indicated that the zone of low resistivity with a value  $<300$  Ohm m was identified on the resistivity lines R2 and R3, and it was interpreted as a saturated zone that has potential as a source of groundwater. The geospatial database was developed with the used of Geographic Information System (GIS) software. A map of the potential groundwater zone was generated and two potential locations of groundwater resources, namely A1 and A2, have been identified based on the line of resistivity R2 with coordinate location is -52364.90 m E, 7748.82 m N and -52376.90 m E, 7806.70 m N, respectively. Finally, locations of these groundwater resources were marked on the ground by using the GPS real-time kinematic (RTK) method. The drilling process has discovered the groundwater source in gabbro rock aquifers with a final depth of 158 m and preliminary estimate of the groundwater rate was found more than 0.5 million of litres per day. Based on the success of the discovery of groundwater resources in the study area, it has been proven that integrating geoinformation approaches has a significant impact on groundwater exploration work.

## ABSTRAK

Air bawah tanah merupakan salah satu alternatif sumber air terpenting bagi memenuhi keperluan harian terutamanya untuk bekalan air minuman yang bersih. Walau bagaimanapun, kebimbangan utama dalam penerokaan air bawah tanah adalah untuk menentukan lokasi tepat zon sumber air bawah tanah. Kajian ini bertujuan untuk mengintegrasikan pendekatan geoinformasi ke dalam kawasan potensi kawasan penerokaan air bawah tanah di Universiti Teknologi Malaysia (UTM), Johor. Imej udara telah dirakam menggunakan pendekatan fotogrametri yang digabungkan dengan titik kawalan Sistem Penentuan kedudukan Global (GPS) yang berkejituan tinggi untuk menjana peta topografi bagi kawasan kajian yang menjadi sumber data utama. Didapati bahawa ketepatan kedudukan komponen mendatar dan menegak untuk maklumat topografi ini adalah masing-masing 9.1 cm dan 10.3 cm, pada tahap keyakinan 95%. Manakala sumber data sekunder pula terdiri daripada data geologi dan geofizik. Peta geologi sedia ada telah diekstrak, dan sampel batuan geologi telah dikumpulkan melalui penyiasatan geologi lapangan. Selepas itu, dua jenis pengumpulan data geofizik dilaksanakan di kawasan kajian iaitu kerintangan dan biasan seismik dengan empat garisan kerintangan (R1-R4) dan satu garisan seismik (S1). Kemudian, maklumat geologi bawah permukaan seperti litologi dan struktur geologi digabungkan bersama untuk menilai profil bawah permukaan. Model profil bawah permukaan menunjukkan bahawa zon kerintangan rendah dengan nilai  $<300$  Ohm m telah dikenal pasti pada garisan kerintangan R2 dan R3 dan ia ditafsirkan sebagai zon tepu yang berpotensi sebagai sumber air bawah tanah. Pangkalan data geospasial dibangunkan dengan penggunaan perisian Sistem Maklumat Geografi (GIS). Peta zon potensi air bawah tanah telah dijana dan dua lokasi potensi sumber air bawah tanah iaitu A1 dan A2 telah dikenal pasti berdasarkan garis rintangan R2 dengan lokasi koordinat masing-masing adalah -52364.90 m E, 7748.82 m N dan -52376.90 m E, 7806.70 m N. Akhirnya, lokasi sumber air bawah tanah ini ditanda di atas tanah dengan menggunakan kaedah Kinematik Masa Hakiki (RTK) GPS. Proses penggerudian telah menemui sumber air bawah tanah di akuifer batuan gabbro dengan kedalaman akhir 158 m dan anggaran awal kadar air bawah tanah didapati lebih daripada 0.5 juta liter sehari. Berdasarkan kejayaan penemuan sumber air bawah tanah di kawasan kajian, telah terbukti bahawa pengintegrasian pendekatan geoinformasi memberi keberkesanan yang penting dalam kerja - kerja penerokaan air bawah tanah.

