An Assessment of GPS Heighting from MyRTKnet and MyGEOID Compared To Conventional Levelling

by

Siti Rodhiah Fazilah (3664)

Dissertation submitted in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons)
(Civil Engineering)

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Approved by,

____

(Dr. Abdul Nasir Matori)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

NOVEMBER 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contain herein have not been undertaken or done by unspecified sources or persons.

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(Siti Rodhiah Fazilah)

ABSTRACT

Global Positioning System (GPS) technology introduced in Malaysia in year 1989 has changed the scenario of surveying rapidly. The existing GPS infrastructure in Malaysia mainly served as a ground control station for mapping purposes. Malaysia Real Time Kinetic Network (MyRTKnet) is a new nation-wide GPS network and system infrastructure developed for GPS users to provide RTK services for positioning application across the country. MyGeoid is the Malaysia version of geoid separation (N) model, meant to complement and strengthen the existing geodetic infrastructure for Malaysia. Even though the use of GPS has gained popularity amongst Malaysian surveyors, the accuracy in GPS heighting is currently overshadowed by conventional levelling. This study mainly focus on accessing the accuracy of GPS levelling using MyRTKnet and MyGeoid established by JUPEM as compared to conventional levelling. Analysis of the results showed that the accuracy of height determination is consistent with JUPEM circulation on MyRTKnet (KPUP 9/2005) and MyGeoid (KPUP 10/2005).

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CHAPTER 1
INTRODUCTION

1.1 Background of study

GPS infrastructure that have been established in Malaysia such as "Rangkaian Geodetik Saintifik Semenanjung Malaysia" in 1993, Coordinated Cadastral System (CCS), Malaysia Active GPS System (MASS), Coordinated Cadastral System II (CCS II), and Geocentric Datum for Malaysia (GDM), and recently MyRTKnet covers only horizontal component of GPS. These GPS infrastructure are mainly served as a ground control station and mapping purposes.

Another element that has not been utilized is the height component of GPS. It is due to its low accuracy compared to their horizontal component. The reference surface for heights in Malaysia is traditionally taken as the mean sea level (MSL). However, heights derived from GPS are relative to the GPS reference ellipsoid.

In order to obtain highly accurate vertical height values (orthometric height) from GPS measurements, a geoid separation model has to be utilised. MyGeoid which is the Malaysian version of the geoid separation model is meant to complement and strengthen the existing geodetic infrastructure for Malaysia, consequently enabling the extended use of services rendered by GPS.

1.2 Problem Statement

Currently height information applied in engineering surveying is obtained through cumbersome process of levelling. Even though GPS also provides height information, it is not similar to that obtained from levelling due to different datum definition. Recently however JUPEM has started the initiative to use GPS for height purposes or GPS levelling through the introduction of MyRTKnet services and MyGeoid. The project is aimed to assess the quality of GPS levelling as compared to conventional levelling.

1.3 Objectives and Scope of Study

1.3.1 The Relevancy of the Project

This project is to asses whether GPS levelling can be an alternative of conventional levelling for height determination. It is also a good research on GPS levelling to make the levelling process easier and faster. The end finding of this project is to get accurate GPS heighting using MyRTKnet and MyGeoid.

1.3.2 Feasibility of the Project within Scope and Time Frame

The scope of the project is to determine the orthometric height of benchmark using GPS survey and compare it with second-class conventional levelling.

The projects include:

a) Theory and practical of processing GPS data:
   Real time data collection using VRS MyRTKnet
b) Theory and practical of processing orthometric height from GPS data
   Process the RTK data using MyGeoid to get the orthometric height

Twenty- eight (28) weeks or two semesters have been given to complete the project.

CHAPTER 2

LITERATURE REVIEW AND/OR THEORY

Until very recently with the advent of GPS in 1987, we relied on using traditional, line-of-sight survey measurements between physical reference points even as technology advanced from telescopic levels to modern laser levels.

Figure 1: Conventional line-of-sight survey method: Early days levelling survey party (http://www.photolib.noaa.gov/historic/c&gs/theb1773.htm)

However with the advent of GPS in 1987, the survey world and other positional applications have been forever changed. GPS (Figure 4) is a constellation of 28 satellites, which transmit radio signals that can be received by GPS receivers worldwide. This system is a tremendous asset to geodetic positioning, because GPS surveys can be accomplished without having intervisible stations (i.e. stations that can be seen from another point) and is not constrained by distance or terrain.

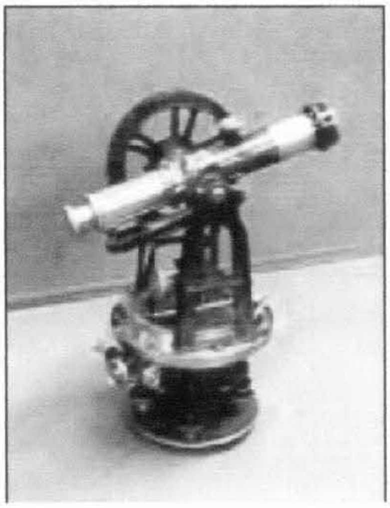

Figure 2: Telescopic level used in the early days of surveying
(http://www.surveyhistory.org/index.htm)

Figure 3: Present-day levelling survey parties: laser levels
(http://www.zeiss.com/survey/digital/dini11.shtml).

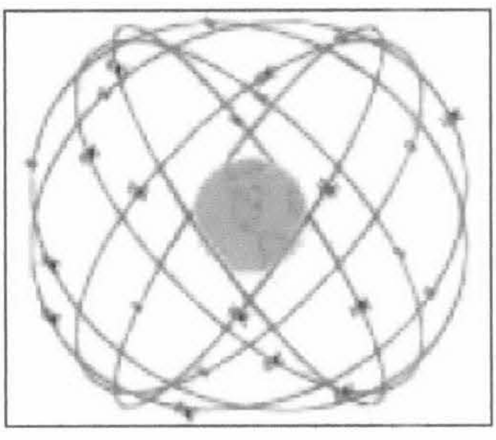

Figure 4: Global positioning system (GPS) composed of 28 satellites orbiting the earth at 20,200 km (http://www.colorado.Edu/geography/gcraft/contents.html).

Figure 5: A Trimble GPS receiver and antenna
(http://www.trimble.com/products/pdf/geosurvey.pdf)

Using GPS technique, the positions are determined as related to geocentric WGS84 (World Geodetic System 1984) reference ellipsoid of which surface is assumed as the datum of points' heights which are derived from GPS measurements. However, in most of the geodetic applications, it is necessary to use orthometric heights referenced to geoid.

Since the satellite based positioning techniques, especially GPS (Global Positioning System), were being used in a wide range of geodetic and surveying applications it is becoming more important to accomplish the transformation between ellipsoidal heights and orthometric heights.

2.1 GPS Levelling Theoretical background

The fundamental expression of relationship between ellipsoidal heights obtained from GPS measurements and heights with respect to a vertical geodetic datum established from spirit levelling data with gravimetric corrections is as given in the equation 1 (Heiskanen and Moritz, 1967).

$$\mathbf{H} = \mathbf{h}_{GPS} - \mathbf{N} \qquad (1)$$

Where, h_{GPS} is the GPS height above the ellipsoid and N the geoid seperation. In the above equation it is important to realize that H refers to a local vertical datum, h_{GPS} refers to a geocentric system (ITRF/WGS84), to which the computed (gravimetric) geoid also usually refers.

2.2 The Geoid and Mean Sea Level

There have been many definitions of the geoid. Nevertheless, it can be deemed as the equipotential surface of the Earth's gravity field which best fits, in a least square sense, the global mean sea level. For all intents and purposes, the geoid can be taken to be the same as the mean sea level.

The mean sea level is the average level of the ocean surface halfway between the highest and lowest levels recorded by tide gauges at specified locations. It is utilised as a plane upon which heights of features on, above or below the ground can be referenced.

2.3 Orthometric Height or Elevation

The height of a feature above mean sea level is called an orthometric height or an elevation. Elevations are measured by one of two methods, i.e. either by using levelling or by using GPS derived height.

