Assessment of Malaysian Active GPS Station (MASS) Data for Deformation Analysis of an Oil Platform

by

Nur Jasmin Bt Abdul Hakim (2810)

Dissertation submitted in partial fulfillment of
the requirements for the
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(Civil Engineering)

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Approved by,

(Dr. Abdul Nasir Matori)

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TRONOH, PERAK

June 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 contained herein have not been undertaken or done by unspecified sources or persons.

NUR JASMIN BINTI ABDUL HAKIM

ABSTRACT

Currently, Global Positioning System (GPS) is becoming more popular technique in surveying and other applications in Civil Engineering. The Project undertaken for the Final Year Project "Assessment of Malaysian Active GPS Station (MASS) Data for Deformation Analysis of an Oil Platform" is basically an analysis of the deformation for an oil platform using MASS as the reference stations for Global Positioning System (GPS) technique. The study is to compare the accuracy of using Malaysian Active GPS System (MASS) stations and other conventional reference stations for the deformation analysis of the oil platform. Deformation of an engineering structure is often measured in order to ensure that the structure is exhibiting safe deformation behavior. The availability of free GPS data from MASS station could promote the use of Global Positioning System (GPS) technique for application relevant in Civil engineering such as deformation monitoring for high rise structure, bridge, oil platform and dam, at a reduced cost. One of the PETRONAS Oil Platform, Pulai which is currently undergoing subsidence has been chosen for the analyses. Three field points in the platform, three conventional reference stations in the onshore and four MASS stations have been analyzed. The analysis has been done by using relevant GPS software which is GeoGenius. The accuracy using GPS data from conventional reference stations and MASS stations are almost the same. In future, existing MASS stations can be used as the reference stations instead of setting up new reference stations for GPS deformation analysis of any engineering structures at a reduced cost.

ACKNOWLEDGEMENT

The greatest thankfulness to Allah Almighty who gives me courage to complete this project. I would like to deeply express my gratitude to my supervisor, Dr. Abdul Nasir Matori who has constantly given the directions and advices throughout this study. Sincere thanks to Geodesy Section, Geodetic Survey Division, Department of Survey and Mapping, Malaysia (DSSM) and PETRONAS Carigali Sdn. Bhd. (PCSB) for providing the necessary data for this study. This study is not complete without these data. Heartfelt appreciation goes to the postgraduate students from Civil Engineering Department of Universiti Teknologi PETRONAS namely; Mr. Basith and Mr. Dedi for the help and advices regarding the use of software. I would to thank lecturers and staffs of Civil Engineering Department of Universiti Teknologi PETRONAS, for spending time to provide additional support and advice throughout this study. My special thankfulness also goes to my family for their encouragement and morale support especially to my parents namely; Hj. Abdul Hakim B Abu Bakar and Hjh. Jainambu Banu Bt. Ismail who always beside of me. To my beloved friends especially Mr. Mohamed Ali Abdullah, Ms. Syakirah Mohamed, Ms. Siti Farahah Hassan, and Ms. Norashikin Shawalluddin thank you for continuous support to me. Not forgetting those who directly or indirectly involved in making this project success. Thank You.

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CHAPTER 1: INTRODUCTION

1.1 Background of Study

The ever-increasing number of engineering structures has increased the needs for deformation measurement. Deformation of engineering structure is often measured in order to ensure that the structure is exhibiting a safe deformation behavior. Engineering structures are subject to deformation due to factors such as changes of ground water level, tidal phenomena, and tectonic phenomena [4].

Recently, Pulai Oil Platform located at Peninsular Malaysia Operation (PMO) undergoes settlement due to the crater formation underneath the platform. There is a need to determine the best and suitable technique and instrument that applicable to detect and analyze deformation with maximum efficiency. Therefore precise measurement is needed to determine the magnitude of deformation in order to counter the problem and to avoid any failure.

Deformation survey is one of the important activities in engineering surveying that can be beneficial to determine the magnitude and direction of such movements for the purpose of safety assessment and as well as preventing any disaster in the future. Their results are relevant to the safety of human life. The measurements techniques are generally divided into geodetic, geotechnical and structural methods. This project focuses on geometrical analysis of deformation using the Global Positioning System (GPS).

In this project, deformation of Pulai Oil Platform has been monitored using GPS positioning. Data collected from some reference stations that located in onshore of Pulai Platform have been analyzed and compared with the analysis using Malaysian Active GPS System (MASS) stations.

The availability of free GPS data from Malaysian Active GPS System (MASS) stations could promote the use of Global Positioning System (GPS) technique to detect certain magnitude of deformation at reduced cost and eliminate the need to build other new reference points or stations for the deformation analysis purpose.

1.2 Problem Statement

Deformation has become one of the main problems for any engineering structure such as bridges, high rise buildings, oil platforms, and dam. Deformation analysis is needed in order to investigate the movement or displacement on the structure which is due to some factors such as landslide, tectonic movements, differences in underground water level and others.

Deformation analysis needs more detail and careful observation in order to produce precise results. Therefore, the best and suitable techniques/instruments are needed to detect deformation on the structure. GPS Positioning technique could cater such requirement will be the static relative positioning. This will require setting up of few reference stations at certain location from the structure being monitored. The setting up of these reference stations would increase the cost in the form of man power, instruments, and time.

The availability of free GPS data from MASS station could promote the use of GPS technique for application relevant in Civil engineering such as deformation monitoring for high rise structure, bridge, oil platform, and dam, at a reduced cost by eliminating the need to build other new reference stations for the deformation analysis. However, the quality of MASS network stations may not be sufficient to perform deformation monitoring.

1.3 Objectives and Scope of Study

1.3.1 The relevancy of the Project

The objectives of the project:

1. To assess the quality (precision and integrity) of MASS data for GPS deformation studies for an Oil Platform.
2. To assess the configuration of GPS network for GPS deformation studies of an Oil Platform.
3. To compare the accuracy of the deformation analysis using MASS data and the data obtained from other reference stations.

1.3.2 Feasibility of the project within the scope and time frame

The feasibility of the project has been measured with respect to the time frame, scope of the work, and resource availability and ability to carry out the research/work. The feasibility study of the project is within the scope that is the study on deformation that exists for an oil platform that has be measured using free GPS data from MASS stations. The analysis is being done to determine the lower cost methods of using GPS to detect deformation of an oil platform. The free GPS data from MASS stations have been analyzed and compared with the data from the other conventional reference stations, if the deformation can be measured accurately using existing Malaysian Active GPS System (MASS) thus we can reduce the need to build other reference stations and hence reduced the cost and man power.

The overall scope of the project has been based on a span of 28 weeks (2 semesters). The project scope covers the literature study, experimental and data analysis within the time frame. Basically the project has been divided into three major execution phases:

1. Literature Review represents 20% of the project time allocation
2. Data Collection represents 40% of the project time allocation
3. Data Analysis represents 40% of the project time allocation

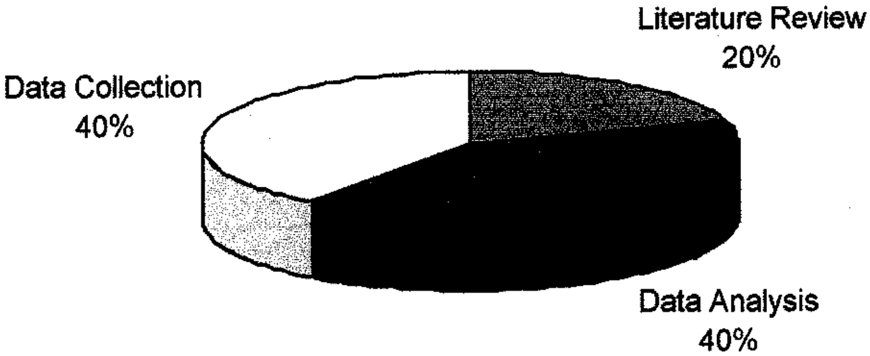

Figure 1: Time allocation in percentage for each phase of the project

The project is feasible to be conducted since the acquired GPS data of various MASS stations are available for distribution to the users for post processing application by the Geodesy Section, Geodetic Survey Division, Department of Survey and Mapping, Malaysia. The feasibility of the project was also based on the availability of the GPS software which is called as GeoGenius in laboratory that has been used for the data processing.

CHAPTER 2: LITERATURE REVIEW

2.1 Deformation

Deformation is one of the major problems that exist in any engineering structure such as high rise structure, bridge, oil platform and dam. These engineering structures can undergo deformation due to landslide, tectonic movement, differences in underground water level and many other factors [4]. Deformation can be defined as any displacement or movement occurred to the part or the whole body of the structure due to force or load applied of any engineering structure. Deformation of an engineering structure is often measured in order to ensure that the structure is exhibiting safe deformation behavior. It is important to measure this movements for the purpose of safety assessment and as well as preventing any disaster in the future.

The slope failures at NKVE (New Klang Valley Express lane) and Highway Bukit Lanjan, Gua Tempurung landslide, Highland Tower collapse, and road settlement along Genting Highlands roads are some tragedies that had shocked us resulted in lost of life due to deformation problem [5]. Figure below shows one of the tragedies due to deformation problem. Recently, one of the PETRONAS Oil and Gas Platform, Pulai Platform located at Peninsular Malaysia Operation (PMO) undergo settlement and this increased the need to determine the best and suitable technique to detect and analyze deformation with maximum efficiency at a reduced cost.

Figure 2: Settlement along Genting Roadway

2.2 Pulai Platform Subsidence

The settlement of Pulai Platform is affected by the crater formation surrounding and underneath the platform. The crater formation is due to continuous charging of shallow gas or bubble gas to shallower soil layer affect soil behavior and platform foundation. In this context, shallow gas is referred as those gases either hydrocarbon or biogenic gas. It migrated or charged from deeper source or reservoir into shallower sediments.

Platform subsidence is not a new phenomenon in oil and gas industry. Other example of this kind of subsidence is the settlement of Duyong Platform, PETRONAS oil and gas platform located at PMO.

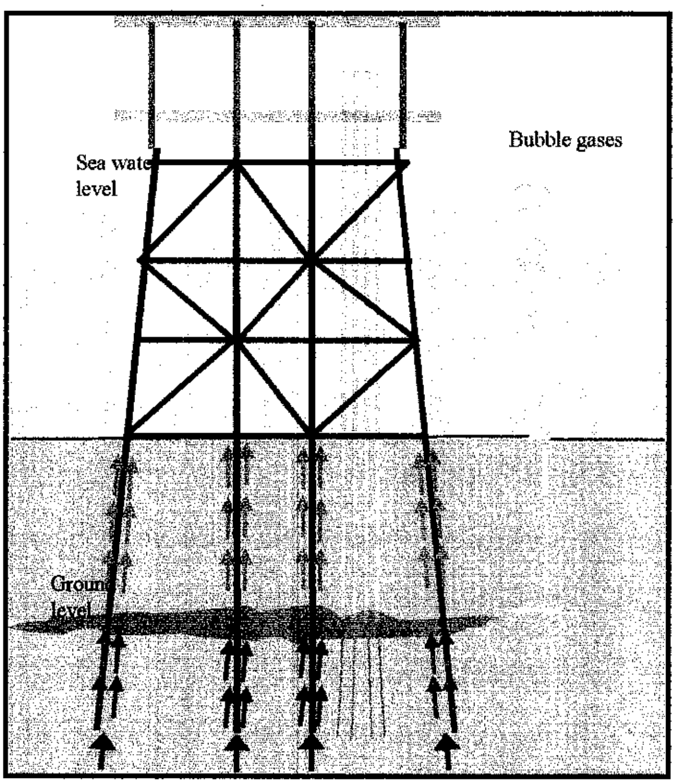

Figure 3: Formation of Bubble Gases

2.3 Deformation Analysis

Deformation measurement techniques generally can be divided into geotechnical, structural and geodetic methods [2]. In this project, the technique that will be used is geodetic which is using GPS [8].

GPS survey techniques can be used to monitor the motion of points on a structure relative to stable monuments. This can be done with an array of antennas positioned at selected points on the structure and on remote stable and fix monuments [3]. Measurements can be made on a continuous basis. A GPS structural deformation system can be operating unattended and is relatively easily installed and maintained.