## TABLE OF CONTENTS

	<b>TITLE</b>	<b>PAGE</b>
	<b>DECLARATION</b>	<b>iii</b>
	<b>DEDICATION</b>	<b>iv</b>
	<b>ACKNOWLEDGEMENT</b>	<b>v</b>
	<b>ABSTRACT</b>	<b>vi</b>
	<b>ABSTRAK</b>	<b>vii</b>
	<b>TABLE OF CONTENTS</b>	<b>viii</b>
	<b>LIST OF TABLES</b>	<b>xi</b>
	<b>LIST OF FIGURES</b>	<b>xiii</b>
	<b>LIST OF ABBREVIATIONS</b>	<b>xvii</b>
	<b>LIST OF SYMBOLS</b>	<b>xix</b>
<b>CHAPTER 1</b>	<b>INTRODUCTION</b>	<b>1</b>
	1.1 Introduction	1
	1.2 Problem Background	2
	1.3 Research Aim	4
	1.4 Research Objectives	4
	1.5 Research Scope	5
	1.6 Significance of the Study	6
	1.7 Thesis Structure	6
<b>CHAPTER 2</b>	<b>LITERATURE REVIEW</b>	<b>9</b>
	2.1 Introduction	9
	2.2 Overview of Groundwater	9
	2.3 Groundwater Status in Malaysia	10
	2.4 Groundwater Exploration Approaches in Malaysia	15
	2.4.1 Geological Setting	22
	2.4.2 Electrical Resistivity	23

2.4.3	Seismic Refraction	26
2.5	Integration of Geoinformation Approach in Groundwater Resources Exploration	28
2.5.1	Accuracy Assessment for Aerial Photo Mapping	37
2.6	Interpretation of Groundwater Potential Zone by Using Subsurface and Geoinformation Approach	41
2.7	Summary	43
<b>CHAPTER 3</b>	<b>RESEARCH METHODOLOGY</b>	<b>45</b>
3.1	Introduction	45
3.2	Research Methodology	45
3.3	Conceptual Design	49
3.4	Data Acquisition	50
3.4.1	UAV Data Collection	50
3.4.1.1	Establishment of Ground Control Point (GCP) And Check Point (CP)	52
3.4.1.2	Flight Planning Preparation	56
3.4.2	Subsurface Mapping	59
3.4.2.1	Geological Mapping	59
3.4.2.2	Geophysical Field Investigation	61
3.5	Pre-processing Data	67
3.5.1	GPS Data Processing	67
3.5.1.1	GCPs and CPs Data Processing	67
3.5.1.2	Geophysical Location Point Data Processing	69
3.5.2	Aerial Image Data Processing	70
3.5.3	Mapping Subsurface Profile	74
3.6	Groundwater Exploration Geospatial Database and Mapping	74
3.7	Summary	76
<b>CHAPTER 4</b>	<b>RESULT AND DISCUSSION</b>	<b>77</b>
4.1	Introduction	77
4.2	Generation of Mapping Groundwater Resources Potential	77



4.2.1	Topographic Mapping	80
4.2.1.1	Elevation	80
4.2.1.2	Slope Gradient	82
4.2.1.3	Land Use and Land Cover	84
4.2.2	Subsurface Mapping Profile	86
4.2.2.1	Geological Mapping	86
4.2.2.2	2D Subsurface Profile	90
4.3	Accuracy Assessment	94
4.3.1	GPS Accuracy Assessment	94
4.3.1.1	Ground Control Point (GCP) And Check Point (CP)	94
4.3.1.2	Geophysical Position	103
4.3.2	Aerial Photo Assessment	108
4.4	Generation of Potential Zone Groundwater Resources	112
4.5	Correlation of Potential Groundwater Resources Location with Topographic Information	114
4.6	Precise Marking Potential of Groundwater Resources	117
4.7	Discovery of Groundwater Resources	119
4.8	Summary	122
<b>CHAPTER 5</b>	<b>CONCLUSION</b>	<b>123</b>
5.1	Conclusion	123
5.2	Recommendation	124
<b>REFERENCES</b>		<b>127</b>
<b>LIST OF PUBLICATIONS</b>		<b>135</b>