2.4 Determination of the Geoid Model

The geoid can be considered as the mean sea level plus its natural continuation under the landmass. This extension must be determined mathematically or modelled. The geoid model is actually based on gravity data collected, be it acquired through ground, airborne or space gravity surveys. Once the geoid is determined, the difference between the two surfaces, the ellipsoid and the geoid can then be computed anywhere in the country.

2.5 Use of the Geoid Model

The Geoid model contributes to the vertical component of the reference system so that ellipsoidal GPS heights can be converted to orthometric elevations for practical uses. The real challenge lies in knowing the relationship between the ellipsoid and the geoid. Once the difference between these two surfaces, called the "geoid-ellipsoid separation" or "geoidal height", at a given point is determined, then application of the geoidal height to the GPS height measurement can be made to obtain the mean sea level elevation (Figure 6)

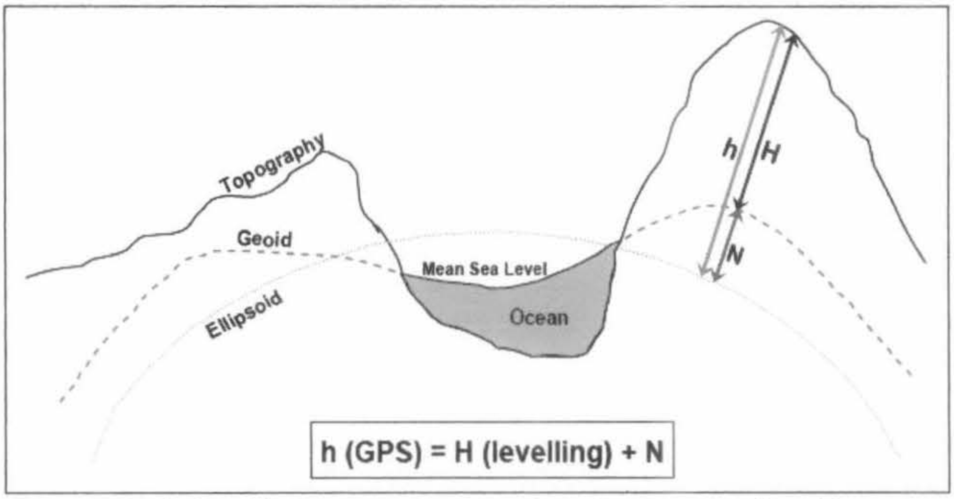

Figure 6: Relationship between Topography, Geoid and Ellipsoid

2.6 The Geoid-Ellipsoid Separation

The reference surface for heights in Malaysia is traditionally taken as the Mean Sea Level (MSL). As indicated earlier, the geoid is a surface of equal gravity potential which closely approximates the mean sea level. However, heights derived from GPS are relative to the GPS reference ellipsoid. The separation between the geoid and ellipsoid is known as the geoid-ellipsoid separation (or N value). Considering that N value is relative to a specific ellipsoid, extreme care must be taken to ensure that the N value used refers to the correct ellipsoid. In the examples below, both the N value and the ellipsoidal height refer to the same ellipsoid (usually WGS84 when working with GPSderived ellipsoidal heights or GRS80 ellipsoid; note that WGS84 is taken as being the same as GRS80 ellipsoid):

Example 1

In an absolute sense, N is used as follows:

H = h - N

If **h** = 62m and **N** = -12m

H = 62 - (-12) = **74m.**

Example 2

In a relative (baseline) sense where the change in N is used:

(H2 - H1) = (h2 - h1) - (N2 - N1)

i.e. Δ**H** = Δ**h** - ΔN

H2 = H1 + ΔH

If **H1** = 636.5m (known); **h1** = 623m; **h2** =581m; **N2** = -17m;

N1 = -15m

Δ**h** = 581 - 623 = - 42m

Δ**N** = -17 - (-15) = - 2m

Δ**H** = (- 42) - (- 2) = - 40m

H2 = 636.5 + (- 40) = 596.5 m

2.7 Spirit (Conventional) Levelling

The spirit level is placed on a tripod in the middle between the two points whose height difference is to be determined (Figure 7); the points are marked by markers or benchmarks in the rock or soil. A levelling staff or rod is placed on each point, with measured graduations, usually in centimetres and fractions thereof. The observer focuses in turn on each rod and reads the value from it. Subtracting the "back" and "forward" value provides the height difference.

For the greatest precision the distances to the rods should not be too large, typically 30-60 m, and should be approximately equal in order to eliminate systematic errors such as the residual misalignment between telescope axis and tube level axis.

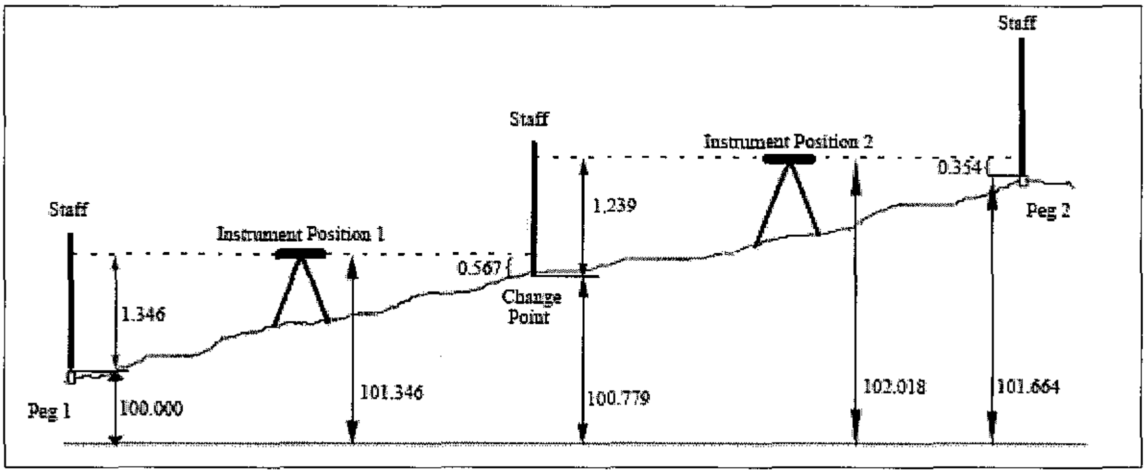

Figure 7: Conventional Levelling

2.8 Real Time Kinetik (RTK) Surveying

Real Time Kinematic (RTK) survey method is relative positioning whereby multiple receivers are linked by radios simultaneously in collecting observations. The reference station broadcasts its differential data and the roving units receive it through a data port, directly connected to a radio receiver. The roving units can then display position, velocity, time and precise positioning.

2.9 Virtual Reference Station (VRS)

The new generation of RTK known as "Virtual Reference Station (VRS)" is based on having a network of GPS reference stations continuously connected via telecommunication network to the control centre. A computer at the control centre continuously gathers information from all receivers, and creates a living database of Regional Area Corrections. With VRS system, one can establish a virtual reference station at any point and broadcast the data to the roving receivers.

2.10 MyRTKnet

MyRTKnet is a new nation-wide GPS network and system infrastructure developed for GPS users to provide RTK and DGPS services with unmatched accuracy and coverage for positioning applications across Malaysia. As a wide-area satellite based service, the broadcast MyRTKnet corrections can be obtained anywhere in Malaysia using a custom-built MyRTKnet GPS receiver. The positioning data from MyRTKnet reference stations is optimised for Malaysia, resulting in superior centimeter-level accuracy with most GPS receivers. Compared to existing solutions, MyRTKnet provides better coverage and performance, a superior technology platform for continued accuracy improvements, plus the assurance of working with a national GPS network infrastructure that ensures spatial integrity.[MyRTKnet guideline,2005]

2.10.1 MyRTKnet Features

MyRTKnet reduces physical infrastructure costs to establish one own's master GPS and should increase productivity with the use of highly portable GPS systems. It provides high performance solution well-suited to real-time data collection needs of Malaysian users. The network (Figure 8), which includes the provision of redundancy at the data collection, transmission and processing layers, has a high degree of service reliability. At the same time, a web site by JUPEM is made available to download GPS data for post-processing solutions (The data can be downloaded at http://www.rtknet.gov.my).

