

GEOCENTRIC DATUM GDM2000 FOR MALAYSIA: IMPLEMENTATION AND IMPLICATIONS

Majid Kadir, Shahrum Ses, Kamaludin Omar, Ghazali Desa and Abdullah Hisam Omar

Faculty of Geoinformation Science and Engineering
Universiti Teknologi Malaysia
Skudai, Johor

Kadir Taib, Teng Chee Hua, Azhari Mohamed, Chang Leng Hua, Rahim Saleh and Soeb Nordin

Department of Survey and Mapping Malaysia
Jalan Semarak, Kuala Lumpur

ABSTRACT

The Department of Survey and Mapping Malaysia (DSMM), in collaboration with the Universiti Teknologi Malaysia(UTM), has carried out a study towards the establishment of a new geodetic framework for the country. The new Geocentric Datum for Malaysia (GDM2000) is being built by GPS space geodetic technology based on International Terrestrial Reference Frame (ITRF2000) and Geodetic Reference System 1980 (GRS80) reference ellipsoid. GDM2000 is connected to ITRF2000 by the inclusion of 17 International GPS Service (IGS) sites from the nearby regions in the precise baselines processing and adjustment of a network of existing Malaysian Active GPS System (MASS) stations. The process of implementing GDM2000 in particular matters related to datum transformation and map projection is being addressed. New sets of transformation parameters concerning conversion from the existing local datum to the new GDM2000 have been developed. Its implication on the existing cadastral and mapping practices, various GPS non-mapping applications, and GIS/LIS related applications have been considered. In addition to that, its socio-economic implications on the implementation of GDM2000 is also presented.

1.0 INTRODUCTION

A datum is the coordinate system used to describe the absolute and relative position of points on (or close to) the earth's surface. In order to define fully a 3-dimensional datum, six (6) parameters must be specified: three (3) to define the center of the system and the rest to define the direction of the three orthogonal axes. In addition, if ellipsoidal coordinates (latitude and longitude) are required, it is also necessary to define the size and shape of a reference ellipsoid onto which points can be projected. Note that it is always assumed that the ellipsoid center coincides with the center of the datum and that the minor axes and z-axis are coincident. In principle the position of points on or close to the earth's surface can be defined in any datum. The center could be anywhere and the axes could point in any three orthogonal directions.

Classically 3-dimensional coordinates of points are given in terms of latitudes, longitudes and heights (see Figure 1). The latitudes and longitudes are defined by projecting points from the earth's surface to a so-called reference ellipsoid. The position, orientation, size and shape of this ellipsoid is what constitutes a classical geodetic datum. Hence a classical datum can be thought of as a model for the earth, or at least part of it. Modern datums are a little different in which the center and orientation of a cartesian coordinate system is defined and most computations carried out using cartesian coordinates. Latitudes and longitudes are simply computed by introducing an

ellipsoid with the same center and orientation. For mapping, and many other, purposes latitudes and longitudes can be further transformed to plane coordinates by the use of suitable formulae.