## LIST OF TABLES

<b>TABLE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
Table 2.1	Type of aquifer in Malaysia (JMG, 2019)	12
Table 2.2	Previous study on groundwater assessment by using geological and geophysical approach	17
Table 2.3	Resistivity values based on the type of rock and soil material (Saad <i>et. al.</i> , 2012; Zakaria <i>et. al.</i> , 2020)	24
Table 2.4	Resistivity values of some types of waters (Saad <i>et. al.</i> , 2012; Zakaria <i>et. al.</i> , 2020)	25
Table 2.5	Resistivity values based on the type of rock (Saad <i>et. al.</i> , 2012; Zakaria <i>et. al.</i> , 2020)	25
Table 2.6	Seismic value based on the type of rock and minerals (Saad <i>et. al.</i> , 2012; Zakaria <i>et. al.</i> , 2020)	27
Table 2.7	Rippability rating chart (Saad <i>et. al.</i> , 2012)	27
Table 2.8	Previous study on groundwater assessment by using geoinformation approach	29
Table 2.9	Horizontal accuracy classes according to American Society of Photogrammetry and Remote Sensing (ASPRS) standard (ASPRS, 2015)	40
Table 2.10	Vertical accuracy classes according to American Society of Photogrammetry and Remote Sensing (ASPRS) standard (ASPRS, 2015)	41
Table 3.1	Parameter for preparation of the flight plan	57
Table 3.2	Format dataset in groundwater exploration database	76
Table 4.1	Total area and percentage the categories of elevation at the study area	82
Table 4.2	Total the area and percentage the categories of slope gradient at the study area	83
Table 4.3	Total area and percentage the categories of land use and land cover at the study area	85
Table 4.4	Total area and percentage the categories of geological rocks at the study area	87

Table 4.5	List of 3D geographical coordinate (GDM 2000) of GCP stations, G01 – G28. The elevation is based on the ellipsoidal height and the MSL height	96
Table 4.6	List of coordinates 2D Cassini Geocentric (Johor) of GCP stations, G01 – G28 along with the difference for the horizontal and vertical components	98
Table 4.7	List of 3D geographical coordinate (GDM 2000) of CPs stations, C01 – C06. The elevation is based on the ellipsoidal height and the MSL height	101
Table 4.8	List of coordinates 2D Cassini Geocentric (Johor) for two (2) sets of coordinates from GPS data processing; the first set of coordinates refers to ISK1 station and is checked by the second set of references to the G14 station	102
Table 4.9	List of 3D geographical coordinates (GDM 2000) of geophysical position. The elevation is based on the ellipsoidal height and the MSL height	105
Table 4.10	List of coordinates 2D Cassini Geocentric (Johor) for two (2) sets of coordinates from GPS data processing; the first set of coordinates refers to ISK1 station and is checked by the second set of references to the G11 station	106
Table 4.11	Results of the accuracy for horizontal component	110
Table 4.12	Results of the accuracy for vertical component	111
Table 4.13	Parameters of the topographic and geological information on the potential location of groundwater	115

## LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
Figure 1.1	Location of the study area.	5
Figure 2.1	Groundwater condition (JMG, 2019)	10
Figure 2.2	Hydrogeological map of Peninsular Malaysia (JMG, 2019)	11
Figure 2.3	Groundwater vs surface water on public water supply in Malaysia (2005-2017) (JMG, 2019)	13
Figure 2.4	Percentage of usage follows by sector development in Malaysia (Manap <i>et. al.</i> , 2014)	13
Figure 2.5	Location of tube well in Malaysia (JMG, 2019)	14
Figure 2.6	Groundwater usage by state of Malaysia (2008-2017) (JMG, 2019)	15
Figure 2.7	Geological map of Johor (JMG, 2019)	23
Figure 2.8	An arrangement of electrodes for a 2-D electrical survey and the sequence of measurement used to build up a pseudo section (Saad <i>et. al.</i> , 2012; Zakaria <i>et. al.</i> , 2020)	24
Figure 2.9	Direct wave, reflection and refraction ray (Saad <i>et. al.</i> , 2012; Zakaria <i>et. al.</i> , 2020)	26
Figure 2.10	An example the production of thematic maps (Manap <i>et. al.</i> , 2014)	33
Figure 2.11	An example of Landsat 7 data (How <i>et. al.</i> , 2020)	34
Figure 2.12	An example of flow chart for GIS method processing (Nampak <i>et. al.</i> , 2014)	35
Figure 2.13	An example of digital orthophoto for the study area (Udin <i>et. al.</i> , 2013)	36
Figure 2.14	An example of DEM for the study area (Udin <i>et. al.</i> , 2013)	37
Figure 2.15	An example of 2D profile resistivity model (Lee <i>et. al.</i> , 2021)	42
Figure 2.16	An example of a map of groundwater potential (Saifuddin <i>et. al.</i> , 2021)	43
Figure 3.1	Research framework.	48
Figure 3.2	Conceptual design of the study area	50

Figure 3.3	DJI Phantom 4 Pro V2.0	51
Figure 3.4	GPS observations carried out with the height of this GPS instrument are setting with high antenna to avoid object obstacles around the study area.	53
Figure 3.5	Establishment of the monument for GCPs and CPs stations in the study area	53
Figure 3.6	Location of GCP and CP in the study area	54
Figure 3.7	Placement of the target marker on GCPs and CPs stations	55
Figure 3.8	Observation form was used during establishment of ground control point (GCP) and check point (CP) station	55
Figure 3.9	Design of flight plan in the study area.	57
Figure 3.10	Design of flight plan based on divided into 49 flight sessions.	58
Figure 3.11	Aerial photo data collection carried out in the study area	58
Figure 3.12	A) planning before the implementation of geological mapping based on geological information in the study area. B) Geological mapping has carried out in the study area	60
Figure 3.13	A) Scale the size of the rocks that have been collected B) Examples of geological rock samples that have been collected in the study area	60
Figure 3.14	Location of resistivity and seismic survey line in the study area	62
Figure 3.15	ABEM TERRAMETER SAS4000.	63
Figure 3.16	Resistivity survey has been conducted in the study area	63
Figure 3.17	ABEM TERRALOC MK8	64
Figure 3.18	Seismic refraction measurement conducted in the study area	65
Figure 3.19	Location of point resistivity and seismic survey	66
Figure 3.20	GPS fast static observations for location of point resistivity and seismic survey	66
Figure 3.21	Location of point resistivity and seismic survey	68
Figure 3.22	Design of the GPS network baseline processing	68
Figure 3.23	Each CPs is connected to the ISK1 and checked using GCP14 for quality assurance	69

Figure 3.24	Each point of geophysical line survey is connected to the ISK1 and checked using GCP 11 for quality assurance	70
Figure 3.25	Interface Agisoft Metashape software	71
Figure 3.26	Example of aerial image in JPEG format	71
Figure 3.27	Project setting for aerial image data processing	72
Figure 3.28	Procedure of aerial image data processing	73
Figure 3.29	Framework in development of groundwater exploration database.	75
Figure 3.30	Interface ArcGIS software	75
Figure 4.1	Digital orthophoto for the study area.	79
Figure 4.2	DEM for the study area	79
Figure 4.3	Contour map	80
Figure 4.4	Elevation map	81
Figure 4.5	Total of area and percentage the categories of elevation at the study area	82
Figure 4.6	Slope gradient map	83
Figure 4.7	Total of area and percentage the categories of slope gradient at the study area	84
Figure 4.8	Land use and land cover map	85
Figure 4.9	Total area and percentage the categories of land use and land cover at the study area	86
Figure 4.10	Geological map	87
Figure 4.11	Total area and percentage the categories of elevation at the study area	88
Figure 4.12	The sample of granite rock	89
Figure 4.13	The sample of granite rock	90
Figure 4.14	Resistivity section of line R1	91
Figure 4.15	Resistivity section of line R2	92
Figure 4.16	Resistivity section of line R3	92
Figure 4.17	Resistivity section of line R4	93
Figure 4.18	Seismic section of line S1 geology maps and subsurface rock profiles	94