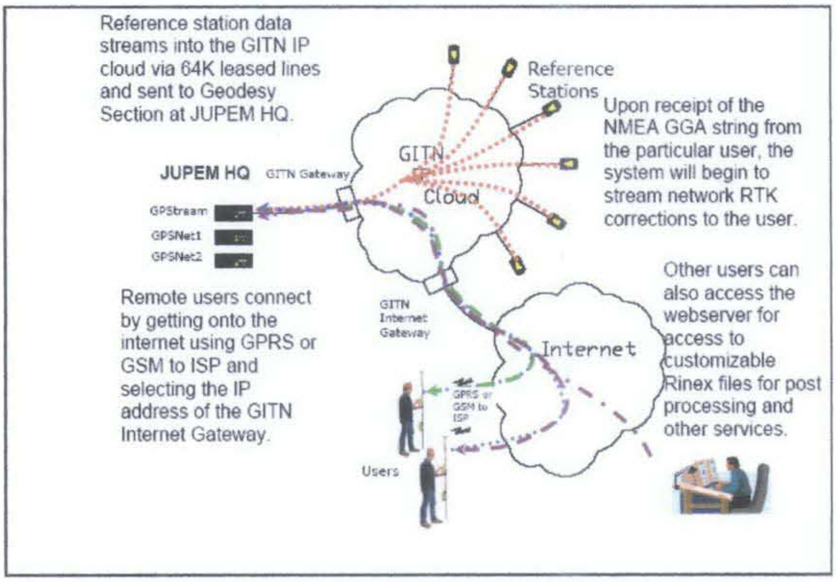

Figure 8: Conceptual Diagram of MyRTKnet System

2.10.2 Network Coverage

The present coverage of MyRTKnet includes three dense networks that provide centimetre accuracy around Lembah Klang, Pulau Pinang and Johor Bahru, (Figure 9) and a sparse network covering the whole nation. Other areas in the vicinity of 30 km radius from the permanent reference stations will also provide centimetre accuracy. This coverage is expected to be further densified in the years to come as JUPEM endeavours to provide better extent of the facilities to GPS users.

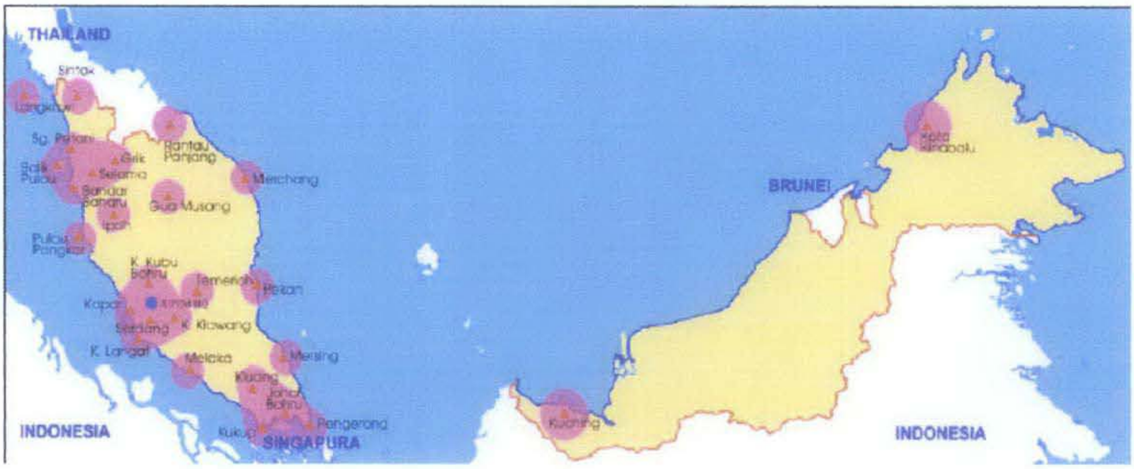

Figure 9: MyRTKnet Network Coverage

2.10.3 MyRTKnet Sevices

MyRTKnet provides various levels of GPS correction and data. Their use will depend on the technique and application to be employed. Virtual Reference System (VRS) data, Single Base data and Network Base DGPS data are meant for real time applications whereas Virtual RINEX and RINEX data are for post-processed applications.

Correction is provided for the whole of Peninsular Malaysia and areas within 150 km radius from Kota Kinabalu and Kuching. Any receiver that is capable of handling Real Time Corrections and cell phone data service can be used to receive DGPS solutions' Real Time RTCM corrections. Distance dependant errors are eliminated for users' observations due to DGPS's array of base station locations.

2.10.4 Virtual Reference System (VRS) Data

VRS is an integrated system which links and utilizes data from permanent reference stations to model errors throughout the coverage area. This model is used to synthesize virtual reference stations near the user's location which then provide a localized set of standard format correction messages to the roving receiver. To enable the modeling, the rover must provide its approximate position to the control centre. This is done via cellular modem using the standard NMEA GGA string. The control centre automatically receives this positioning information, interpolates and applies corrections for ephemeris, tropospheric and ionospheric errors and generates the virtual reference station for that individual rover. It then produces a set of standard format correction messages as if they were coming from the virtual reference station and transmits them via cellular modem back to the rover.

2.11 MyGeoid

Malaysian geoid model (MyGeoid) is used to compute orthometric heights (H) that refer to the national geodetic vertical datum (NGVD). In practice, the expression shows the possibility of using GPS levelling technique, knowing the geoidal height (N), the orthometric height (H) can be calculated from ellipsoidal height (h). Deriving orthometric height using this technique with certain level of accuracy, could replace conventional spirit levelling and therefore make the levelling procedures cheaper and faster. [MyGeoid guideline,2005]

2.11.1 MyGeoid Models

The Malaysian geoid models or in short, MyGeoid consist of the following:

• Peninsular Malaysia – WMGEOID04 (Figure 10)

• Sarawak and Sabah – EMGEOID05 (Figure 11)

The geoid models are hybrid ones, combining the gravimetric geoids with datum transformations and GPS ellipsoid heights on leveled bench mark. **Table 1** shows the specifications of the geoid models.

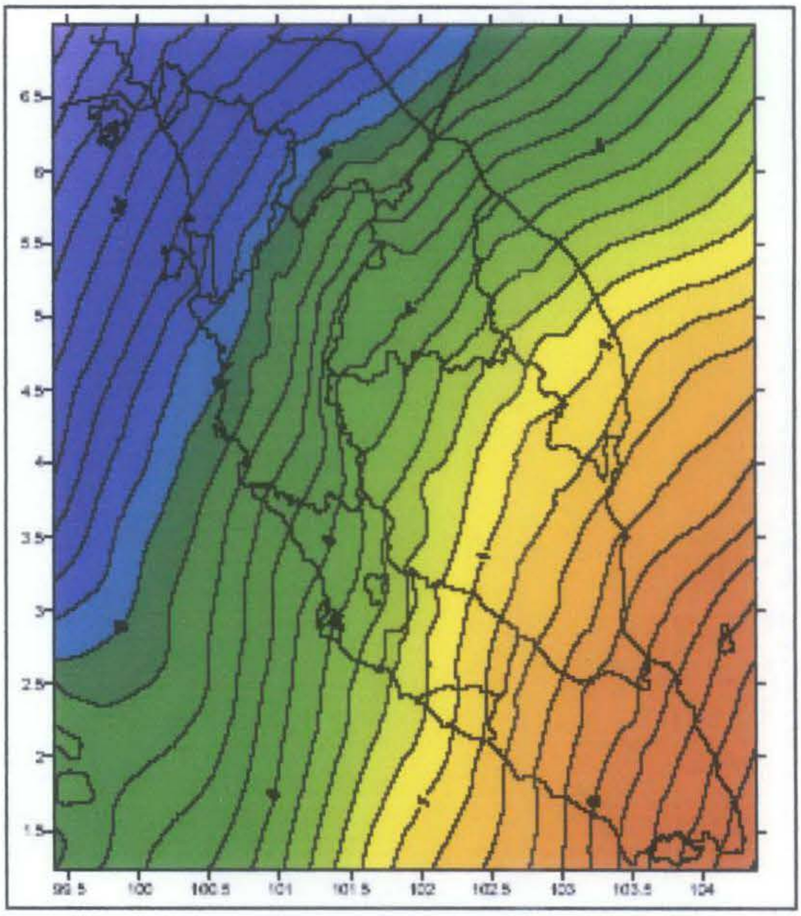

Figure 10: Peninsular Malaysia Geoid 2004 (WMGEIOD04)