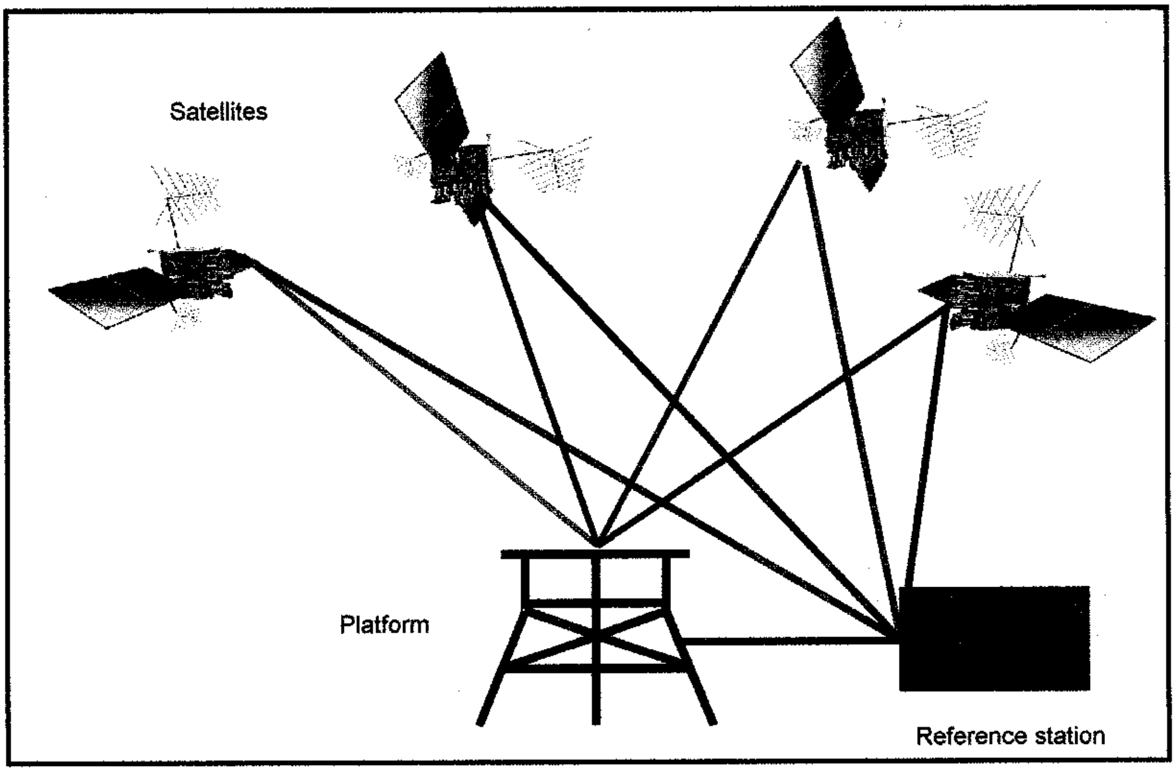

Figure 4: Point on Structure Relative to Fix Point

2.4 Global Positioning System (GPS)

GPS is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by U.S. Department of Defense [2]. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day.

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time when a signal was transmitted by a satellite with the time it was received. The time difference let the GPS receiver detect the how far the satellite is located.

Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map [1]. A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude, and altitude).

The first and most obvious application of GPS is the simple determination of a position or location. GPS is the first positioning system to offer highly precise location data for any point on the planet. Knowing the precise location of something is especially critical when the consequences of inaccurate data are measured in human terms. GPS uses reference points to calculate positions accurate to a matter of meters. In fact, with advanced forms of GPS enable to make measurements in smaller units [1].

GPS coordinates are provided in the earth-centered, earth-fixed coordinate system defined by the GPS satellite ephemeredes (the WGS84 system when the broadcast ephemeris is used). Results may need to be transformed into a local geodetic system before they can be integrated with results from conventional surveys. GPS results are, in general, more accurate than the surrounding control marks established by terrestrial techniques over time.

2.5 Malaysian Active GPS System (MASS)

The Malaysian Active GPS System (MASS) is a network of GPS Permanent Stations established throughout the whole country. The stations automatically record and archive data from available GPS satellites for accurate position determination 24 hours a day [7]. MASS will provide code range and carrier phase data in support of post processing applications. The acquired GPS data is available for distribution to the public by the Geodesy Section, Geodetic Survey Division, Department of Survey and Mapping, Malaysia (DSSM) [6].

Eighteen (18) MASS Sites have been established at selected sites as in *Table 2*. Each permanent GPS Stations consists of a TRIMBLE 4000 Series (SSI or SSE) dual frequency receiver, antenna and TRIMBLE Universal Reference Station (URS) software operating on the Windows NT System platform [7]. All stations are tied to local geodetic survey networks to a high degree of accuracy.

The location of 18 MASS stations is being shown in *Figure 5*. The network is remotely operated and managed from the Geodetic Data Processing Centre, Geodesy Section, Kuala Lumpur (GDPC). The full range of GPS observables are recorded and made available for 14 days over the internet, after which the data are archived. The archived data can be made available to users on special request and is offered for distribution on most available storage mediums and in the format of RINEX.

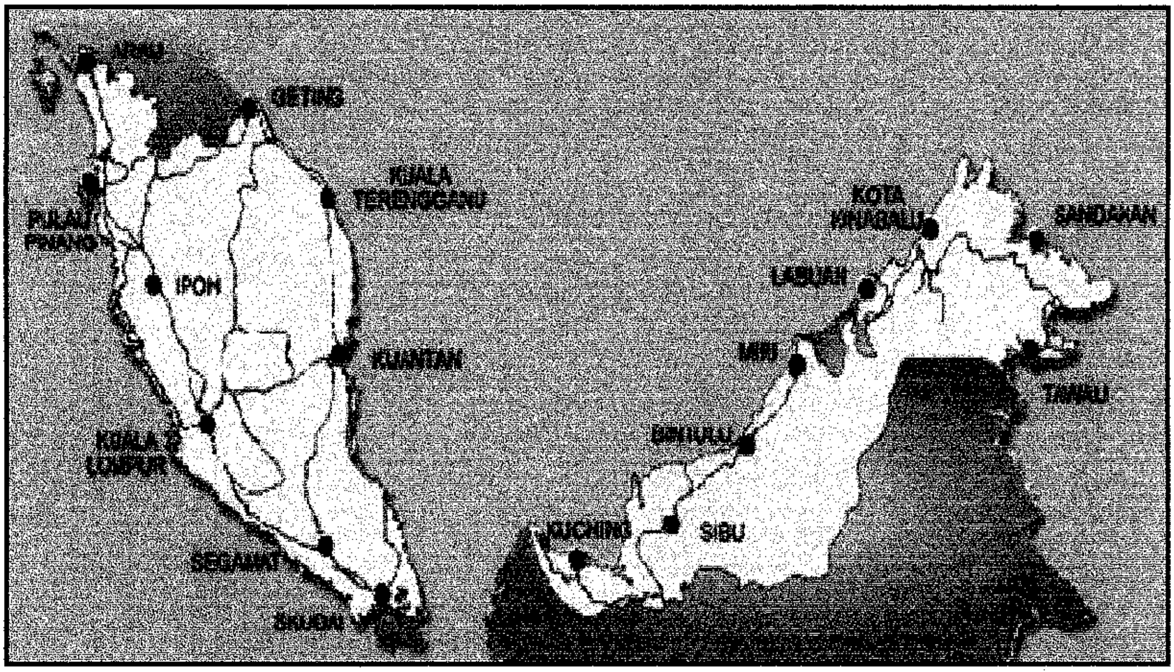

Figure 5: MASS Network

CHAPTER 3: METHODOLOGY

3.1 Project Process Flow

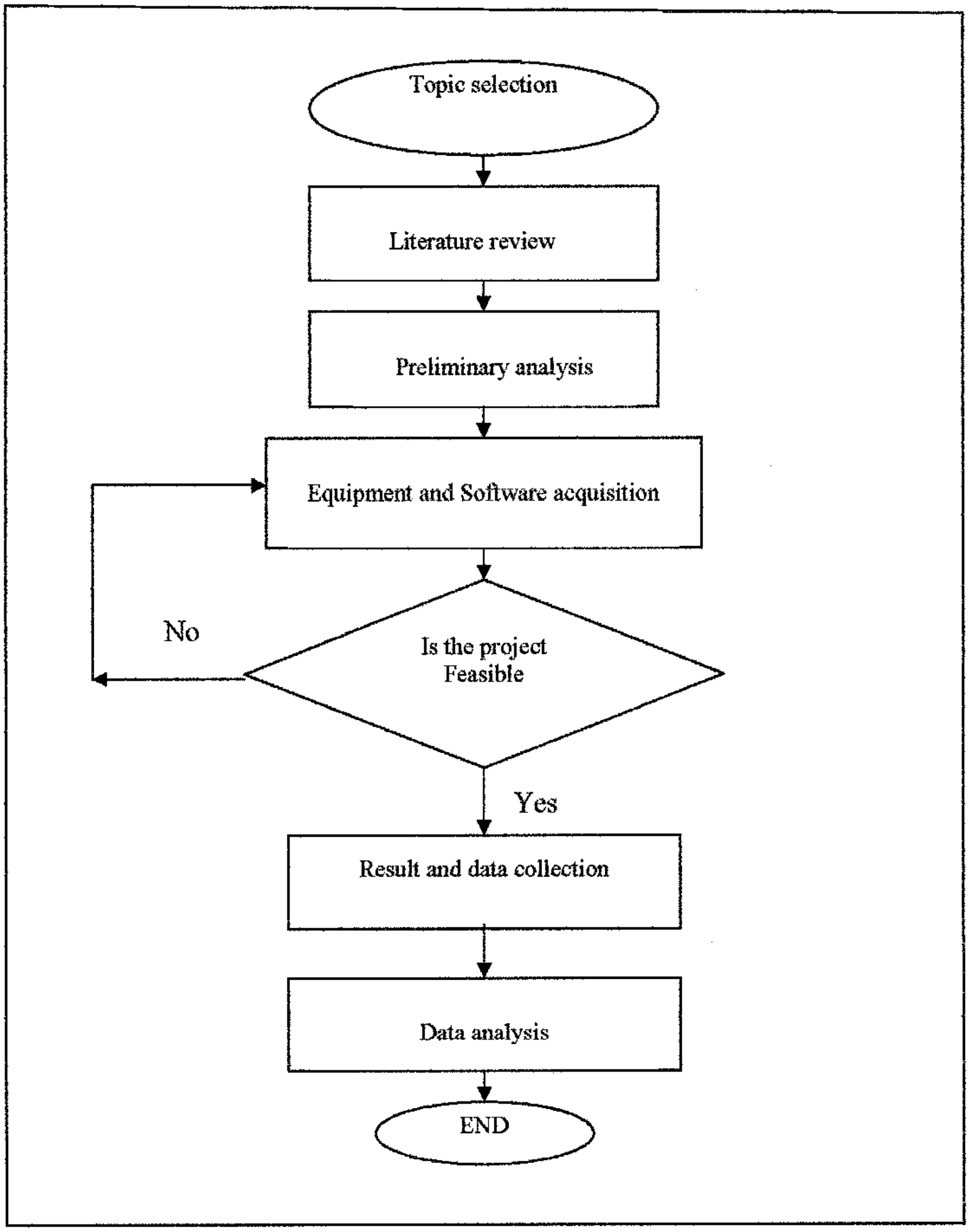

Figure 6: Flow Chart of the Project

3.2 Network Design

Pulai platform is located in Peninsular Malaysia Operation (PMO). Three (3) points on the platform have been chosen for the purpose of analysis. The conventional reference stations that have been set up by request from PETRONAS and located in onshore of the platform, which are in Beserah, Kuala Terengganu, and Rantau Panjang. Coordinates of conventional reference station are shown in *Table 1* below:

Table 1: Conventional Reference Stations Coordinates

No.	Location	Station	Latitude (N)	Longitude (E)	Ell. Height (m)
1	Rantau Panjang	P249	6° 00' 28.83241"	101° 59' 02.01683"	2.387
2	Kuala Terengganu	P232	5° 22' 47.66211"	103° 06' 15.09330"	3.896
3	Beserah	GP34	3° 51' 33.60129"	103° 21' 54.87239"	7.782

For the purpose of this project, four (4) MASS Stations have been chosen for the analyses which are;

1. Miri, Sarawak
2. Tanjung Dumpil, Kota Kinabalu, Sabah
3. Universiti Teknologi Malaysia, Skudai, Johor
4. Institut Tanah dan Ukur Negara, Tanjung Malim, Perak

The coordinates of those stations can be referred in *Table 2* below.