Figure 4.19	Error for each GCP in the horizontal and vertical component	100
Figure 4.20	Coordinate difference for each CPs station as derived from ISK1 and GCP14 station	103
Figure 4.21	Coordinate difference for each geophysical measurement position as derived from ISK1 and GCP11 stations	104
Figure 4.22	The location of these observations is obstructed by the presence of natural objects and the minimum space opening rate	108
Figure 4.23	Coordinate difference for each CPs in horizontal and vertical component	109
Figure 4.24	Groundwater potential zone map	112
Figure 4.25	Potential groundwater area and drilling area at UTM study area	113
Figure 4.26	Potential locations superimposed on geological parameter	114
Figure 4.27	Potential locations superimposed on elevation parameter	115
Figure 4.28	Potential locations superimposed on slope gradient parameter	116
Figure 4.29	Potential locations superimposed on land use and land cover parameter	116
Figure 4.30	GPS RTK method have been applied in the forest of the study	118
Figure 4.31	ISK 1 station located within UTM	118
Figure 4.32	Site cleaning and preparation of drilling machines at the study area location	119
Figure 4.33	Preparation of drilling machines at the location of the study area	120
Figure 4.34	Process of drilling groundwater resources was carried out in the study area	120
Figure 4.35	Breakthrough of the discovery of groundwater resources in the study area	121
Figure 4.36	Discovery of groundwater resources was found in a gabbro rock aquifer	121

## LIST OF ABBREVIATIONS

DR	-	2D Resistivity
2D	-	2-Dimension
ASPRS		American Society of Photogrammetry and Remote Sensing
AHP	-	Analytic Hierarchy Process
AOI	-	Area of Interest
CP	-	Check Point
CORS	-	Continuously Operating Reference Station
JMG	-	Department of Minerals and Geosciences
DSMM	-	Department of Survey and Mapping
DEM	-	Digital Elevation Model
ERT	-	Electrical Resistivity Tomography
EBF	-	Evidential Belief Function
FR	-	Frequency Ratio
GDM 2000	-	Geocentric Datum of Malaysia 2000
GIS	-	Geographical Information System
GnG	-	Geomatic Innovation Research Group
GPS	-	Global Positioning System
GCP	-	Ground Control Point
GSD	-	Ground Sample Distance
JPEG	-	Joint Photographic Experts Group
MyRTKnet	-	Malaysia Real-Time Kinematic Gns Network
MSL	-	Mean Sea Level
MP	-	Megapixel
MLD	-	Millions of Litre Per Day
NRE	-	Ministry of Natural Resources and Environment
MCA	-	Multicriteria Analysis
MCDA	-	Multicriteria Decision Analysis
NRC-net	-	National Reference CORS Network
NSSDA		National Standard for Spatial Data Accuracy
RTK	-	Real-Time Kinematic



RMSE	-	Root Mean Square Error
SR	-	Seismic Refraction
TBC	-	Trimble Business Center
USGS	-	United States Geology Survey
UTM	-	University Teknologi Malaysia
UAV	-	Unmanned Aerial Vehicle
V	-	Voltage
WLC	-	Weighted Linear Combination

## LIST OF SYMBOLS

$A_i$	-	CP Coordinate Value from The GPS Measurement
$B_i$	-	CP Coordinate Value from The Aerial Photo Processing
$n$	-	The Total Number Of CP
$^{\circ}$	-	Degree
'	-	Min
''	-	Sec
m	-	Meter
cm	-	Centimeter
ac	-	Acres
$\Omega m$	-	Ohm-m
m/s	-	Meter Per Second
$i$	-	An Integer Ranging

# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

Groundwater is a vital component of water resources in nature and is being used in various usage such as agricultural, industrial and especially for drinking water supply. Since the demand for groundwater resources has increased with population growth, it is necessary to explore them more intensively. The groundwater resources depend greatly on the capability of water flows and the capacity to store the water underground. In addition, it is also strongly reliant on the rock and soil type, geological structures, regional environment and geomorphology factor. Therefore, proper management of surface water resources and groundwater resources are needed in groundwater exploration through systematic inventory, conservation and proper planning is essential for of any country's economic and social development.

The best approach to identify subsurface layer thickness and provide the discreet location of groundwater resources is provided by using a drilling test. However, this approach is too expensive and requires skilled manpower (Yang *et. al.*, 2018). Nowadays, the integration of geological and geophysical studies is commonly used in groundwater exploration. Usually, this approach is combined with geoinformation knowhow such as field survey and supported with existing topographic and thematic maps. Nevertheless, the advancement in geoinformation applications such as aerial photo mapping, precise global positioning system (GPS) surveying and geographical information system (GIS) data management could be utilized to augment the groundwater exploration (Savita *et. al.*, 2018; Pandey *et. al.*, 2014; Sinha *et. al.*, 2012; Rahman, 2008). Moreover, the applications of geoinformation approach such as GIS application can be cost effective and time efficient to assess and manage geospatial information of groundwater resources (Nampak *et. al.*, 2014; Manap *et. al.*, 2013).

Malaysia is a tropical country that experiences hot and humid summer throughout the year and receives an annual rainfall of 2500 mm to 3000 mm contributed to the country's water resource needs (Paterson et. al., 2015). In general, water resources in Malaysia can be divided into surface water resources and groundwater (shallow groundwater - deep rock aquifers). In addition, Malaysia has adequate surface water reserves based on the total number of rivers and lakes reservoirs available. In 2016, surface water consumption rate for Malaysia is 13330.6 million litres per day (MLD) and 95% from the clean water supply is channelled from the rivers and existing dams (JMG, 2019). However, some problems aroused concerning these surface water resources especially in meeting the demands of clean water supply for the daily usage. Factors contributing to these problems was the level of water pollution is at an alarming state and also climate change. These factors resulted in the clean water treatments cost to be unreasonably increased and consequently declining the water levels in water catchment areas.

Hence, there is an alternative to overcome this problem by fully utilized of groundwater resources. This resource has unlimited reserves and availability to continuously supply fresh water. Therefore, groundwater exploration in this country requires support and integration of the modern geoinformation approaches into the exploration works, which can produce high chances to identify groundwater resources potential zone

## **1.2 Problem Background**

Water is the basic human need; however, many countries nowadays face a lack of adequate supply of freshwater to fulfill demand in several important sectors such as agriculture, industry and drinking water. According to a statement from the world water development report in 2015 (UNESCO, 2015), water demand will increase by 55 per cent by 2030. However, existing reserves of water resources can only supply 60 per cent of the world's water needs. Moreover, Malaysia is also facing a problem meeting the demand for fresh water supply. This problem is due to nature environment and the human impact such as climate change and water pollution at the critical levels.

Consequently, there is an alternative of groundwater resources to fulfill the demand of water supply. This distinct groundwater or specifically rock aquifer usually has unlimited reserves of fresh water supply.

Groundwater exploration studies are increasingly being implemented in several developed countries, which include Malaysia. Furthermore, the major challenge of this exploration is to identify the precise location and depth of the potential that exists in the deep rock aquifer which could provide a more sustainable water resource. The drilling approach is one of the best methods often used to identify the source location of this aquifer. However, this method is difficult to operate, expensive and time-consuming (Ahmed & Mansor, 2018; Manap *et. al.*, 2014). Therefore, this exploration requires effective approaches and expertise to understand the criteria of subsurface geological systems (Tajuddin *et. al.*, 2018).