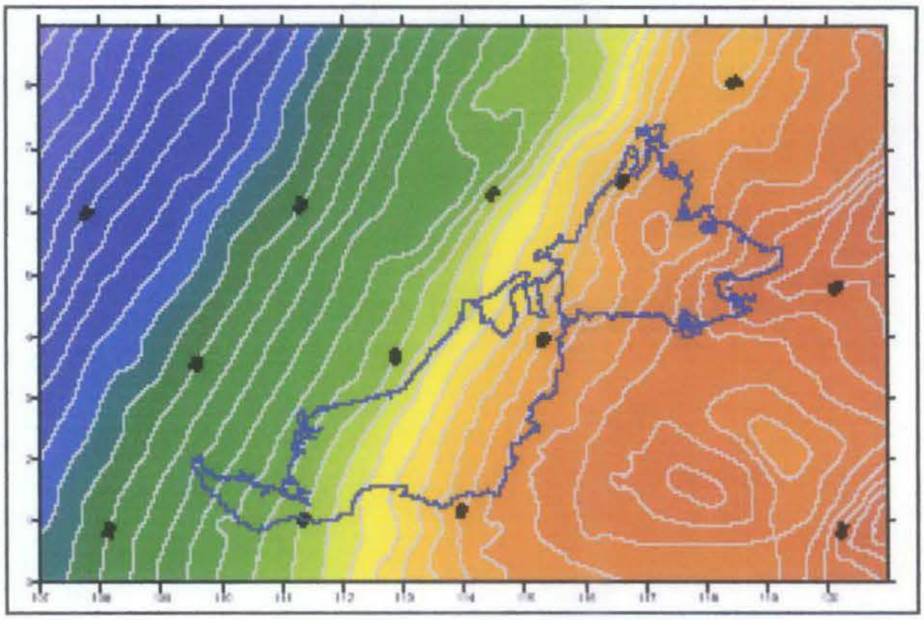

Figure 11: Sabah & Sarawak Geoid (EMGEOID05)

Table 1: WMGEOID04 and EMGEOIDID05 Geoid Models of Malaysia

Category	WMGEOID04 (Peninsular Malaysia)	EMGEOID05 (Sabah and Sarawak)
Year	2004	2005
Gravimetric Base Model	WMG03A	EMG03C
Gravity Measurements	Terrestrial = 5,634 points Airborne = 24,855 points	Terrestrial = 891 points Airborne = 37,109 points
Altimetry Data	KMS02	KMS02
DEM	DTED/SRTM	DTED/SRTM
Terrain Corrections (Resolution)	DTED = 3" SRTM = 30"	DTED = 3" SRTM = 30"
Terrain Corrections (Method)	2-D FFT	2-D FFT
Global Geopotential Model	GGM01C	GGM01C
Geocentric Reference Frame	ITRF2000 (GDM2000)	ITRF2000 (GDM2000)
Horizontal Resolution	1.5'	3'
NGVD bias estimate	1.317 meter	1.252 meter
GPS on Benchmark	37 points	60 points
Accuracy (1 Sigma) w.r.t. GPS/ Benchmark	4.2 cm	4.1 cm

MyGeoid is Malaysia's first ever geoid model, which fits the local Mean Sea Level of Peninsular Malaysia as well as that of Sabah and Sarawak. Absolute comparison of gravimetric geoid-ellipsoid separation with the geometric (GPS minus benchmark heights) equivalent revealed existence of datum bias, or datum ambiguity. Therefore, MyGeoid was computed by fitting the GPS-levelling and the gravimetric geoid.

Final geoid inherits the possible systematic errors of GPS levelling, and thus could no longer be an equipotential surface. However, the geoid will match the vertical datum of Malaysia, and thus convert GPS heights in ITRF to level heights in the said datum.

The WMGEOID04 geoid model is fitted to the NGVD in Peninsular Malaysia, which is based on 10 years observation of the Mean Sea Level at Port Klang taken from 1984 to 1993.

The EMGEOID05 geoid model for Sabah and Sarawak is fitted to the Sabah Datum 1997 which is based on 10 years of Mean Sea Level observation at Kota Kinabalu Tide Gauge Station taken from 1988 to 1997.

CHAPTER 3
METHODOLOGY

3.1 Procedures Identification

This project involved several methods to archive the objective of the study. Basically, the methodology has been divided into five main stages as mentioned below:

1) **Literature Review**

   Most information is gathered from journal, internet, JUPEM guideline on MyRTKnet and MyGeoid and through discussion with Supervisor, JUPEM personnel and colleagues. Available research by individual on related topics was also a useful reference for basic understanding.

2) **Instrumentation**

   Identification on the GPS instrument was used to carry out the project.

3) **Selection of Study Case Area**

   The area of study for this project was done around Klang Valley

4) **Field work**

   For this project, the GPS levelling was done on the benchmarks, as provided by JUPEM.

5) **Data Processing and analysis**

   The data gathered from GPS levelling was processed by using TRIMBLE GEOMATICS OFFICE (TGO) Version 1.61 processing software, MyRTKnet and MyGeoid to get the orthometric height on each point. The result will be compared to benchmark value from conventional levelling.

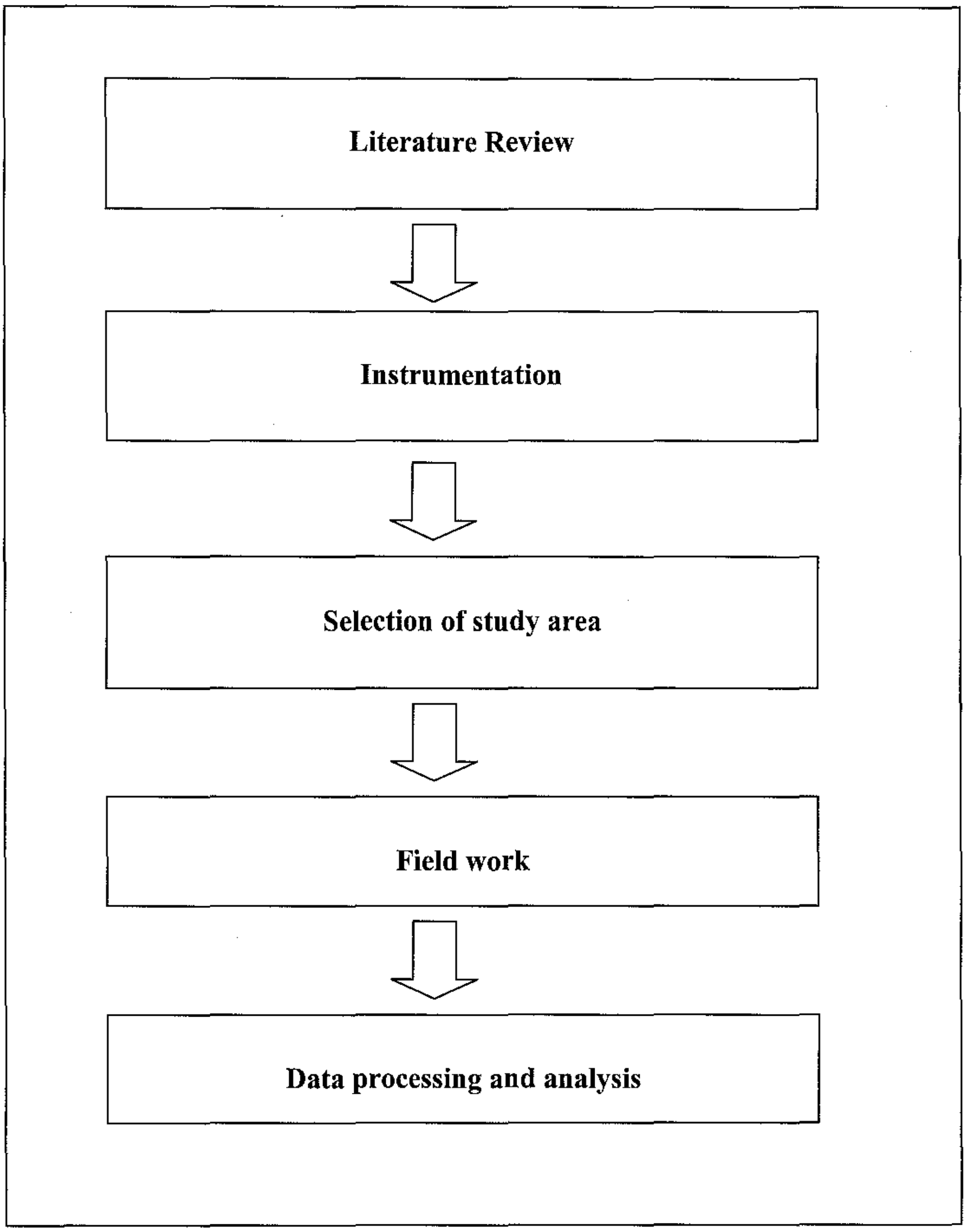

Figure 12: Procedure Flow Chart for The Project

3.2 Instrumentation

GPS instrument used for this project, access to MyRTKnet and MyGEOID was by courtesy from JUPEM. Not only that, they had gave the guidance on how and the dos and don'ts in using the equipment.