Table 2: MASS Stations Coordinates

No.	Location	Station Id	Latitude (N)	Longitude (E)	Ell. Height (m)	Ref.
1.	Department of Survey and Mapping, Pahang	KUAN	3° 50' 03.80583"	103° 21' 01.23479"	24.883	PPGN93
2.	Tide Station, Bintulu Port, Bintulu, Sarawak	BINT	3° 15' 41.44769"	113° 04' 01.99648"	48.824	EMGN97
3.	**Tanjung Dumpil, Kota Kinabalu, Sabah**	**KINA**	**5°54' 16.59963"**	**116° 02' 21.47404"**	**51.857**	**EMGN97**
4.	Institut Teknologi Mara, Arau, Perlis	ARAU	6° 27' 00.61655"	100° 16' 47.01709"	17.782	PPGN93
5.	KTPK, Wisma Tanah, Kuala Lumpur	KTPK	3° 10' 15.44112"	101° 43' 03.35363"	99.267	PPGN93
6.	Politeknik Kuching, Sarawak	KUCH	1° 37' 56.65751"	110° 11' 42.33220"	79.435	EMGN97
7.	Bukit Pak Apil, Terengganu	KUAL	5° 19' 08.04746"	103° 08' 20.88834"	54.495	PPGN93
8.	Geting, Kelantan	GETI	6° 13' 34.33833"	102° 06' 19.62910"	-0.946	PPGN93
9.	**Miri, Sarawak**	**MIRI**	**4° 22' 19.58696"**	**114°0 8' 06.27526"**	**62.473**	**EMGN97**
10.	Labuan	LABU	5° 16' 57.64012"	115° 14' 41.23437"	49.838	EMGN97
11.	**Universiti Teknologi Malaysia, Skudai Johor**	**UTMJ**	**1° 33' 56.97424"**	**103° 38' 22.39800"**	**79.811**	**PPGN93**
12.	Politeknik Ungku Omar, Ipoh, Perak	IPOH	4° 35' 18.54071"	101° 07' 34.19882"	41.322	PPGN93
13.	Jalan Istana, Sandakan, Sabah	SAND	5° 50' 32.67999"	118° 07' 14.10412"	133.603	EMGN97
14.	Tawau, Sabah	TAWA	4° 15' 46.01271"	117° 52' 53.93362"	72.038	EMGN97
15.	Universiti Sains Malaysia, Penang	USMP	5° 21' 28.08195"	100° 18' 14.49779"	19.465	PPGN93
16.	Institut Teknologi MARA, Kampus Johor, Batu 8, Jln Muar, 85200 Jementah Segamat, Johor.	SEGA	2° 29' 10.67068"	102° 43' 55.34908"	25.152	PPGN93
17.	Jabatan Kerja Raya bahagian Sibu, Sarawak.	SIBU	2° 16' 12.13418"	111° 50' 33.96153"	46.640	EMGN97
18.	**Institut Tanah dan Ukur Negara(INSTUN) 35910 Tanjung Malim, Perak.**	**BEHR**	3° 45' 55.33344"	101° 31' 1.96370"	**68.690**	**PPGN93**

Figure 7 below shows the location for all the stations:

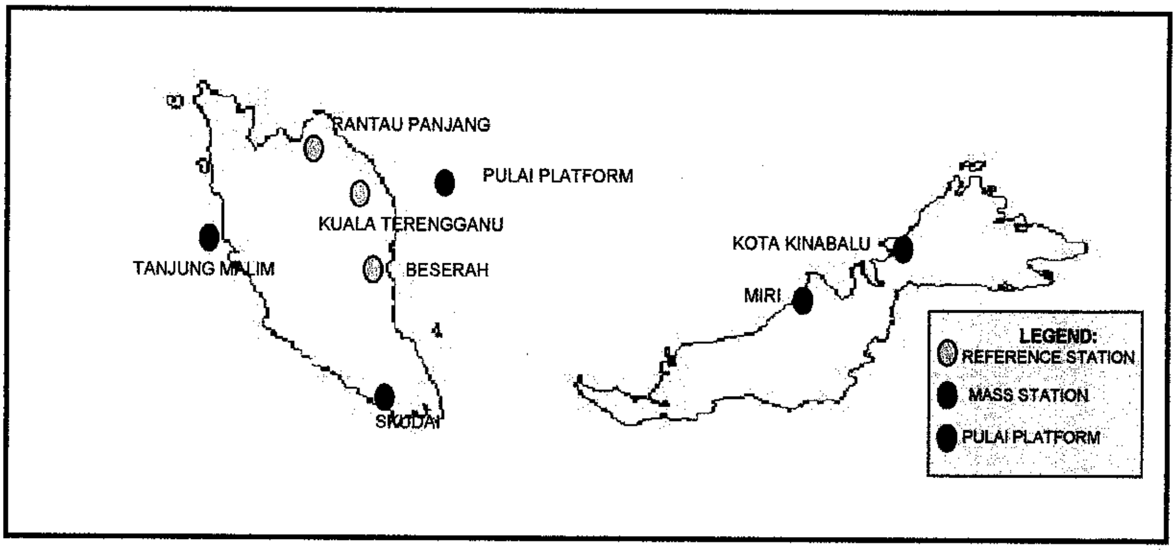

Figure 7: Location of all Stations

The following table summaries all stations that involved in the analysis.

Table 3: List of Stations

Station	Location	Station Description
P 232	Kuala Terengganu	Primary GPS station – onshore
P249	Rantau Panjang	Primary GPS Station - onshore
GP34	Beserah	Primary GPS Station - onshore
BEHR	Tanjung Malim	Malaysian Active GPS System (MASS) station - onshore
MIRI	Miri	Malaysian Active GPS System (MASS) station - onshore
KINA	Kota Kinabalu	Malaysian Active GPS System (MASS) station - onshore
UTMJ	UTM Skudai	Malaysian Active GPS System (MASS) station - onshore
PUA1	Pulai A Platform	Observation station – offshore
PUA2	Pulai A Platfrom	Observation station – offshore
PUA3	Pulai A Platfrom	Observation station – offshore

Diagram of the GPS observation network is shown in *figure 8* and *9* below:

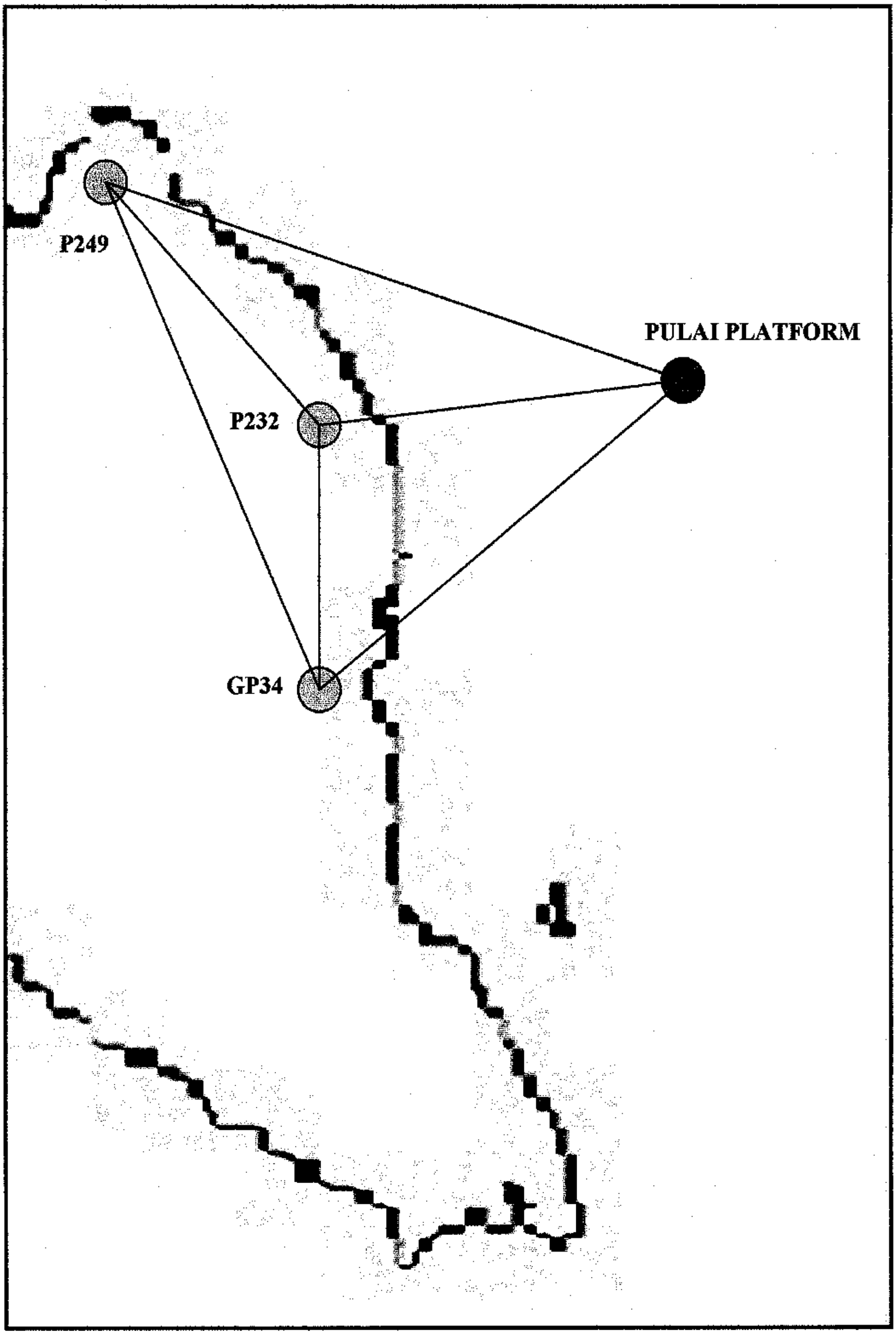

Figure 8: Network view using Conventional Reference Station

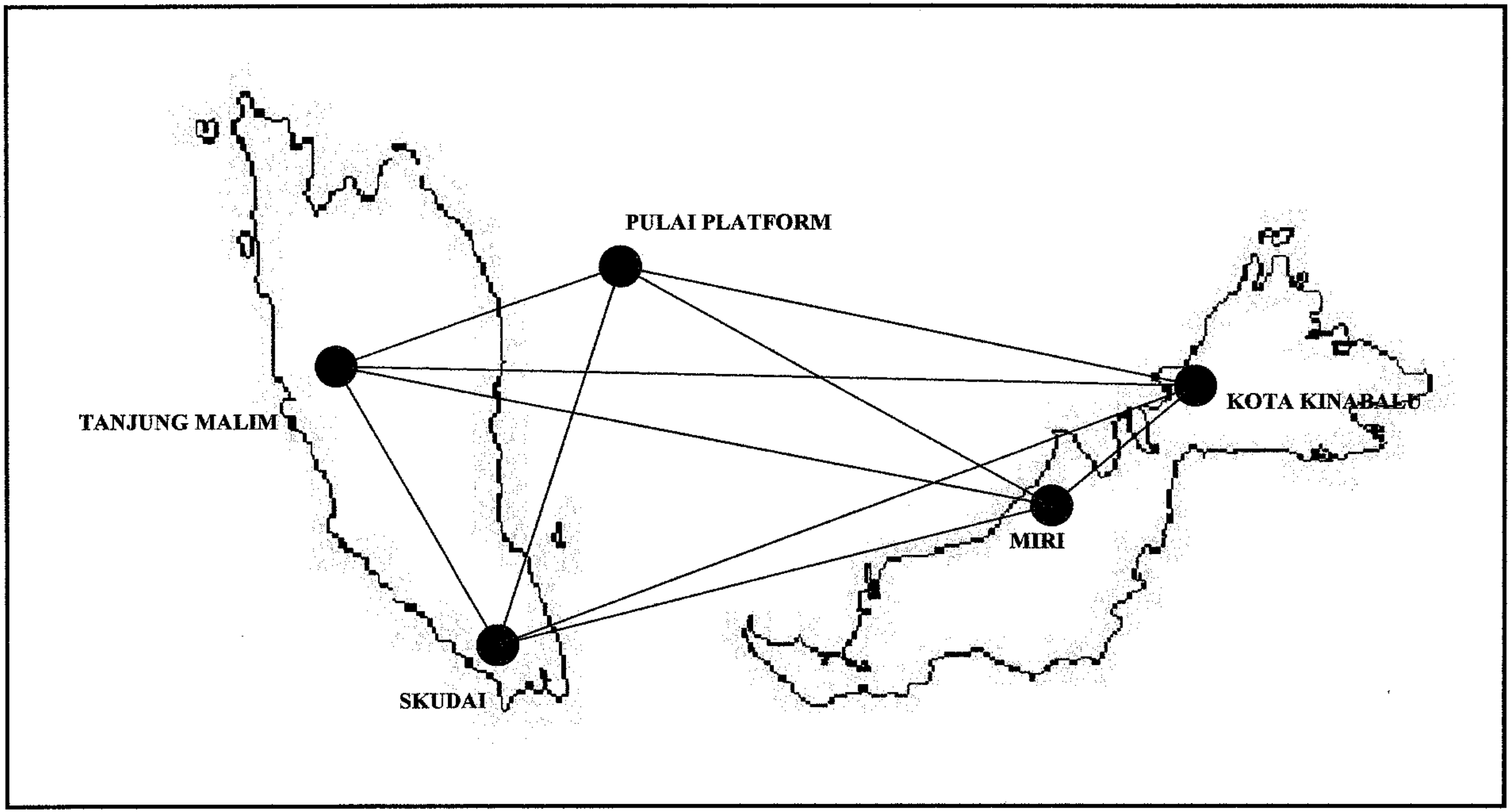

Figure 9: Network View using MASS Station

3.3 Data Collection

The deformation analysis for Pulai Platform was being done for 3 months which are July-September 2003. Below is duration of the analysis in terms of GPS calendar.

- July – June 26, 2003 until July 10, 2003 (177 until 191)
- August – August 6, 2003 until August 15, 2003 (218-227)
- September – September 3, 2003 until September 13, 2003 (246-255)

Four (4) MASS Stations have been chosen for the analysis. The acquired GPS Data from the chose MASS Stations have been obtained from Geodetic Data Processing Centre, Geodesy Section, Kuala Lumpur (GDPC). The selection of the MASS Stations was based on the availability of the data for the duration of the deformation analysis as mentioned earlier.

The GPS data for the other three reference stations which are located in Kuala Terengganu, Beserah, and Rantau Panjang and also for Pulai platform have been obtained from Dr. Abdul Nasir Matori, supervisor of the project. All the obtained data are in RINEX format including MASS data.

The availability of all the data can be referred in Appendix A.

3.4 Data Processing Software

The obtained GPS data for Pulai Platform, reference stations, and MASS Stations was being used for the analysis using GPS software which is GeoGenius. This is commercial software that available in UTP laboratory. The author has used this software throughout the project in order to process all the raw data involved in the analysis.