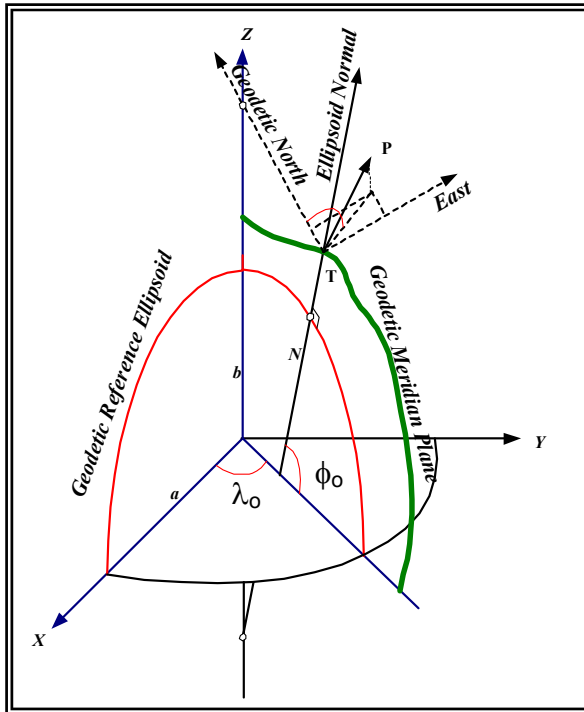


Figure 1: Local Geodetic System

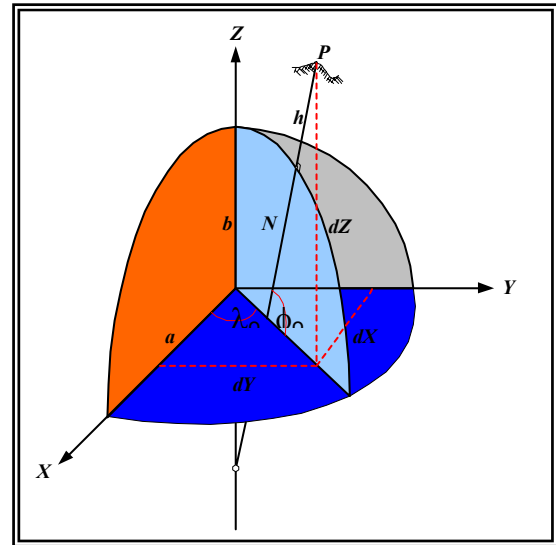


Figure 2: Geocentric System

Local datums are defined implicitly by assigning coordinates to one or more points within the region being mapped. Their center is not explicitly defined and, in practice, could be many hundreds of meters from the geocenter. Directions of axes are defined according to local astronomical phenomena at the time of the definition.

Geocentric systems (see Figure 2), by definition, have their center at the center of mass of the earth and the direction of their axes are defined arbitrarily (usually used averaged astronomical phenomena). Whilst such systems are easy to define, realization of coordinates within them needs very high accuracy space geodetic techniques. Their associated ellipsoids may not fit a particular region well and might lead to significant corrections having to be made when processing surveying data. Their advantages are that they can provide seamless positioning across the world and they relate directly to the modern space-based positioning systems that are nowadays being used for various purposes including surveying and mapping.

There are two existing local geodetic reference systems in Malaysia namely the Malayan Revised Triangulation (MRT) for Peninsular Malaysia and Borneo Triangulation System 1968 (BT68) for Sabah and Sarawak. The MRT is the coordinate system used for mapping in Peninsular Malaysia (see Figure 3). The datum is based on the old Repsold Triangulation and computed using data collected mainly in the period 1948 to 1966 using the Modified Everest ellipsoid. It consists of about 1,200 stations plus a number of more recent *standard traverses* and has an inter-station accuracy of around 13 to 15 ppm. Coordinates in this system are known as MRT48 coordinates which represent a unified datum, albeit distorted (see Lithen, 1993), for the whole Peninsular.

The first datum for Sabah and Sarawak was the Primary Triangulation of Borneo 1948 (BT48) established by the Directorate of Overseas Survey (DOS) which was based on the Timbalai Datum and Everest Ellipsoid for referenced. This triangulation was further strengthened through the

readjustment and was later known as Borneo Triangulation 1968 (BT68). This network consists of the Borneo West Coast Triangulation of Brunei and Sabah (1930-1942), Borneo East Coast Triangulation of Sarawak, extension of the West Coast Triangulation of Sabah (1955-1960) and several Doppler points surveyed between 1961 to 1968. The adjustment produced an overall accuracy of about 5ppm. The BT68, which also referred as the Timbalai Datum, uses the Modified Everest ellipsoid for referenced (see Figure 4).

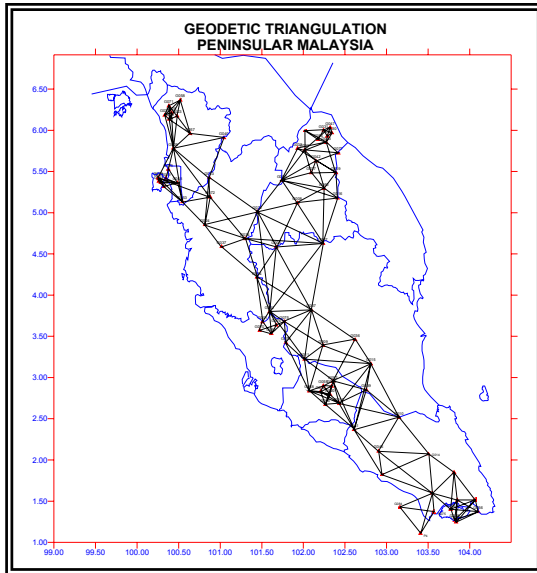


Figure 3: Malayan Revised Triangulation 1948 (MRT48)