3.2.1 GPS Receiver

TRIMBLE GPS receiver was used to supports the MyRTKnet services for this project.

The GPS receiver has several components (Appendix A):

a) Antenna
b) Carbon Fibre Range Pole
c) 5700 GPS Receiver Pole Mount Bracket
d) Data controller bracket
e) TRIMBLE survey controller – TSCE and pen stylus
f) Lithium-Ion Rechargeable Battery
g) TRIMBLE 5700 GPS Receiver
h) Memory Card - Compact Flash Card
i) Hand Phone & Charger
j) Power Supply Cable
k) Y-Cable – 1.5 Meter
l) Multi Port Adapter
m) RS232 Cable
n) USB Download Cable
o) Cable 5700 to TSCE Cable
p) Antenna Cable

3.2.2 TRIMBLE GEOMATICS OFFICE (TGO) version 1.61

This software is capable of processing GPS data (RTK and Post processed) and other measurement technique. TGO is used to transfer field data from TSCe to computer. The data will then be exported to Microsoft Excel.

3.2.3 MICROSOFT EXCEL

Geographical (ϕ, λ, h) data from TGO will be exported to Exel for calculation and analysis.

3.2.4 Access to JUPEM MyRTKnet

MyRTKnet is used for correction of the data measured from GPS. Data obtain from MyRTKnet is ellipsoidal height (h_{gps}). The access to MyRTKnet is courtesy from JUPEM.

3.2.5 Access to JUPEM MyGeoid

MyGeoid will give the value of geoid separation (N) at each point. The value of N is used to obtain the orthometric height (H) as per equation 1 (Heiskanen and Moritz, 1967). The access to MyGeoid is also courtesy of JUPEM.

3.3 Selection of Study Area

The study area of this project was in Klang Valley. The project was done in two places namely Seri Kembangan - Putrajaya route and Ampang – Hulu Langat route. These two places were selected because it is in the dense Klang Valley VRS network.

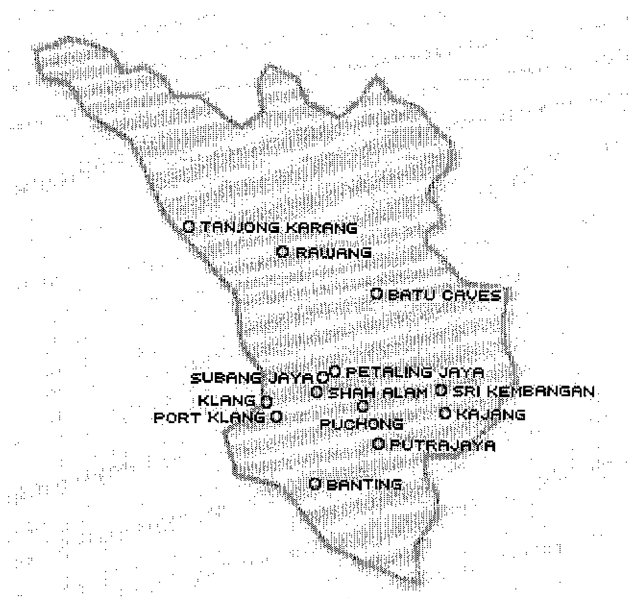

Figure 13: Location of Study Area, Klang Valley

3.4 Field Work

The field work was done on benchmark with known height value. This is due to manpower and time constrain. Besides, yours truly is not a professional surveyor. The usage of benchmark is to reduce the error in levelling process and to reduce time to complete this project in two semesters.

For Seri Kembangan – Putrajaya route, average of 20 readings was taken for each benchmark. For the second route Ampang – Hulu langat, average of 30 readings for each benchmark.

3.5 Data Processing and Analysis

The data obtained from the field work was downloaded from TSCe to computer using TGO. The data from TGO was then being exported to Microsoft Excel to calculate the average (Latitude, Longitude, Height) of each benchmark. The results of which will be use to compute the geiod height (N). Equation 1 (Heiskanen and Moritz, 1967) was used to obtain orthometric height (H).

CHAPTER 4

RESULTS & DISCUSSION

4.1 Results

The data presented in the tables below was the average ellipsoidal height (h_{GPS}) of each benchmark. The full average data for each benchmark can be referred to Appendix II.

Below are the results obtained from the field work in both study area:

1) The height difference analysis from the GPS levelling in Seri Kembangan - Putrajaya route.

Table 2: Height difference between GPS and Conventional levelling in Seri Kembangan – Putrajaya route.

Benchmark	h_{GPS}	$N_{MyGeoid04}$	$H_{Geometric}$	$H_{Levelling}$	ΔH	ΔH^2
B2014	65.276	-2.089	67.365	67.274	0.091	0.008
B2016	40.008	-2.125	42.133	42.013	0.120	0.014
B2017	34.897	-2.133	37.030	36.952	0.078	0.006
B2019	48.663	-2.135	50.798	50.601	0.197	0.039
B2022	24.399	-2.122	26.521	26.489	0.032	0.001
B2032	52.028	-1.942	53.970	53.850	0.120	0.014
B2033	37.640	-2.095	39.735	39.720	0.015	0.000
B2036	40.355	-2.005	42.360	42.261	0.099	0.010
B2037	36.574	-1.983	38.557	38.431	0.126	0.016
B2038	38.500	-1.960	40.460	40.338	0.122	0.015
B2039	51.346	-1.927	53.273	53.201	0.072	0.005
B2041	44.307	-1.931	46.238	46.210	0.028	0.001

2) The height difference analysis from the GPS levelling in Ampang- Hulu Langat route

Table 3: Height difference between GPS and Conventional levelling in Ampang- Hulu Langat route.

Table 3 Benchmark	h_{GPS}	$N_{MyGeoid04}$	$H_{Geometric}$	$H_{Levelling}$	ΔH	ΔH^2
B0028	51.532	-2.004	53.536	53.516	0.020	0.000
B0029	59.788	-1.960	61.748	61.693	0.055	0.003
B0515	52.600	-1.650	54.250	54.217	0.033	0.001
B0516	55.565	-1.582	57.147	57.107	0.040	0.002
B1807	142.689	-1.732	144.421	144.460	-0.039	0.002
B1808	106.191	-1.732	107.923	108.007	-0.084	0.007
B1809	62.336	-1.708	64.044	64.010	0.034	0.001
B1810	49.441	-1.677	51.118	51.106	0.012	0.000
B1811	57.887	-1.614	59.501	59.490	0.011	0.000
B1813	64.082	-1.519	65.601	65.633	-0.032	0.001
B1814	69.920	-1.491	71.411	71.384	0.027	0.001

4.2 Discussion

Results from the above tables (Table 2 & Table 3) indicate the average height obtained from each benchmark. The h_{GPS} indicates the RTK value obtained from MyRTKnet. The $N_{MyGeoid04}$ indicates the geiod separation value and $H_{Geometric}$ represent the Orthometric height. $H_{Geometric}$ was obtained from equation 1 (Heiskanen and Moritz, 1967).

$H_{Levelling}$ was the height value for each benchmark obtained from 2nd order levelling. The height difference between the GPS levelling and the Conventional levelling is shown in the table in ΔH column.