3.5 Data Processing Strategy

GPS Data that obtained for Pulai Platform, three reference stations, and four MASS stations were in RINEX format. After the data collection, a preliminary data processing was undertaken to obtain a preliminary result. After getting the precise ephemeredes data downloaded via internet, a post processing data was continued. The post processing was carried out using the same software in order to increase the precision of the result.

Basically the processing procedure has been done for two (2) network designs which are analysis using GPS data from conventional reference stations and another one using MASS stations data as shown in *figure 8* and *9*. Figures below show the network view of both designs using the GeoGenius Software. All the baselines involved in the network view have been processed.

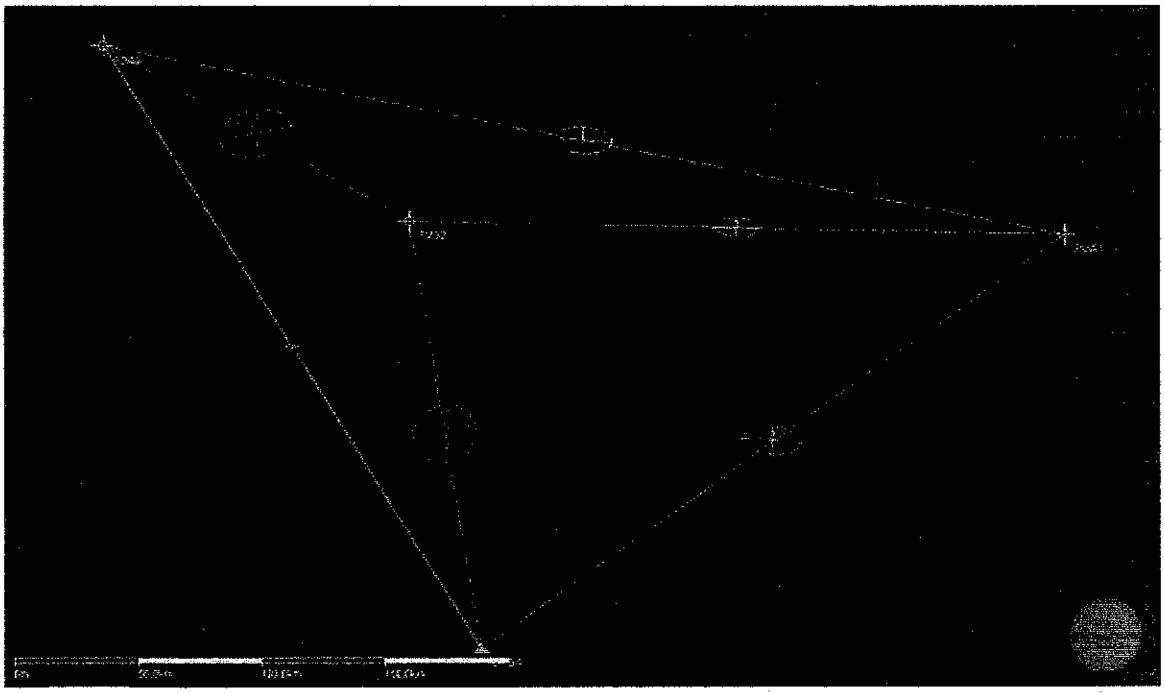

Figure 10: Network View for the Analysis using Conventional Reference Stations

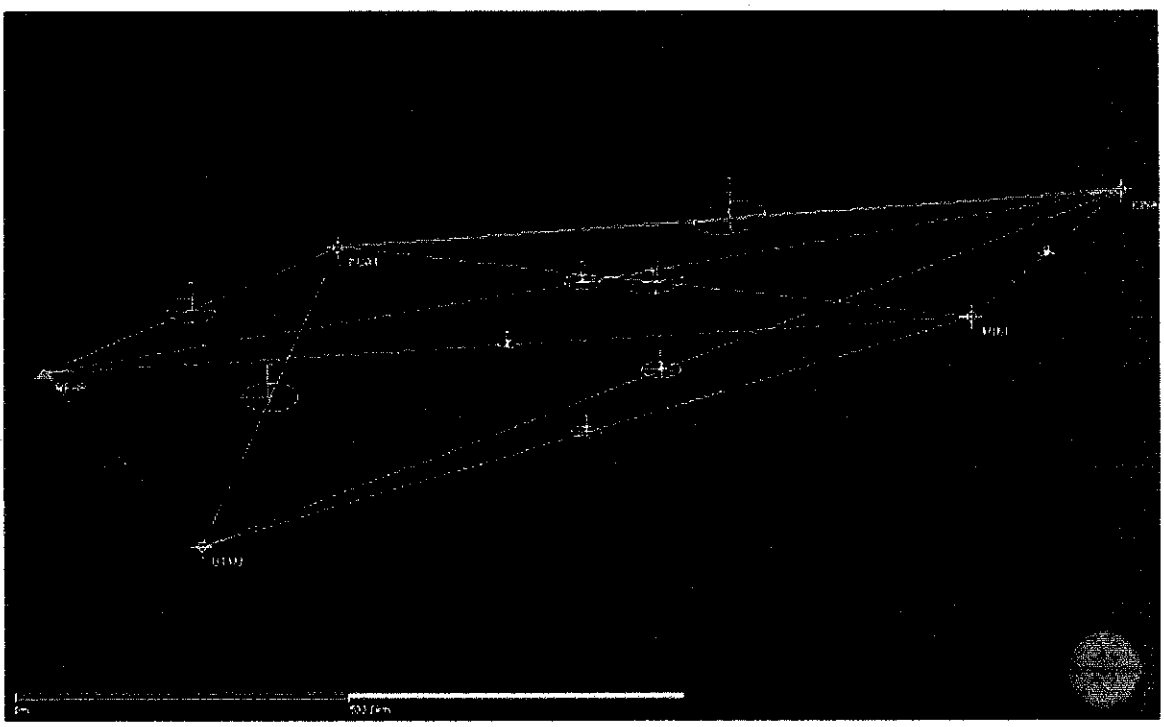

Figure 11: Network View for the Analysis using MASS Stations

CHAPTER 4: RESULT AND DISCUSSION

4.1 Result

The deformation analysis should be for 3 months; July – September 2003. The author has chosen 1 day from each month which is having complete data for Pulai Platform, Reference Stations, and MASS Stations. Basically data processing using Broadcast ephemeredes and precise ephemeredes has been carried out.

Below are result obtained from the basic data processing: -

<u>7th July 2003 (188)</u>

1. Deformation analysis of Pulai platform using GPS data from three (3) conventional reference stations

Table 4: Coordinates of Pulai Platform using conventional reference station for July - 188

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 19 446.00110	549 800.12875	42.8373	11.0	15.7	20.8
Pulai Platform (PUA2)	5 19 423.87725	549 785.002314	42.6973	10.5	6.8	5.4
Pulai Platform (PUA3)	5 19 448.23175	549 812.26879	43.3002	1.9	6.7	4.6

2. Deformation analysis of Pulai platform using GPS data from four (4) MASS Stations

Table 5: Coordinates Pulai Platforms using MASS station for July - 188

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 19 431.92360	5 46 333.85240	42.3471	4.0	14.6	7.9
Pulai Platform (PUA2)	5 19 410.85421	5 46 313.10234	42.1112	4.6	16.6	9.2
Pulai Platform (PUA3)	5 19 440.92360	5 46 745.21000	42.8752	2.7	6.2	5.8

12th August 2003 (224)

1. Deformation analysis of Pulai platform using GPS data from three (3) conventional reference stations

Table 6: Coordinates of Pulai Platform using conventional reference station for August - 224

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 19 446.02547	549 800.12754	42.5384	1.8	4.1	3.0
Pulai Platform (PUA2)	5 19 423.87654	549 785.002312	42.3941	1.5	4.2	2.7
Pulai Platform (PUA3)	5 19 448.23184	549 812.26798	43.0187	1.8	4.0	2.8

2. Deformation analysis of Pulai platform using GPS data from four (4) MASS Stations

Table 7: Coordinates of stations using MASS station for August - 224

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 19 431.923112	5 46 333.852475	41.7567	4.1	8.7	6.2
Pulai Platform (PUA2)	5 19 410.854104	5 46 313.10235	41.8215	1.3	2.9	1.5
Pulai Platform (PUA3)	5 19 440.92356	5 46 745.20008	42.5642	3.9	9.7	6.6

12th September 2003 (255)

1. Deformation analysis of Pulai platform using GPS data from three (3) conventional reference stations

Table 8: Coordinates of Pulai Platform using conventional reference station for September - 255

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 19 446.02542	549 800.127632	42.2124	5.9	8.3	17.2
Pulai Platform (PUA2)	5 19 423.87631	549 785.002227	42.0985	6.4	9.5	19.9
Pulai Platform (PUA3)	5 19 448.23654	549 812.26752	42.7225	2.4	3.5	1.9

2. Deformation analysis of Pulai platform using GPS data from four (4) MASS Stations

Table 9: Coordinates of stations using MASS station for September - 255

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 19 431.923109	5 46 333.852468	41.4567	5.0	10.6	8.4
Pulai Platform (PUA2)	5 19 410.854001	5 46 313.102219	41.5421	1.0	2.6	1.4
Pulai Platform (PUA3)	5 19 440.923112	5 46 745.200456	42.2457	5.1	11.8	9.0

After the basic data processing, the author has continued the procedure using precise ephemeredes which is IGS data. These data have been downloaded via internet accordingly to match the date of the analysis for each month.

The IGS global system of satellite tracking stations, Data Centers, and Analysis Centers puts high-quality GPS data and data products on line in near real time to meet the objectives of a wide range of scientific and engineering applications and studies.

The IGS collects, archives, and distributes GPS observation data sets of sufficient accuracy to satisfy the objectives of a wide range of applications and experimentation. These data sets are used by the IGS to generate the data products mentioned above which are made available to interested users through the Internet. In particular, the accuracies of IGS products are sufficient for the improvement and extension of the monitoring of solid Earth deformations.

The purpose of using this data fro the processing is to improve the precision of the result. Below are the result using precise ephemeredes and represent the final result and analysis of the subsidence on Pulai Platform.

7th July 2003 (188)

1. Deformation analysis of Pulai platform using GPS data from three (3) conventional reference stations and IGS Data (precise ephemeredes).

Table 10: Coordinates of Pulai Platform using conventional reference station and precise ephemeredes for July - 188

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 49 446.00110	567 845.01235	44.7577	1.9	6.7	5.8
Pulai Platform (PUA2)	5 49 446.84521	567 845.24587	42.6973	12.7	7.5	6.4
Pulai Platform (PUA3)	5 49 446.42513	567 845.26879	44.8002	1.8	7.8	4.3

2. Deformation analysis of Pulai platform using GPS data from four (4) MASS Stations

Table 11: Coordinates Pulai Platforms using MASS station and precise ephemeredes for July - 188

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 49 441.00008	545 856.01540	44.2547	4.2	17.2	9.1
Pulai Platform (PUA2)	5 49 441.84354	545 855.99877	42.1947	8.7	10.3	2.0
Pulai Platform (PUA3)	5 49 441.10005	545 856.12569	44.3000	1.2	6.8	4.9

12th August 2003 (224)

1. Deformation analysis of Pulai platform using GPS data from three (3) conventional reference stations

Table 12: Coordinates of Pulai Platform using conventional reference station and precise ephemeredes for August - 224

Stations	Coordinates (m)			Sigmas (mm)		
Name	**Northing**	**Easting**	**Height**	**s(N)**	**s(E)**	**s(H)**
Pulai Platform (PUA1)	5 49 446.00235	567 845.01235	44.6021	1.1	9.5	4.5
Pulai Platform (PUA2)	5 49 446.84524	567 845.24565	42.5475	3.5	2.3	6.3
Pulai Platform (PUA3)	5 49 446.42454	567 845.26657	44.6547	11.8	6.2	8.0

2. Deformation analysis of Pulai platform using GPS data from four (4) MASS Stations

Table 13: Coordinates of stations using MASS station and precise ephemeredes for August - 224

Stations	Coordinates (m)			Sigmas (mm)		
Name	**Northing**	**Easting**	**Height**	**s(N)**	**s(E)**	**s(H)**
Pulai Platform (PUA1)	5 49 441.122121	545 856.01524	44.1085	6.3	6.5	9.9
Pulai Platform (PUA2)	5 49 441.84321	545 855.99853	42.0312	1.2	5.2	5.4
Pulai Platform (PUA3)	5 49 440.99987	545 856.12554	44.1523	15.0	6.7	12.7

12th September 2003 (255)

1. Deformation analysis of Pulai platform using GPS data from three (3) conventional reference stations

Table 14: Coordinates of Pulai Platform using conventional reference station and precise ephemeredes for September - 255

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 49 446.00221	567 845.01212	44.4529	2.1	10.5	5.6
Pulai Platform (PUA2)	5 49 446.84498	567 845.24527	42.3897	5.8	15.4	7.9
Pulai Platform (PUA3)	5 49 446.42397	567 845.2564	44.5054	1.5	3.4	8.4

2. Deformation analysis of Pulai platform using GPS data from four (4) MASS Stations

Table 15: Coordinates of stations using MASS station and precise ephemeredes for September - 255

Stations	Coordinates (m)			Sigmas (mm)		
Name	Northing	Easting	Height	s(N)	s(E)	s(H)
Pulai Platform (PUA1)	5 49 441.122035	545 856.01514	43.9564	8.4	1.3	1.5
Pulai Platform (PUA2)	5 49 441.84318	545 855.99834	41.8712	1.4	6.8	3.4
Pulai Platform (PUA3)	5 49 440.99020	545 856.12535	44.0014	18.7	9.1	3.6

4.2 Discussion

Results from the above tables indicated a movement on the Pulai Platform from July to September 2003. Generally all three (3) stations on Pulai Platform; namely PUA1, PUA2, and PUA3 have shown a subsidence movement about 15cm per every month.