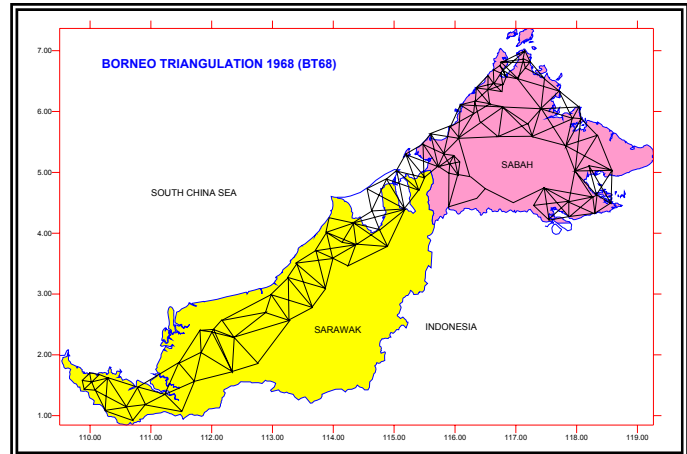


Figure 4: Borneo Triangulation 1968 (BT68)

Over the years, the *Rectified Skew Orthomorphic* (RSO) and *Cassini Soldner* (Cassini) map projection systems have been used for national mapping and cadastral purposes, respectively, based on these two local datums. For example, based on the theory developed by Hotine (1947), the Directorate of Colonial Surveys in Teddington, England, prepared the *RSO Projection Tables for Malaya*. This Table has ever since been used by the DSMM for the RSO topographical mapping projection purposes in the Peninsular. Meanwhile Cassini projection system (Richardus and Adler, 1974) has been used in Peninsular Malaysia for cadastral mapping purposes. With almost each State having its own origin, this system having its advantage in terms of reducing scale distortion for a point located away from the central meridian. However for larger area (for example covering a state), magnitude of the distortion is very significant away from its origin.

A unified coordinate system with referenced to the universally adopted datum is required to accommodate the present and future interest in the acquisition of digital spatial data related to cadastral and topographic mapping information. Kadir, et. al. (2002) highlights the importance of providing a homogeneous geodetic infrastructure as the basis for integration of spatial data for sustainable development decision making. They proposed that the country to adopt a new geocentric datum for the requirements of 3-dimensional geodetic spatial referencing. The increasing use of GPS for various applications, such as providing spatial information for GIS/LIS applications, has further highlighted the shortcomings in existing local datums. The easy transfer spatial data is crucial for both economic development and for the construction of all kinds of infrastructure. These factors are causing many national mapping authorities to reconsider their provision of survey data, and the datum on which it is defined.

Several space-based surveys (Doppler and GPS) have been carried out in Malaysia. These include the establishment of a MASS network and a high density national GPS network. The most comprehensive GPS survey was that completed in 1993 (Lithen, 1993) with approximately 30km spacing of GPS points over the Peninsular. It resulted in a new first order national network

with their published coordinates both on an approximate geocentric datum (WGS84) and local MRT datum. Future development of Real Time GPS Kinematic Network (RTKNet) in the country by DSMM is another example of providing infrastructure for real time applications of GPS which will require coordinate frame preferably in geocentric datum.

This paper highlights the process of implementing GDM2000 with particular emphasis on the matter related to datum transformation and map projection. Its implications on the existing cadastral and mapping practices, various GPS non-mapping applications, and GIS/LIS related applications are presented. In addition to that, its socio-economic implications on the implementation of GDM2000 is also presented.