Although there are numbers of benchmark along the route, most of them cannot be used for this field work because the benchmarks were located under big tress and beside buildings. These obstructions degrade the satellite signals.

4.2.1 Seri Kembangan – Putrajaya route

Average of 20 readings was taken on each benchmark in Seri Kembangan – Putrajaya route. The height difference between each point is shown in Figure 14 below. From the height computation (equation 1), it showed that the maximum height difference is 0.197m, minimum height difference is 0.015m, and the average height difference is 0.092m. The RMS value is 0.104m.

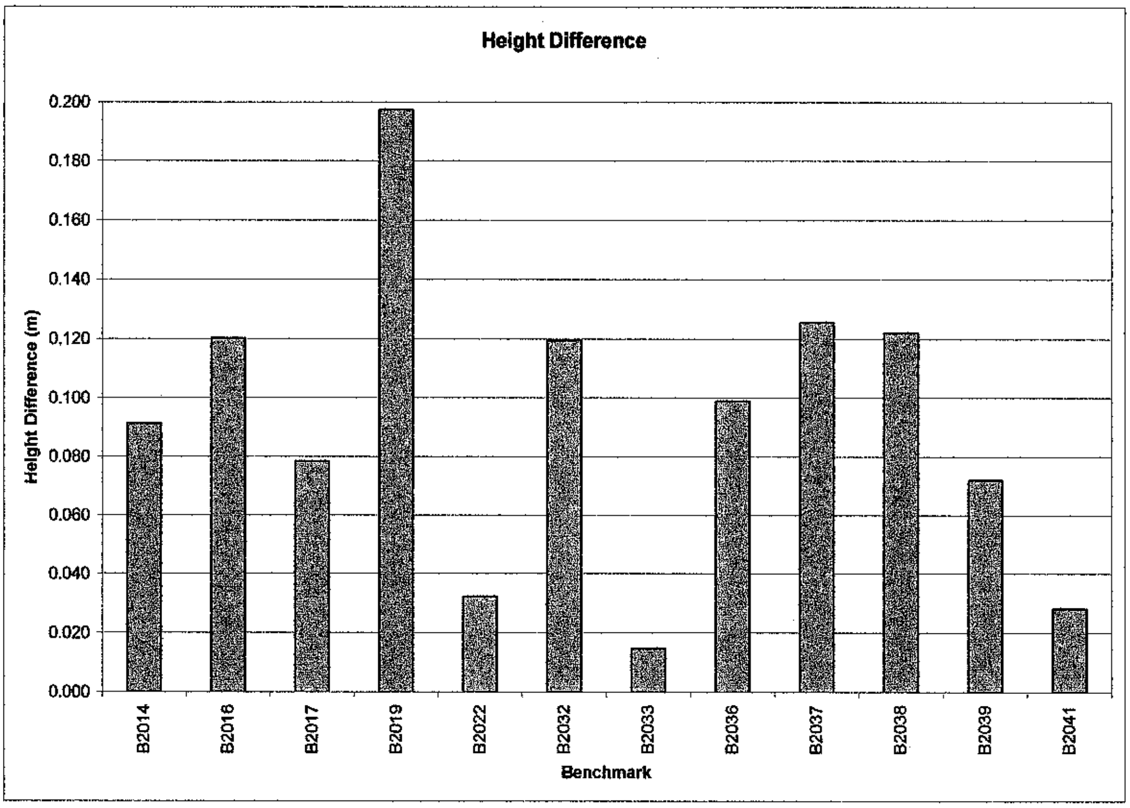

Figure 14: Graph of height difference between GPS levelling and conventional levelling in Seri Kembangan – Putrajaya Route

4.2.2 Ampang – Hulu Langat route

Average of 30 readings was taken on each benchmark for Ampang – Hulu Langat route. The height difference between each point is shown in Figure 15 below. From the height computation (equation 1), it showed that the maximum height difference is 0.055m, minimum height difference is -0.084m and the average height difference is 0.007m. The RMS value is 0.040m.

From the height difference graph it showed that an average of 20 readings at Seri Kembangan – Putrajaya route give a higher height difference compared to Ampang – Hulu Langat route with average of 30 readings.

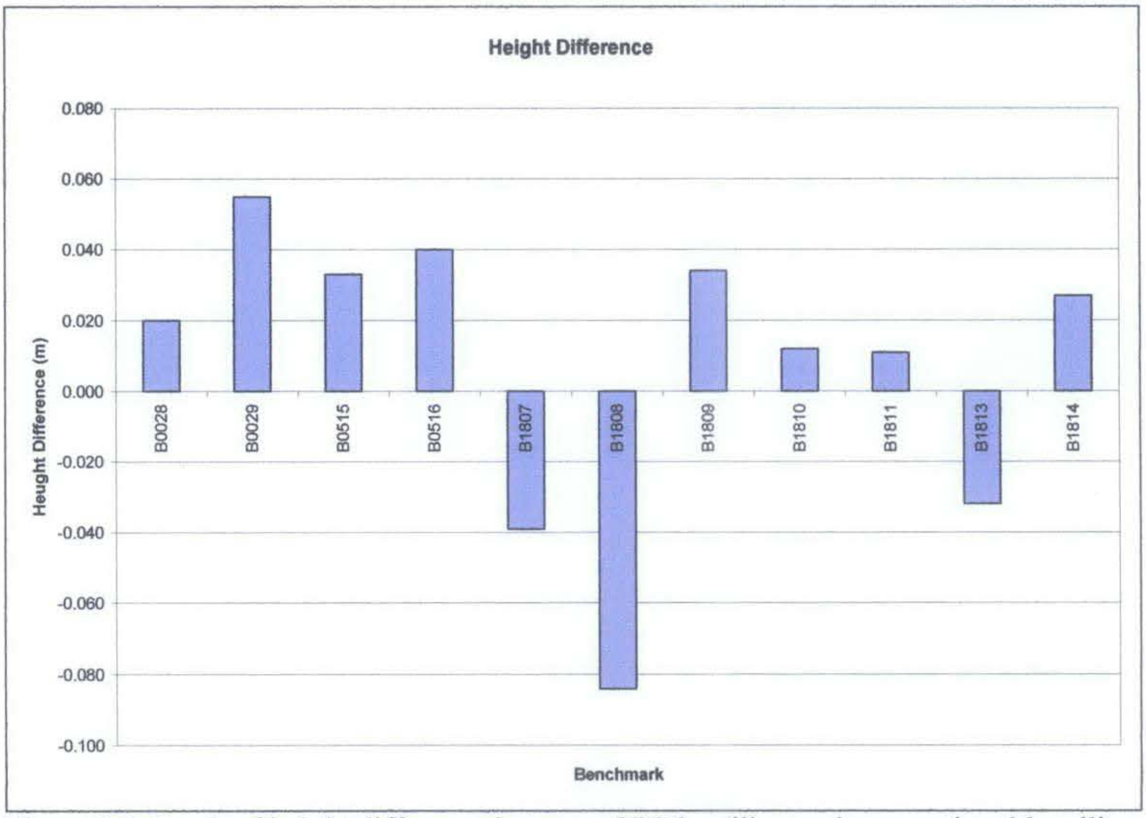

Figure 15: Graph of height difference between GPS levelling and conventional levelling in Ampang – Hulu Langat Route

From MyGeoid (N) computation, it shows that the study area located in the range of (-1) – (-2) meter geoid height. Figure 16 shows the geiod (N) value for the study area.

From JUPEM circulation for MyRTKnet (KPUP 9/2005) and MyGeoid (KPUP 10/2005), it was stated that the achievable accuracy for the height determination with MyRTKnet services is around 6 cm and the accuracy for MyGeoid is 5 cm. The extreme end of the errors is the total of both errors (MyRTKnet + MyGeoid) which is equivalent to 11cm. From findings as per Figure 8 and 9, it shows that the RMS value is 0.104m and 0.040m respectively which is within tolerance error.