Several groundwater exploration studies are conducted with the integration of geological and geophysical approaches in Malaysia (Ilahi *et. al.*, 2021; Zakaria *et. al.*, 2020; Aziman *et. al.*, 2018; Nazaruddin *et. al.*, 2017; and Saad *et.al.*, 2012). However, there is a lack of researchers who have applied and integrated comprehensive geoinformation approaches in the exploration the lack of exposure and application of incorporation geoinformation approach along with geological and geophysical approach in groundwater exploration. The geoinformation approach focuses on the use of remote sensing and GIS analysis in groundwater exploration (Mogaji & Lim, 2017; Manap *et. al.*, 2014; Nampak *et. al.*, 2014; and Manap *et. al.*, 2013).

In addition, there are deficiencies in the management system of the study data. the constraints of systematic and effective management of groundwater survey data are a factor in the difficulty of the implementing the groundwater survey (Abdulazeez, 2018). Moreover, this study of groundwater exploration still lacks in Johor, especially in the southern of Johor because the implementation of this exploration is focused on areas with problems in the lack of clean water supply such as in Kelantan and Perlis (Saifuddin *et. al.*, 2021).

Therefore, the UTM Johor Bahru Campus area located in the southern Johor has been selected to study the potential of groundwater resources. In fact, geoinformation approaches are used and applied together with geological and geophysical approaches in order to identify and increase the chances of discovering groundwater resources in this study. There are three (3) geoinformation approaches applied in the study namely GPS measurement, photogrammetry measurement integrated with UAV technology and GIS approach. The study also focuses on the management of research data by using the GIS approach. Thus, these exploratory works can be enhanced by integrating modern approaches in geoinformation to develop potential groundwater zone renewal maps, geospatial data management reforms and precise spatial placement for groundwater exploration. Therefore, it is desirable to explore further the opportunities to apply the latest geoinformation approaches into groundwater exploration.

### **1.3 Research Aim**

This study aims to integrate of geoinformation approaches into the potential of groundwater exploration.

### **1.4 Research Objectives**

To achieve the aim of the study, the following objectives are specified:

- I. To develop a geospatial database for groundwater exploration,
- II. To analyse the potential of groundwater zones based on the geospatial database.
- III. To locate the potential location of groundwater resources in the study area.

## 1.5 Research Scope

The scopes of this study are given as follows:

- I. The area for this study is in the Universiti Teknologi Malaysia (UTM) Johor Bahru campus, Johor as shown in Figure 1.1. The study area covered the whole campus about 2,816 acres (ac).