The following charts represent the comparison of analysis on Pulai Platform using conventional reference stations and MASS stations

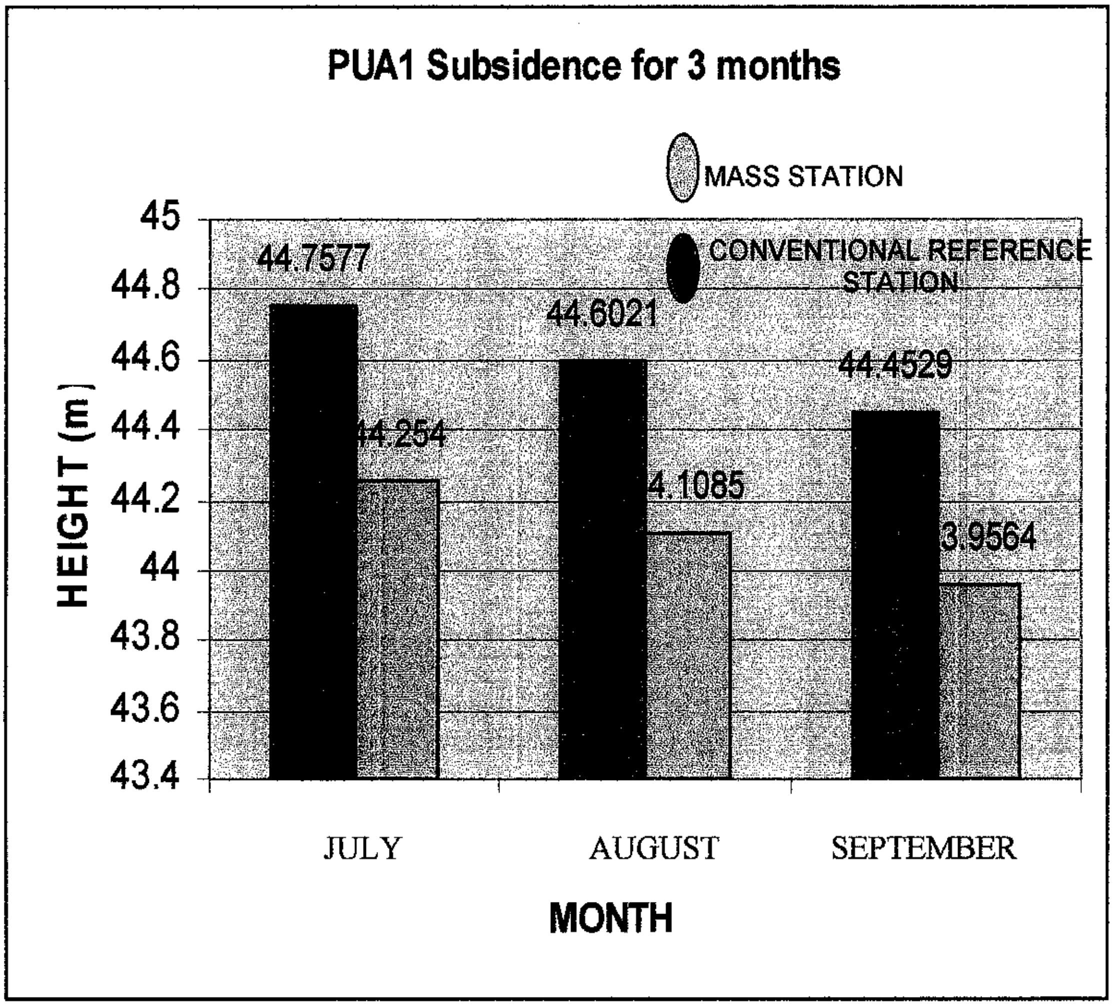

Figure 12: Subsidence of PUA1 for 3months

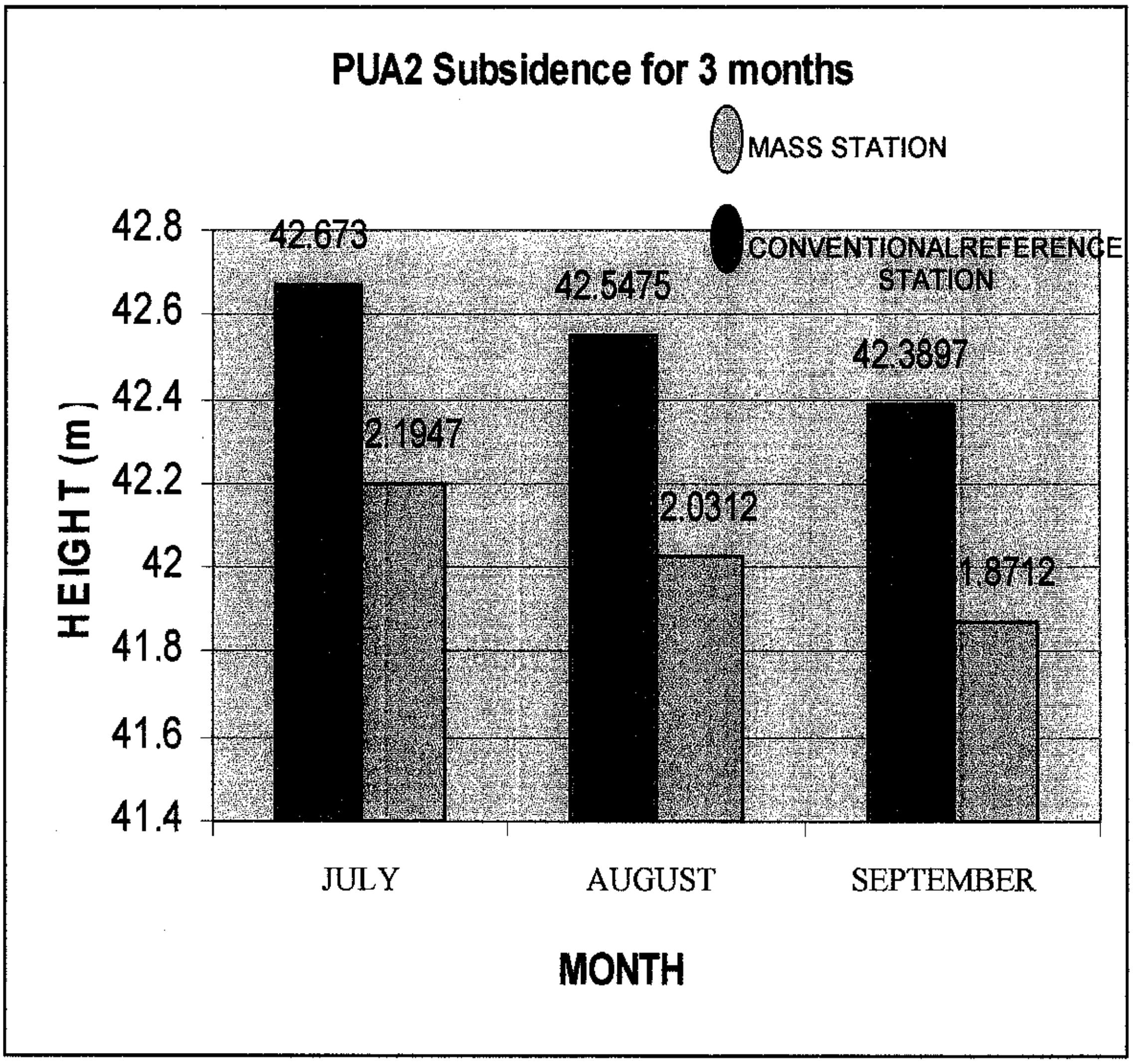

Figure 13: Subsidence of PUA2 for 3months

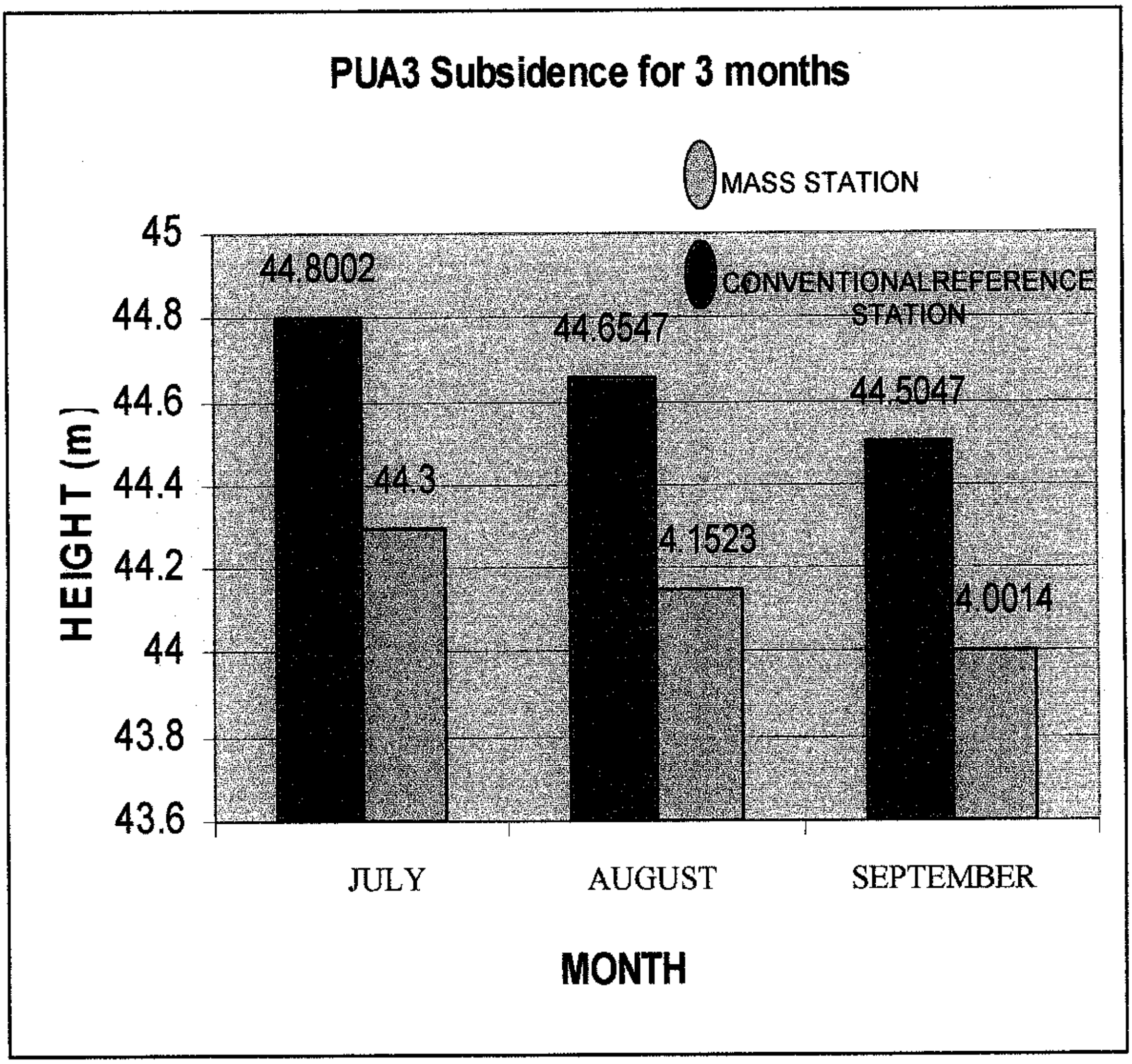

Figure 14: Subsidence of PUA3 for 3months

The accuracy of the subsidence analysis for Pulai Platform using conventional reference stations and MASS stations is almost the same as can be seen from the pattern of the charts above. For both stations, the subsidence determination is almost the same which is about 15cm every month.

The result of the coordinates for Pulai Platform is slightly different for both using conventional reference station and MASS stations. This is because using MASS stations; the network is having greater baselines, so posses to greater errors. These errors can be reduced by doing more high precision data processing technique.

For this project, the author has used only basic data processing, and another further using precise ephemeredes. This is because of the time frame and also the knowledge and skills limitation. The author managed to get the result eventhough facing some problems during the data processing procedure. One of the problems is while doing the familiarization of the software; the author has experienced difficulty to learn new software from beginning stage.

While using precise ephemeredes, all computation are undertaken in stages that comprise the precise orbit of the GPS satellites from the IGS global data set and then estimating the position of Pulai Platform of offshore Terengganu, Peninsular Malaysia.