2.0 IMPLEMENTATION OF *GDM2000*

2.1 Realization of GDM2000

To achieve a practical realization of a reference frame, a set of station coordinates must be established. A geocentric reference frame for this country could be realized through a set of MASS station coordinates defined on the precise reference system such as International Terrestrial Reference System (ITRS) that managed the International Terrestrial Reference Frame (ITRF) derived using GPS observations. Geographical setting of our country is situated in the region where only several IGS sites are available and none of them exist in Malaysia. The closest IGS station is located in Singapore and few other newly established sites are in Indonesia. The only way to define geocentric datum for our country is to establish long baselines connection between the existing MASS stations to these sites and other IGS stations in the nearby regions.

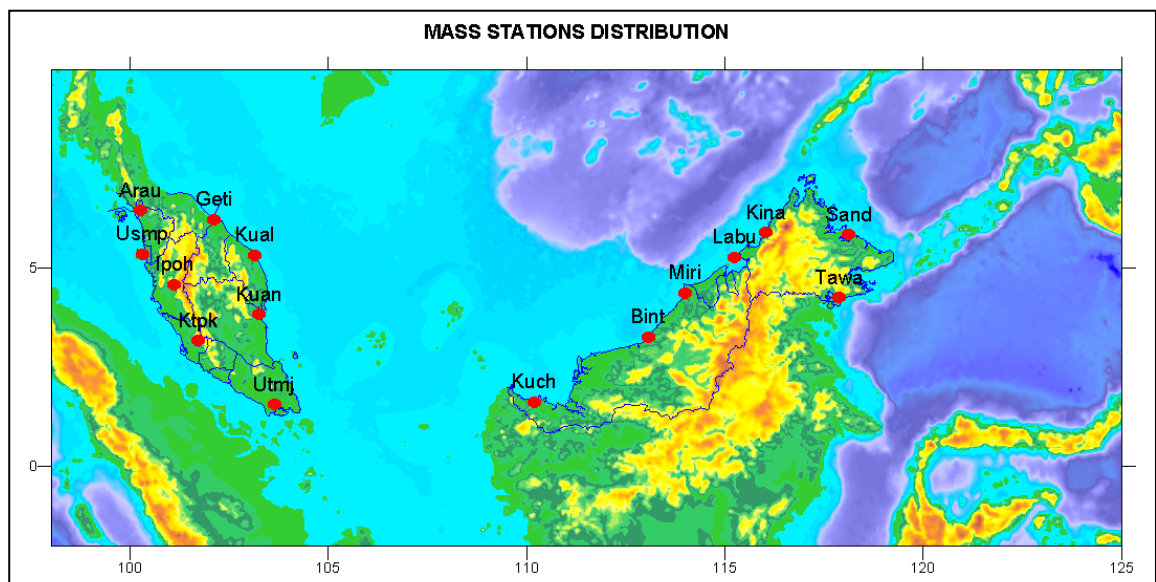


Figure 5 : Distribution of 15 MASS stations in Malaysia

At present seventeen (17) MASS stations operated continuously since 1998, ten (10) of the stations are situated in Peninsular Malaysia and the rest (7 stations) are in Sabah and Sarawak. Data from these (17) permanent GPS stations have been used to define geocentric datum of Malaysia. The distribution of these stations is given in Figure 5. With the availability of precise IGS station coordinates, IGS precise orbits and earth orientation parameters from IERS, the objective to realize a new precise global reference frame in ITRF2000 for Malaysia could be achieved.

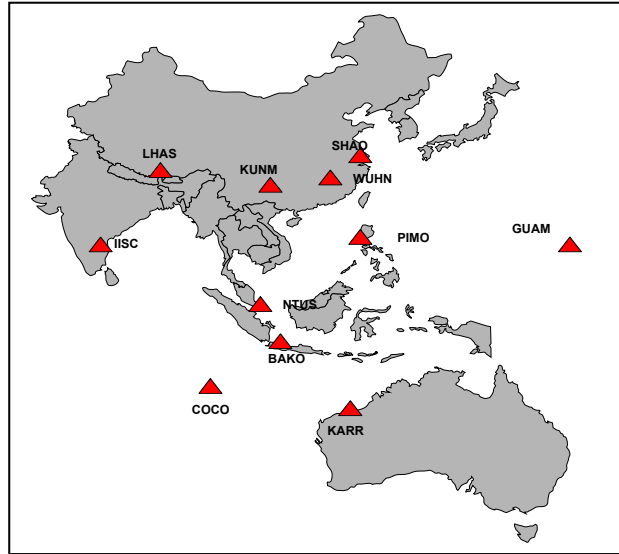


Figure 6: Distribution of eleven (11) IGS stations

The Bernese GPS processing software version 4.2 [Rothacher and Mervart, 1996] was used in the processing of seventeen (17) Mass stations. A total of eleven (11) IGS stations have been included in the processing in order to determine the MASS stations coordinate on ITRS reference frame. The distribution of IGS stations is shown in Figure 6.