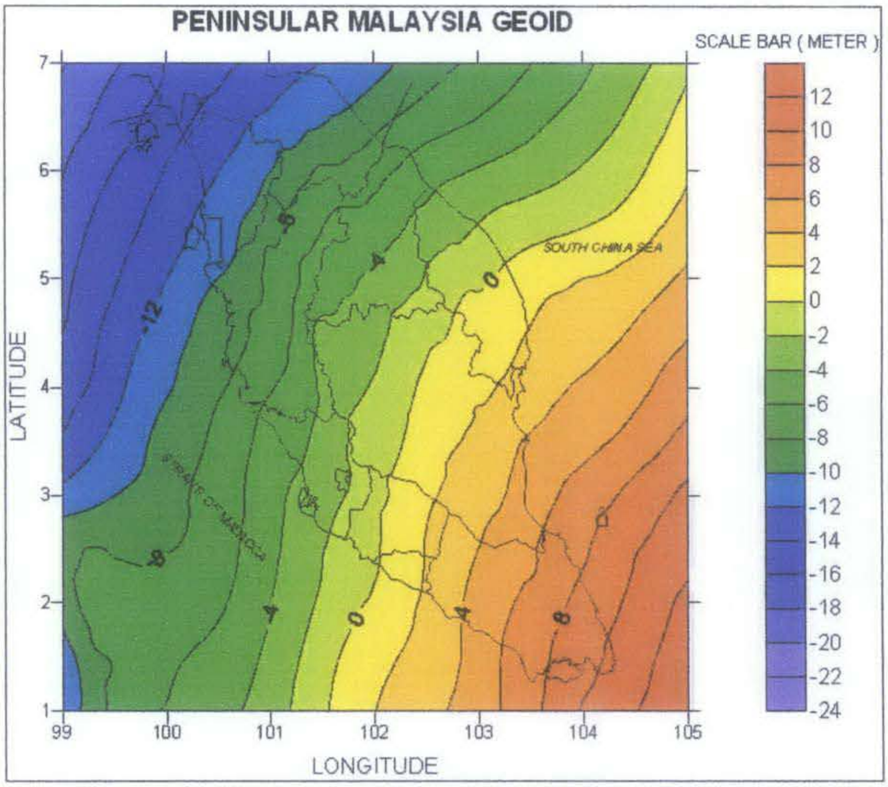

Figure 16: Peninsular Malaysia Geoid 2004 (WMGEIOD04)

4.2.3 Sources of Error

There were two major contributing errors found when conducted this project:

1) GPS signal blockage

The benchmarks in the study area are mostly located beside trees and sign boards. For example, benchmark B2019 along Putrajaya – Kajang highway is located beside a sign board (Figure 17). This is the most contributing error that leads to high RMS value.

2) Communication problem

Hulu Langat being a suburban area and located within the dense MyRTKnet network, the GPS receiver was not able to receive the correction data streamed by the network RTK because of the poor cell phone coverage.

Figure 17: Location of benchmark beside signboards

CHAPTER 5
CONCLUSION & RECOMMENDATION

5.1 Conclusion

Through this project, GPS levelling using MyRTKnet and MyGeoid was assessed by comparing the orthometric height obtained through GPS levelling to the benchmark value. The results from Seri Kembangan – Putrajaya route and Ampang – Hulu Langat route showed that it is in consistent with JUPEM circulation for MyRTKnet and MyGeoid which states that the extreme end of both errors is 11cm.

From the field work done, it can be concluded that GPS levelling using MyRTKnet and MyGeoid can achieve the second order and third order levelling accuracy within tolerance error. In the mean time, GPS levelling still cannot be used for engineering purposes that need high precision and accuracy. However, GPS levelling can be used for quick check for construction work or any other related engineering work because it can give real time results thus reducing the time of computing height through cumbersome process of conventional levelling.

By using GPS, there is no need to consider the distance from the last point where elevation data is obtained, the type of terrain or whether or not the weather is bad. With GPS a survey that once took days to complete by traditional levelling methods can now be done in a fraction of the time and at a fraction of the cost.

5.2 Recommendation

In order to get a high accuracy and reliable data for MyRTKnet, JUPEM need to maintain and improve the development of this infrastructure.

To make MyRTKnet accessible anywhere in Malaysia, JUPEM need to:

1) Build more GPS reference station
2) Establish more dense VRS network
3) Investigate alternate telecommunication solutions for those areas where the cell phone services are not available

For the purpose of engineering and construction works, JUPEM also need to ensure the clear sky view of each benchmark.

Chapter 6

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GLOSSARY

Vertical Datum Bias
The difference in vertical reference between gravimetric geoid and the local mean sea level.

Deflections of Vertical
The angle between the plumb line (line perpendicular to the geoid) and the line normal to the ellipsoid. This angle has both a magnitude and a direction and usually resolved into two components, one in the meridian and the other perpendicular to it in the prime vertical.

Ellipsoid
A smooth mathematical surface used to describe the shape of the earth for geodetic computations. The figure is formed by rotating an ellipse about its minor (shorter) axis and is typically described by dimensions for the semimajor axis (a) together with the semiminor axis (b) or flattening,
(f) = (a-b)/a.

Ellipsoid height
The distance from a point to the reference ellipsoid along a line normal to the ellipsoid.

GDOP
Geometric Dilution of Precision. GDOP represents the uncertainty expected in the three positional coordinates plus the clock offset from a particular configuration of the satellites. High GDOP means low accuracy.

Geocentric Datum of Malaysia (GDM2000)
A geocentric coordinate system for positioning in Malaysia, whose origin coincides with the centre of the mass of the earth which fits into International Terrestrial Reference Frame.

Geoid
An equipotential surface (a surface of equal gravity potential) which most closely matches mean sea level. An equipotential surface is normal to the gravity vector at every point.

Gravimetric Geoids
Geoid model computed based on gravity data.

GRS80 Ellipsoid
Geodetic Reference System 1980. The reference ellipsoid of GDM2000.

Mean Sea Level
The average height of the sea for all stages of the tide over a period (often used as a reference for general leveling operations).

NGVD
A network of reference adopted as a standard geodetic datum for elevation in the country.

Orthometric Height
The distance from the geoid to a point, measured along a line normal to the geoid.

Static GPS
GPS carrier phase differencing technique where the GPS observations are carried out using one or more stationary receivers and where the integer ambiguities are resolved from an extended observation period through a change in satellite geometry.

Ambiguity
The unknown integer number of cycles of the reconstructed carrier phase contained in an unbroken set of measurements from a single satellite passes at a single receiver.

Baseline
The length of the three-demensional (3D) vector between a pair of stations for which simultaneous GPS data has been collect and processed with differential techniques.

Carrier Frequency
The frequency of the unmodulated fundamental output of a radio transmitter.
The GPS L1 carrier frequency is 1575.42 MHz, the GPS L2 carrier frequency is 1227.60 MHz.

Cutoff Angle
The minimum elevation angle below which no more GPS satellites are tracked by the sensor.

DGPS
Differential GPS. The term commonly used for a GPS system that utilizes differential code corrections to achieve an enhanced positioning accuracy of around 0.5 – 5 m.

Ephemeris
A list of positions or locations of a celestial object as a function of time.

Epoch
A particular fixed instant of time used as a reference point on a time scare.

GDOP
Geometric dilution of precision.

Ionospheric Delay
A wave propagation through the ionosphere (which is a non-homogeneous and dispersive medium) experiences delay. Phase delay depends on electron content and affects carrier signals. Group delay depends on dispersion in the ionosphere as well, and affects signal modulation (codes). The phase and group delay are of the same magnitude but opposite sign.

Multipath error
A positioning error resulting from interference between radio waves which have travelled between the transmitter and the receiver by two paths of different electrical lengths.

NMEA
National Marine Electronics Association. Defined a standard (NMEA 0183) to enable marine electronics instruments, communication and navigation equipment to communicate. This standard is used to get time and position data out of GPS instruments in many applications.

Post Processing
The process of computing positions in non-real-time, using data previously collected by GPS receivers.

Rapid Static Survey
Term used in connection with the GPS System for static survey with short observation times. This type of survey is made possible by the fast ambiguity resolution approach.

RINEX
Receiver INdependent Exchange format. A set of standard definitions and formats to promote the free exchange of GPS data.

RTCM
Radio Technical Commission for Maritime services. Commission set up to define a differential data link to relay GPS messages from a monitor station to a field user.

RTK
Real Time Kinematic. A term used to describe the procedure of resolving the phase ambiguity at the GPS receiver so that the need for post-processing is removed.