Since the accuracy of the deformation analysis for Pulai Platform using GPS data from conventional reference stations and MASS stations almost the same, thus in future; the setting up of new reference stations for the deformation analysis of any engineering structures can be eliminated. Usage of MASS stations as the reference stations can be very useful to analyze deformation at a reduced cost in terms of monetary and manpower.

CHAPTER 5: CONCLUSION

5.1 Conclusion

Basically, the project has been completed within the time allocated, scope of the project, resources availability, and the ability to conduct the project.

The quality of the MASS data for GPS deformation analysis has been assessed. MASS data is having a good precision and integrity, but the authority still need to maintain and improve the development of this Malaysian Active GPS System (MASS) in order to increase the precision. MASS stations can act as a reference point and provide data for measurements in the relative mode for application such as deformation monitoring.

In order to assess the quality of this MASS, the author has chosen a real structure to be analyzed which is PETRONAS Pulai Platform in offshore Terengganu, Peninsular Malaysia. Pulai platform currently undergoes subsidence. GPS network for the deformation analysis of Pulai Platform has been assessed using two different type of reference station; which are conventional reference stations that have been set up by PETRONAS previously and MASS stations which are already existed and established by Geodesy Section, Geodetic Survey Division, Department of Survey and Mapping, Malaysia (DSSM).

Both type of stations show the same pattern on the Pulai Platform subsidence. Pulai Platform is determined to have about 15cm of subsidence per month within the duration of the analysis.

The accuracy of deformation analysis using MASS data and the data obtained from the conventional reference stations is almost the same. In future, the setting up of new conventional reference stations for the deformation monitoring can be eliminated since setting up this station requires most cost. MASS stations can be used as the reference stations for deformation monitoring for any engineering structures at a reduced cost in terms of monetary and manpower.

5.2 Recommendation

In order to strengthen the network solutions, it is necessary to include more adjacent MASS stations in future survey, it means a better result could be achieved by increasing the number of reference station.

Department of Survey and Mapping, Malaysia (DSSM) has to maintain and improve the development and establishment of MASS in order to provide more precise data, to be used for any engineering application such as deformation monitoring.

Since using MASS, the analysis will deal with longer baselines network which posses to greater errors, high precision GPS processing technique is required for more accurate and precise result. The analysis could be furthered using more techniques in modeling and removing of errors in phase measurements and ambiguity resolution. Better GPS software system required to improve the accuracy of the solutions.

In future, MASS stations can be used as a reference stations for GPS deformation monitoring of any engineering structures at a reduced cost.

REFERENCES

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3. American Society of Civil Engineers, *"Navstar Global Positioning System Surveying"*, 2nd edition, ASCE Press.
4. www.gmat.unsw.edu
5. www.sciencedirect.com
6. www.jupem.gov.my
7. GIS Bulletin, *"Malaysian Active GPS System (MASS) Project"*, May 2000, Department of Survey, and Mapping Malaysia (DSMM).
8. Ukur Bulletin, *"Functional and Stochastic Models for Geometrical Detection of Deformation in Engineering"*, Jun 1995.

APPENDIX A

DATA AVAILABILITY

Appendix A.1: Data Availability for July

STATIONS / DATE		177	178	179	180	181	182	183	184	185	186	187	188	189	190	191
Pulai Platform	Pulai (PUA1)							√	√	√			√			
	Pulai (PUA2)										√	√	√	√		
	Pulai (PUA3)												√	√	√	√
Reference Stations	Beserah (GP34)	√	√	√	√											
	Kuala Terengganu (P232)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
	Rantau Panjang (P249)			√	√	√	√	√	√	√	√	√	√	√	√	√
MASS Stations	Kota Kinabalu (KINA)			√	√	√	√	√	√	√	√	√	√	√	√	√
	Miri (MIRI)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	UTM Skudai (UTMJ)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	INSTUN Tanjung Malim (BEHR)			√	√	√	√	√	√	√	√	√	√	√	√	√

Appendix A.2: Data Availability for August

STATIONS / DATE		218	219	220	221	222	223	224	225	226	227
Pulai Platform	Pulai (PUA1)		√	√	√	√	√	√			
	Pulai (PUA2)							√	√	√	
	Pulai (PUA3)				√	√	√	√	√	√	
Reference Stations	Beserah (GP34)	√	√	√	√	√	√	√	√	√	√
	Kuala Terengganu (P232)	√	√	√	√	√	√	√	√	√	√
	Rantau Panjang (P249)	√	√	√	√	√	√	√	√	√	√
MASS Stations	Kota Kinabalu (KINA)			√	√	√	√	√	√	√	√
	Miri (MIRI)	√	√	√	√	√	√	√	√	√	√
	UTM Skudai (UTMJ)	√	√	√	√	√	√	√	√	√	√
	INSTUN Tanjung Malim (BEHR)	√	√	√	√	√	√	√	√	√	√

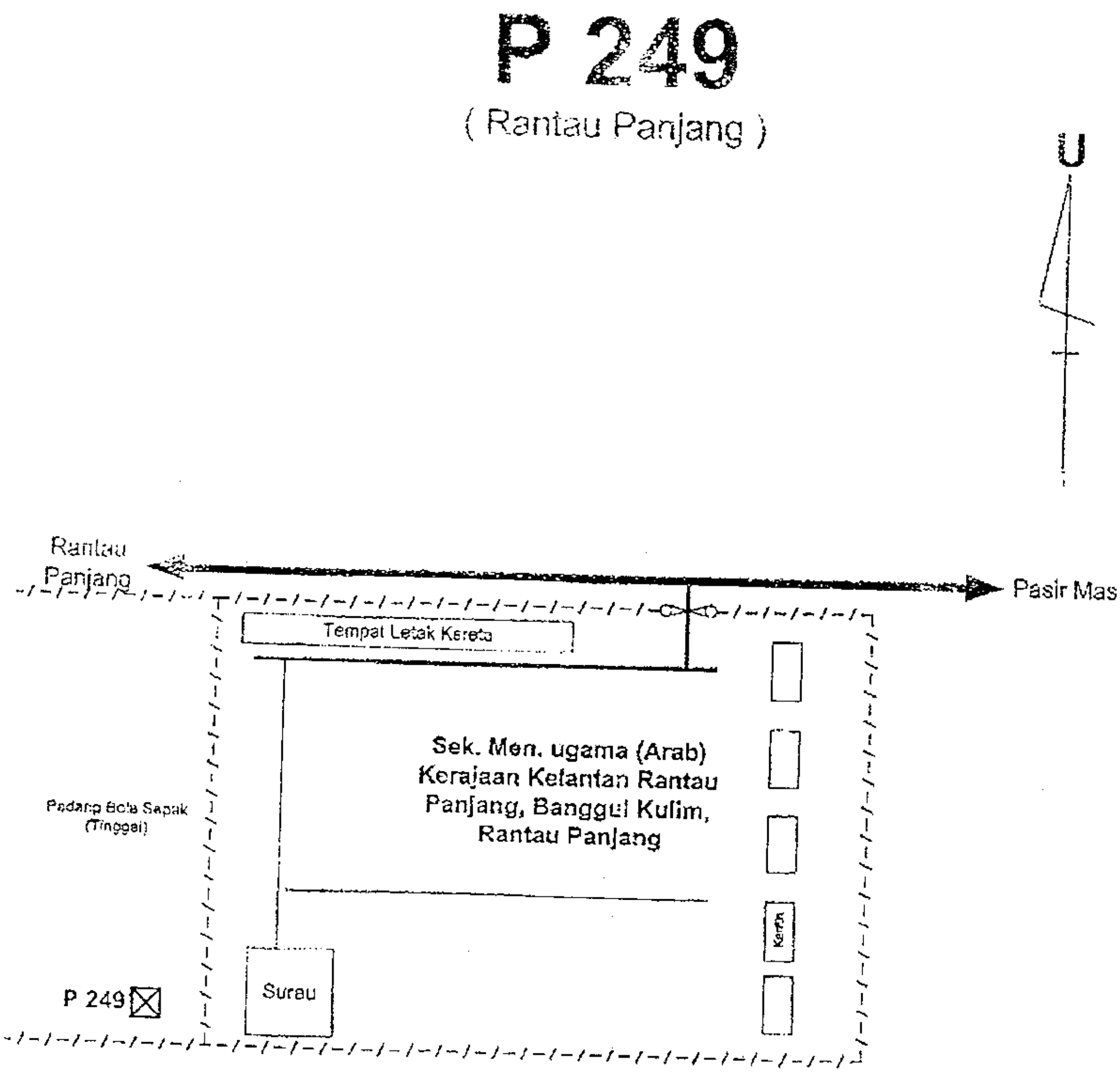
Appendix A.3: Data Availability for September

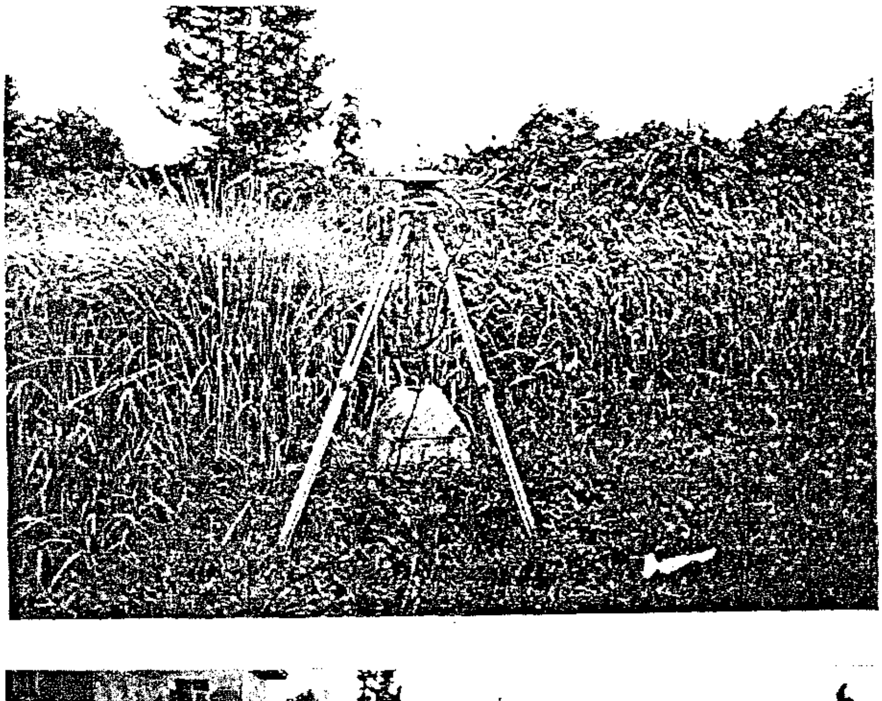
STATIONS / DATE		246	247	248	249	250	251	252	253	254	255
Pulai Platform	Pulai (PUA1)		√	√	√	√	√	√	√	√	√
	Pulai (PUA2)							√	√	√	√
	Pulai (PUA3)										√
Reference Stations	Beserah (GP34)	√	√	√	√	√	√	√	√	√	√
	Kuala Terengganu (P232)	√	√	√	√	√	√	√	√	√	√
	Rantau Panjang (P249)	√	√	√	√	√	√	√	√	√	√
MASS Stations	Kota Kinabalu (KINA)	√	√	√	√	√	√	√	√	√	√
	Miri (MIRI)	√	√	√	√	√	√	√	√	√	√
	UTM Skudai (UTMJ)	√	√	√	√	√	√	√	√	√	√
	INSTUN Tanjung Malim (BEHR)	√	√	√	√	√	√	√	√	√	√