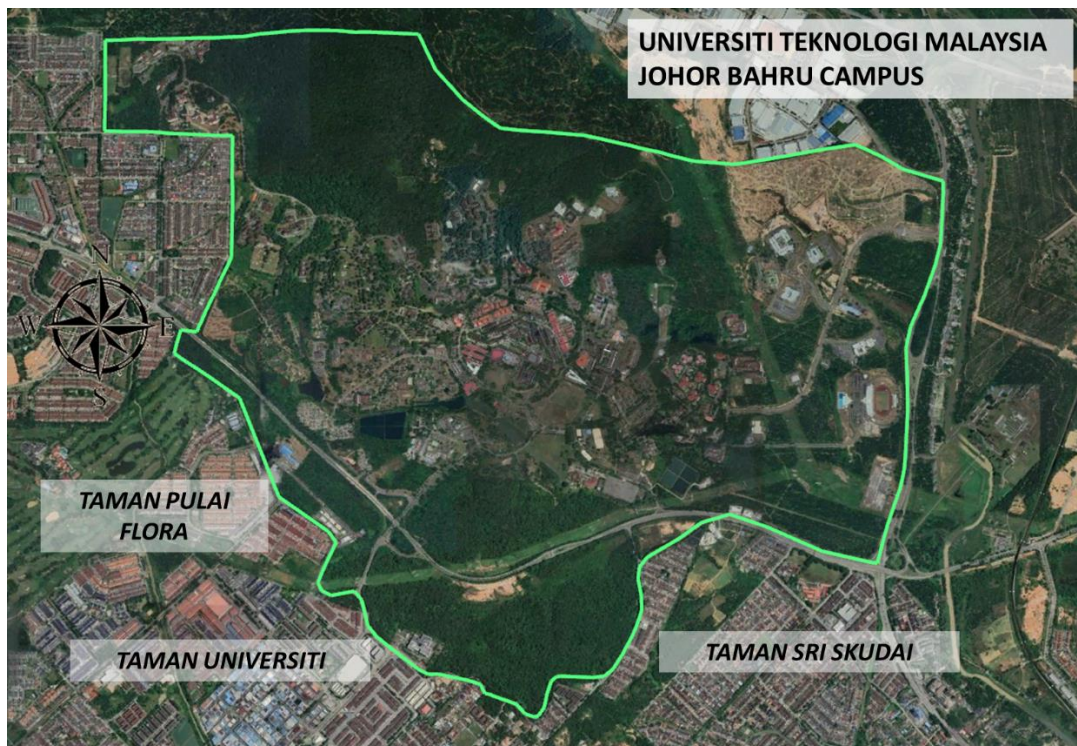


Figure 1.1 Location of the study area.

- II. There are two types of data was used in this study, namely primary and secondary data. Primary data involving GPS observations data and digital aerial imagery. Meanwhile, secondary data involves geological and geophysical mapping information based on previous studies in the study area.
- III. Integration of geological, geophysical and topographic information in developing of geospatial databases to produce potential maps of groundwater resource zones using GIS environment.

- IV. The implementation of GPS data observations only focuses on the utilized of satellite constellations from GPS satellites only.

## **1.6 Significance of the Study**

The significance of this study can be summarized as follows:

1. This study will help position potential exploration groundwater accurately and develop a database by integrating the geological and geophysical approach into geoinformation applications.
2. This study will help better understand subsurface profile condition in order to identify the location potential zone of groundwater in this study.
3. From this study, the potential zones of groundwater resources and suitable geospatial locations for potential exploration of groundwater shall be identified.

## **1.7 Thesis Structure**

The thesis structures consist of five chapters. The descriptions for each chapter are as follows:

### **Chapter 1: Introduction**

This chapter described the background, problem statement, objectives of study, scope and significance of the study.



## **Chapter 2: Literature Review**

This chapter has been focused on several topics such as exploration of the status of utilization of groundwater and its exploration groundwater in Malaysia are also discussed. This chapter also reviewed the integration of geoinformation approach in groundwater resources exploration and the interpretation of groundwater potential zone by using subsurface and geoinformation approach.

## **Chapter 3: Research Methodology**

Describes the research methodology for this research. This proposal is divided into five different phases as mentioned in sub-chapter 1.7. The methodology is set out to achieve the objectives of the research. Besides, it explained about the method of data acquisition and pre-processing.

## **Chapter 4: Result and Discussions**

This chapter discussed on the analysis of the accuracy assessments which were carried out on the final coordinate for GPS measurement data and aerial photo mapping used to produce information of topographic in the study area. Subsequently, the final results of these measurements have been utilized for geospatial database development for groundwater exploration in UTM by adopting the GIS approach. This geospatial database was used to generate several thematic maps related to topographic information and subsurface information. Next, the thematic map was used to analyses the potential of groundwater resource zones within the study area. Based on the potential map, the location marking of the potential of groundwater resources is carried out by using the GPS RTK measurement method in the field before drilling of groundwater resources in the study area.

## **Chapter 5: Conclusion and Recommendations**

This chapter summarizes the thesis and draws some conclusions. Several recommendations were suggested for further works in the future.

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## LIST OF PUBLICATIONS

- Zamari, M. A., Musa, T. A., Mohamad, E. T., Musliman, I. A., & Aris, W. A. W. (2019). Geospatial approach for groundwater exploration at UTM Johor Bahru Campus. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 42(4/W16).
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