Static Survey
The expression static survey is used in connection with GPS for all nonkinematic survey applications. This includes the following operation modes :
- Static Survey
- Rapid static survey

Stop & Go Survey
The term of Stop & Go survey is used in connection with GPS for a special kind of kinematic survey. After initialization (determination of ambiguities) on the first site, the roving receiver has to be moved between the other sites without loosing lock to the satellite signal. Only a few epochs are then necessary on there sites to get a solution with survey accuracy. Once loss of lock occurred, a new initialization has to be done.

Topography
The form of the land of a particular region.

Appendix A

GPS Component

Figure 17: TRIMBLE rover antenna using dual-frequency without *geodetic ground plane*

Figure 18: 2m height Carbon Fibre Range pole used to set up the rover unit during surveying. The spirit bubble at the middle of the pole is use to adjust the antenna placing.

Figure 19: 5700 GPS Receiver Pole Mount Bracket were clipped to the Receiver. It is use to hold the Receiver to Range Pole

Figure 20: Data Logger Bracket Use to hold TRIMBLE survey controller (TSCe) Data Controller to range pole

Figure 21: Trimble Survey Controller – TSCe and Pen Stylus. *Data Logger* has to equip with Window CE. The data will be display on TSCe screen.

Figure 22: Lithium-ion Rechargeable Battery

Figure 23: Trimble 5700 GPS Receiver used as mobile rover for GPS RTK survey. It has two slots for battery, one slot for memory card and 3 ports for cables.

Figure 24: 128mb Compact Flash Card. Only Compact Flashcard Type 1 compatible with Receiver 5700.

Figure 25: Hand phone. The purpose is to receive the corrected data from control centre at Geodesy section. The hand phone will be connected to TSCe during the surveinig.

Figure 26: The charger used to charge the hand phone.

Figure 27: Power Supply Cable is used with Y-Cable to charge the Receiver battery and TSCe. It comes together with the GPS RTK set.

Figure 28: Y-Cable – 1.5 meter used to connect the receiver and TSCe to power supply when charging.

Figure 29: Multi port Adapter use to download data from TSCe to computer.

Figure 30: Cable RS232 used to connect hand phone to TSCe.

Figure 31: USB Cable used to download data from TSCe to computer.

Figure 32: Short 5700 to TSCe Cable is use to connect receiver to TSCe.

Figure 33: Antenna Cable use to connect receiver to antenna.

Appendix B

Equipment setup

Procedure for Rover setup:

Figure 34: Battery is inserted to the receiver

Figure 35: Memory card is inserted to the receiver

Figure 36: Pole mount bracket is attached at the back of 5700 GPS receiver

Figure 37: Both poles are joint and make sure the sharp ends were downward

Figure 38: “Zephyr” antenna is set to the pole and make sure it is tighten

Figure 39: Bracket TSCe is installed at the upper part of the pole and make sure it is tighten

Figure 40: TSCe is placed to the bracket and make sure it is tighten

Figure 41: 5700 GPS receiver is attached to the lower part of the pole, and then locked the bracket to the pole.

Figure 42: Receiver that had been attached to pole

Figure 46: Cable RS232 is connected to hand phone

Figure 47: Connect Cable RS 232 to TSCe serial port 9 pin

Pole is placed at the station and adjusts the pole by pressing the button at the leg. Make sure the bubble is at the centre.

Figure 48: Setting the pole at station

Figure 43: Cable 1.6m is connected to the antenna. Make sure that it is connected correctly.

Figure 44: Cable antenna is connected to GPS Receiver port that indicate satellite symbol

Figure 45: Cable TSCe is connected from TSCe middle port to receiver port no.1

Figure 49: Adjusting the bubble to level the equipment

Figure 50: GPS RTK equipment that have been set up

Ampang – Hulu Langat Route

Benchmark	Description	Height
B 0028	Di kanan jalan K.Lumpur - Ampang. Di penjuru pagar rumah 'Kuarters Polis Ampang Jaya'. Berhampiran lampu isyarat.	53.516
B 0029	Di kanan jalan Ampang - Hulu Langat. Di simpang ke 'Taman Ampang campuran'. Bertentangan 'Sek. Ren. Keb. Ampang Campuran'	61.693
B 0515	Di kiri Batu 9 Cheras - Ulu Langat. Di hujung jambatan, 100 m selepas simpang `Kg. Sungai Semungkis Batu 14 1/2'.	54.217
B 0516	Di kiri Jalan Ampang - Hulu Langat. Di luar pagar 'Dewan Serbaguna Dusun Tua'. 200 meter selepas 'Pusat Latihan Belia Dusun Tua'.	57.107
B 1807	Di kiri Jalan Ampang - Hulu Langat. Di atas culvert, 100 meter sebelum jalan ke 'Tempat Menyimpang Barang Kontrek'.	71.384
B 1808	Di kiri Jalan Ampang - Hulu Langat. Di atas tapak gerbang papan tanda 'Majlis Perbandaran Kajang, Taman Pinggiran Delima, Hulu Langat', di simpang ke Taman Pinggiran Delima.	144.46
B 1809	Di kiri Jalan Ampang - Hulu Langat. Di atas culvert, simpdang ke 'Sekolah Kebangsaan Abd. Aziz Majid Hulu Langat'.	108.007
B 1810	Di kiri Jalan Ampang - Hulu Langat. Di konkrit di atas dan di hujung 'Jambatan Sungai Gahal', 10 meter selepas 'Sek. Men. Abd. Aziz'.	64.01
B 1811	Di kiri Jalan Ampang - Hulu Langat. Di atas culvert, di simpang Jalan Kenanga, Kampung Batu 15, Hulu Langat.	51.106
B 1813	Di kiri Jalan Ampang - Hulu Langat. Di atas culvert, di simpang ke rumah kediaman (rumah batu berbumbung warna hijau), 1 km sebelum Pekan Batu 18 Hulu Langat.	59.49
B 1814	Di kiri Jalan Ampang - Hulu Langat. Di konkrit di hujong 'Jambatan Sungai Langat', di Pekan Batu 18 Hulu Langat.	65.633

Appendix D
Calculation

Seri Kembangan – Putrajaya route

Benchmark	ΔH	ΔH^2
B2014	0.091	0.008
B2016	0.120	0.014
B2017	0.078	0.006
B2019	0.197	0.039
B2022	0.032	0.001
B2032	0.120	0.014
B2033	0.015	0.000
B2036	0.099	0.010
B2037	0.126	0.016
B2038	0.122	0.015
B2039	0.072	0.005
B2041	0.028	0.001

Mean

$$= \frac{\sum \Delta H}{N}$$

$$= \frac{(0.091+0.120+0.078+0.197+0.032+0.120+0.015+0.099+0.126+0.122+0.072+0.028)}{12}$$

$$= 0.092m$$

Root Mean Square

$$= \sqrt{\frac{\sum \Delta H^2}{N}}$$

$$= \sqrt{\frac{(0.008+0.014+0.006+0.039+0.001+0.014+0.000+0.010+0.016+0.015+0.005+0.001)}{12}}$$

$$= 0.104m$$

Ampang – Hulu Langat Route

Benchmark	ΔH	ΔH^2
B0028	0.020	0.0004
B0029	0.055	0.0030
B0515	0.033	0.0011
B0516	0.040	0.0016
B1807	-0.039	0.0015
B1808	-0.084	0.0071
B1809	0.034	0.0012
B1810	0.012	0.0001
B1811	0.011	0.0001
B1813	-0.032	0.0010
B1814	0.027	0.0007

Mean

$$= \frac{\sum \Delta H}{N}$$

$$= \frac{0.020 + 0.055 + 0.033 + 0.040 + (-0.039) + (-0.084) + 0.034 + 0.012 + 0.011 + (-0.032) + 0.027}{11}$$

$$= 0.007m$$

Root Mean Square

$$= \sqrt{\frac{\sum \Delta H^2}{N}}$$

$$= \sqrt{\frac{(0.0004 + 0.0030 + 0.0011 + 0.0016 + 0.0015 + 0.0071 + 0.0012 + 0.0001 + 0.0001 + 0.0010 + 0.0007)}{11}}$$

$$= 0.040m$$