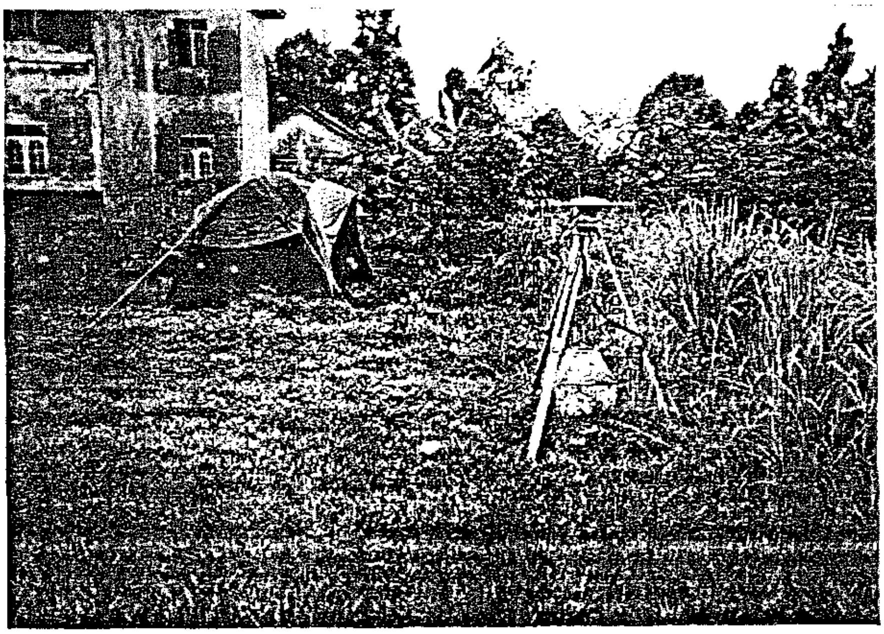
APPENDIX B

CONVENTIONAL REFERENCE STATIONS DESCRIPTION

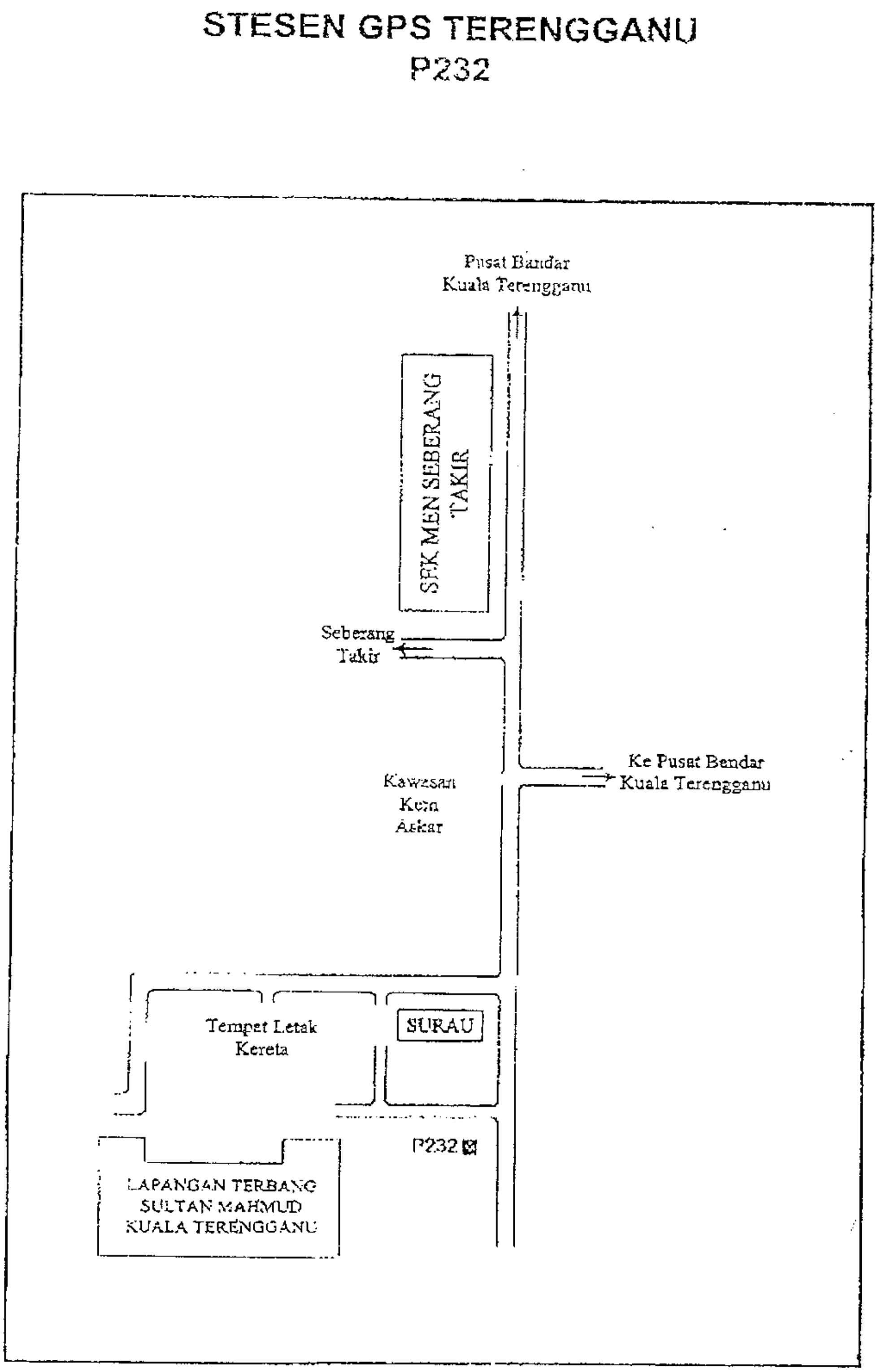
P 249 Location Map

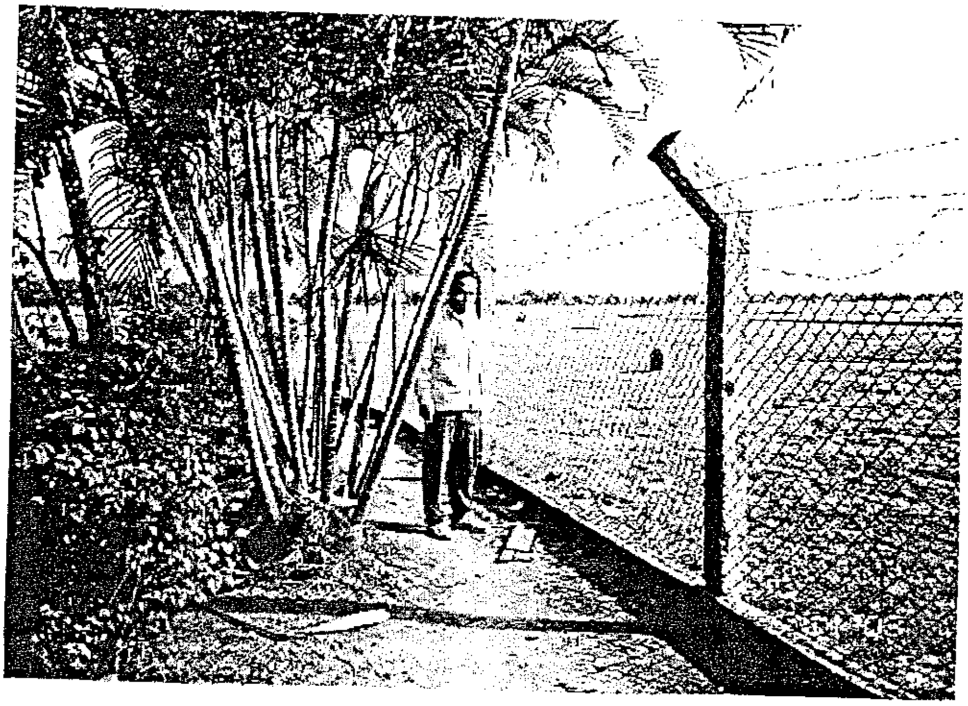




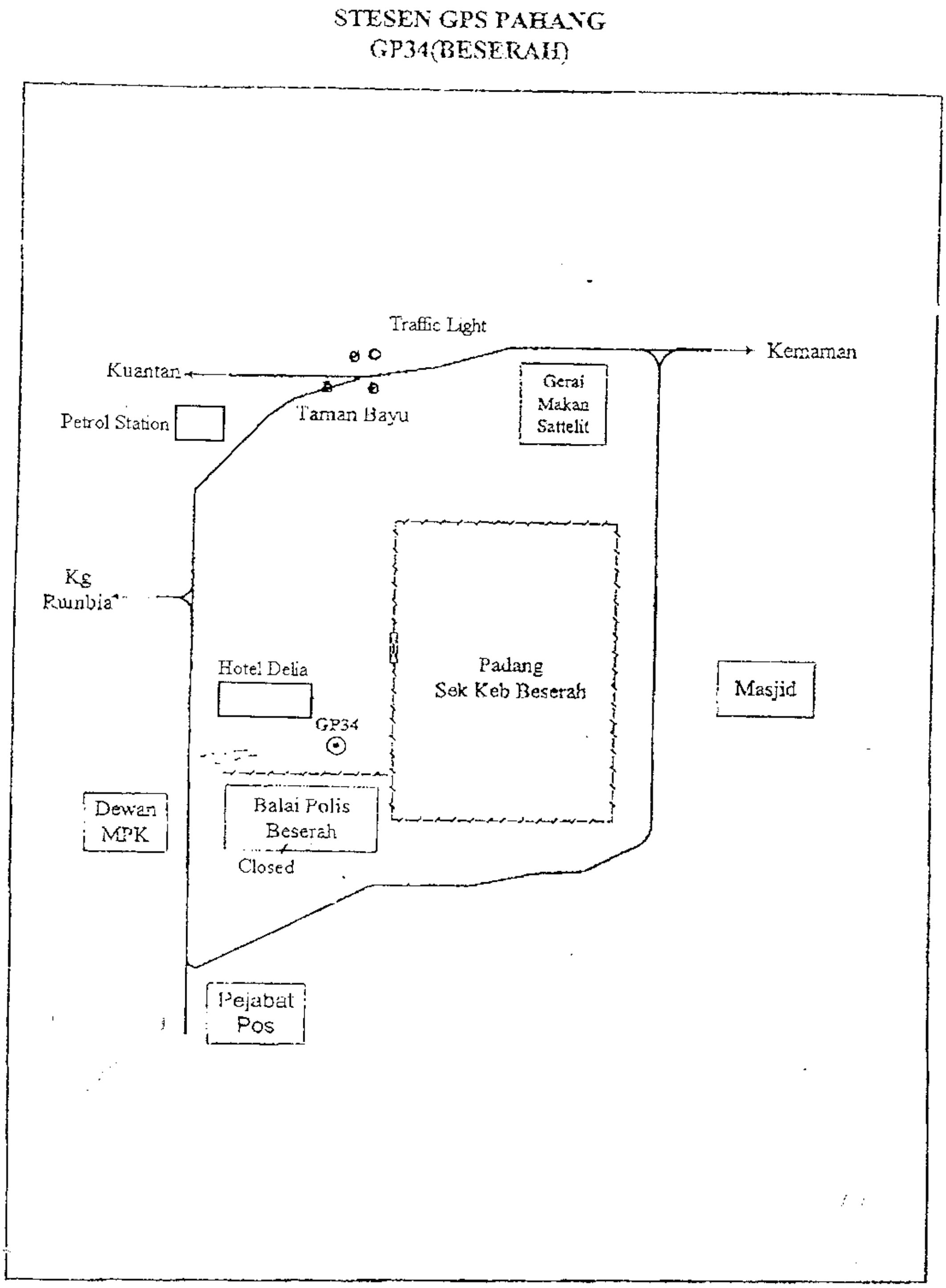


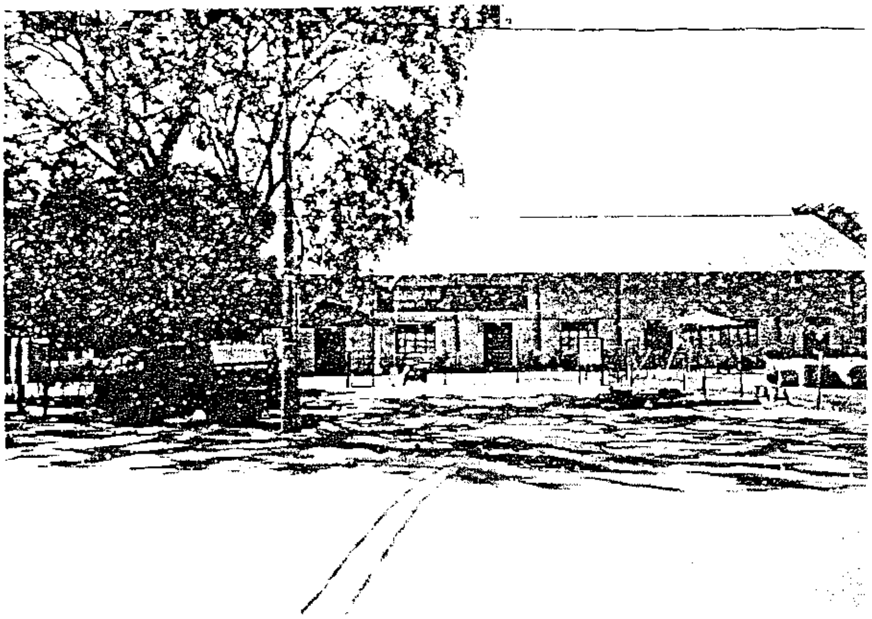
P 232 – Location Map

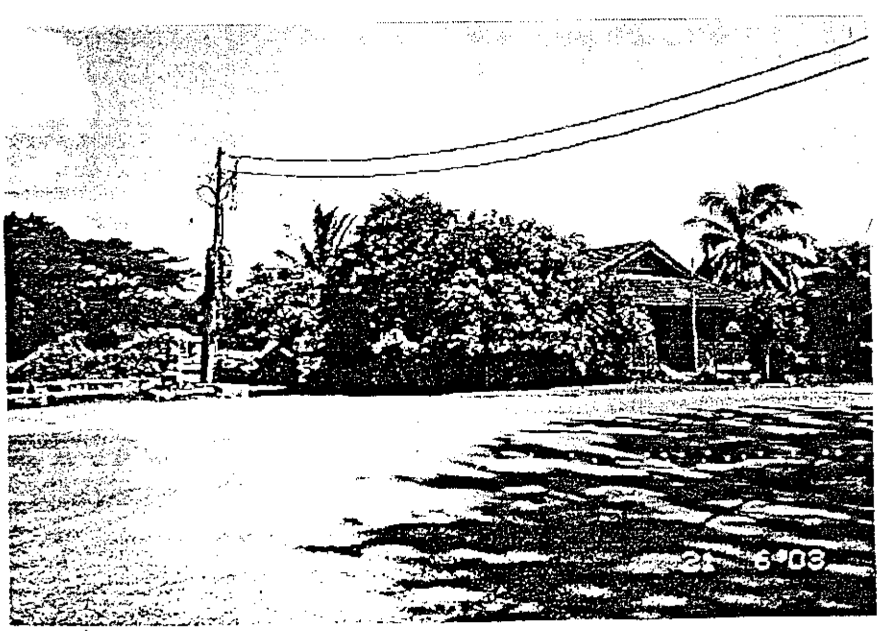




GP 34 – Location Map

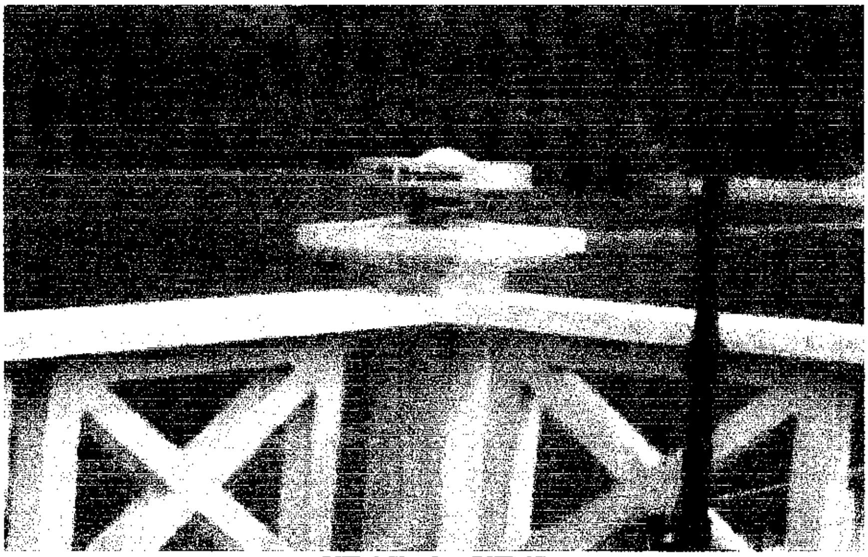




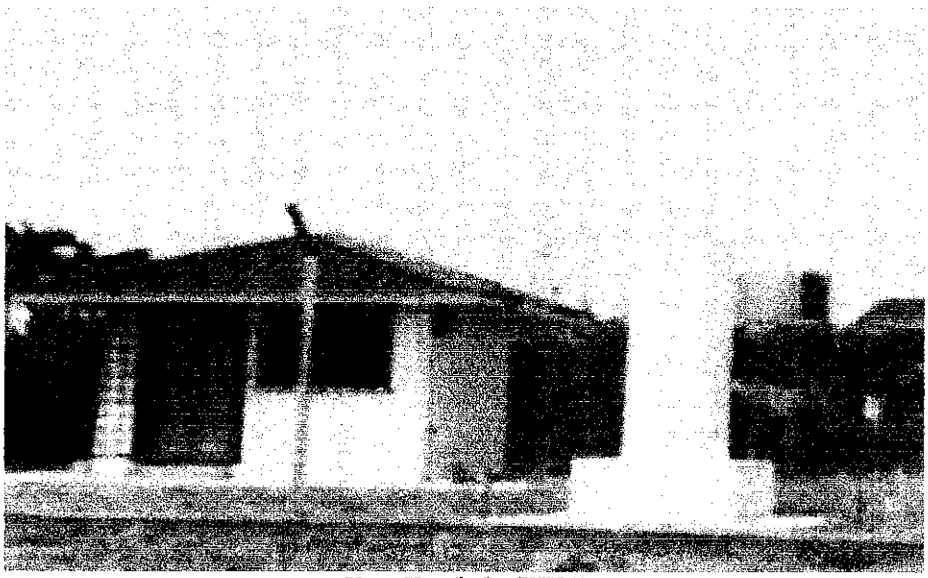


APPENDIX C

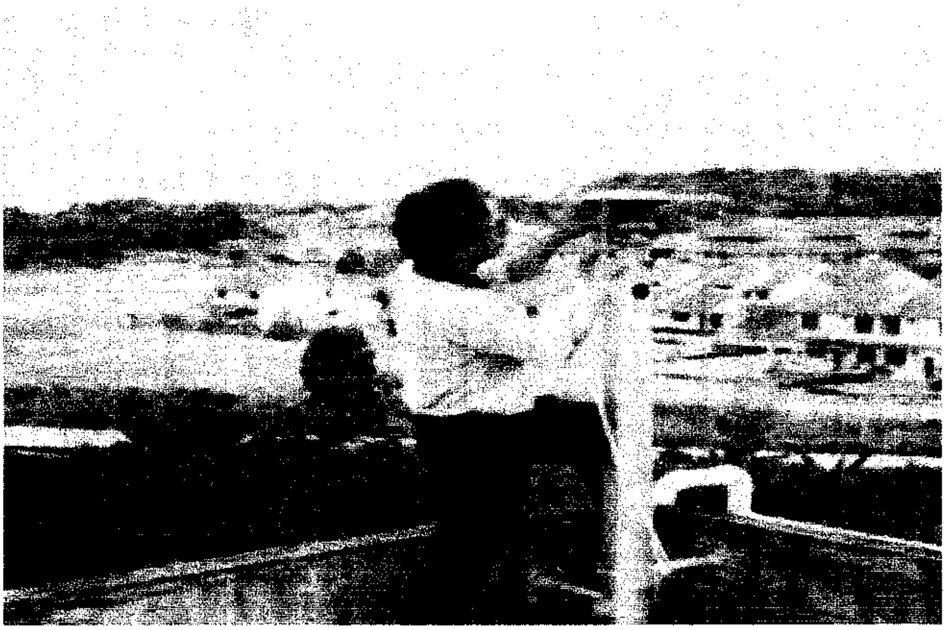
MASS STATIONS DESCRIPTION



UTM Skudai (UTMJ)



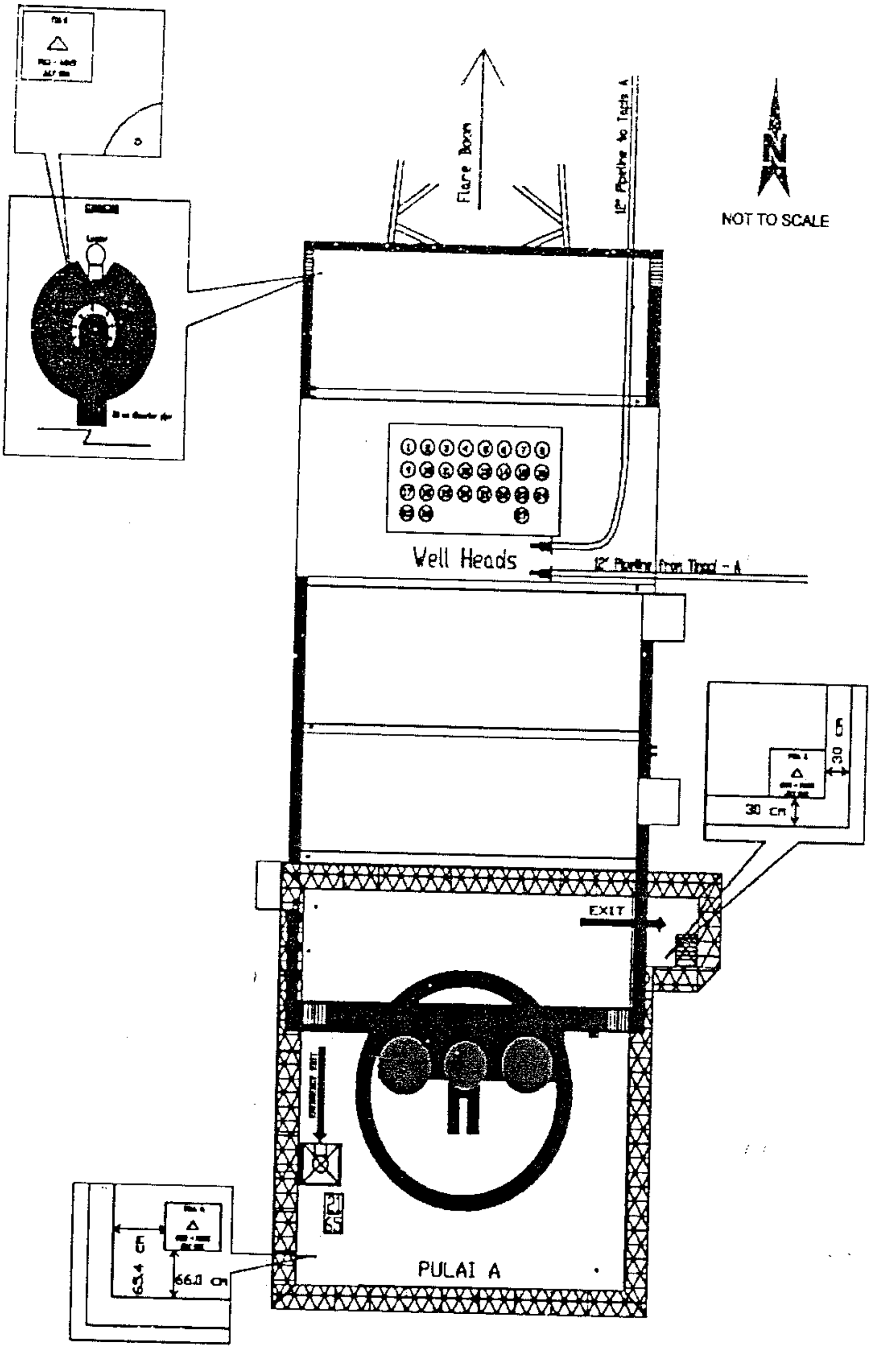
Kota Kinabalu (KINA)



Miri (MIRI)

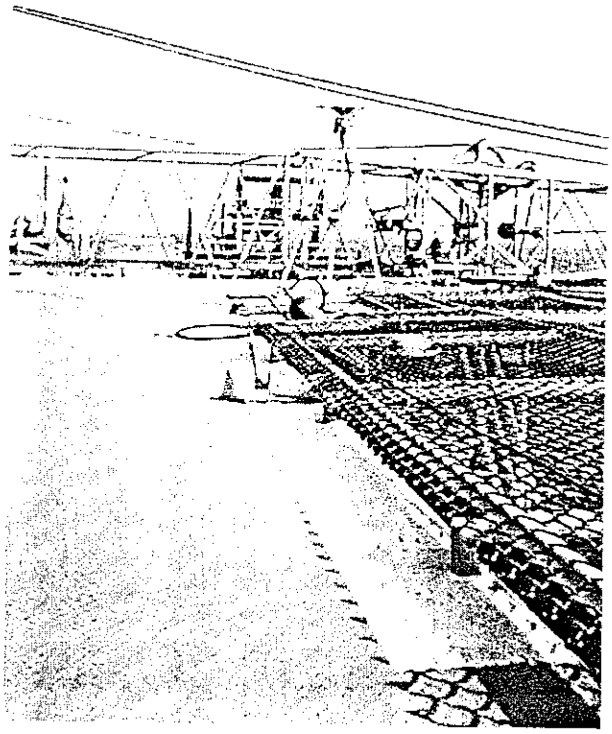
APPENDIX D

PULAI PLATFORM DESCRIPTION

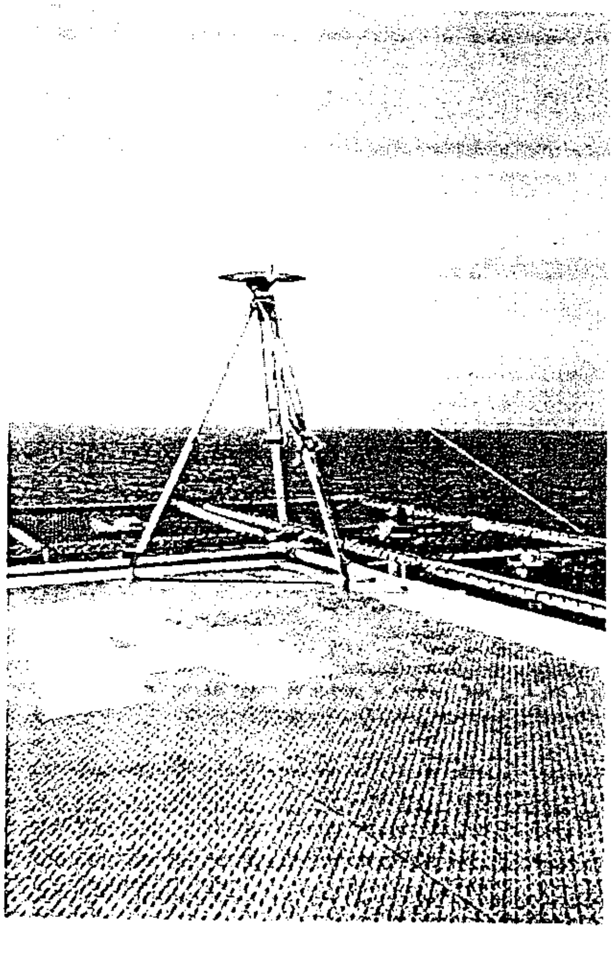


Station description on Pulai - A Platform

PUA 1



PUA 2



PUA 3