A total of 4 years spans of GPS data available at all MASS stations have been used in the processing. All MASS stations are operational and the percentage of GPS data collected from these stations are between 75 to 95%.

An optimum processing strategy has been developed for obtaining high precision and consistent geocentric coordinates from IGS sites. The summary of the specified strategy is as follows:

- Use of IGS final orbits with referenced to ITRF at a certain epoch
- A priori coordinates refer to available ITRF2000 values
- Earth orientation parameters from IERS
- Pre-processing using 24 hours of 30 seconds data interval
- Elevation cut-off angle 15 degrees
- Phase center offsets in height are introduced according to IGS values (table IGS-01)
- Receiver clock synchronization using L3 code data for single point positioning solutions
- Satellite clock biases are not estimated but eliminated by forming double differences
- Pre-processing using triple difference screening for determination of good a priori coordinates
- Phase pre-processing in a baseline by baseline mode using double differences
- Zenith troposphere delays are estimated for every 2 hours, no a priori troposphere model and Dry Niell troposphere mapping used
- Influences of ionosphere are eliminated by forming the L3 linear combination of L1 and L2 phase measurements
- Adjustment using least-squares algorithms of double difference carrier phases, observation a priori sigma 1 m and correlations modeled within baselines only
- Solid Earth tide and ocean tidal Loading corrections are applied
- Ambiguity resolution are made using Quasi Ionospheric Free (QIF) ambiguity fixing strategy in a baseline by baseline mode
- The final processing strategy is the L3 QIF L1 & L2 ambiguity fixed solution

A high accuracy and consistent three-dimensional geocentric coordinates for the seventeen (17) MASS stations of Malaysia from the global network of IGS stations has been determined. The quality of the solutions was assessed using daily position and baseline repeatability. From the final combined solution, the internal accuracy of MASS stations from the free network adjustment is 5 to 11 mm in the horizontal component and 5 to 15 mm in the height component. For the heavily constrained adjustment, the accuracy of station coordinates is between 3 to 16 mm in horizontal and 8 to 13 mm for the height. The difference between the free network and heavily constrained adjustment is at millimeter level.

Thus, the seventeen MASS stations is now based on the ITRF2000 at epoch 2nd January 2000, which is recognized by international organizations such as the International Association of Geodesy (IAG). The absolute accuracy of the seventeen MASS coordinates is at 1-2 cm level and now these coordinates are based on the new geocentric datum of Malaysia GDM2000.

2.2 Defining Parameters

A geocentric datum is also referred to as a global geodetic coordinate system. The GDM2000 is an example of such a datum. For most practical applications the refined WGS reference frame can be considered to be coincident with the ITRF. The level of coincidence between the refined WGS84 frame and the ITRF is estimated to be of the order 10cm. It is customary to define a global geodetic coordinate system through a set of parameters of its reference ellipsoid. The defining parameters for the GRS80 ellipsoid used in GDM2000 are identified below :

- i. The semi-major axis of the ellipsoid of revolution

$$a = 6,378,137 \text{ meters}$$

- ii. Inverse flattening (1/f) of the ellipsoid

$$1/f = 298.257 \ 222 \ 101$$

The GDM2000 is realized by the coordinates of the seventeen (17) MASS stations (called Zero Order Network of Malaysia) referred to the above defined ellipsoid within the International Earth Rotation Service Terrestrial Reference Frame 2000 (ITRF2000) at epoch 2nd January 2000. The absolute accuracy of the MASS stations coordinates is around 1-2 cm. The list of MASS stations coordinates which defines the GDM2000 is given in the Technical Manual of the GDM2000.

3.0 IMPLICATIONS OF ADOPTING *GDM2000*

3.1 Introduction

There is a change occurring in the datum of the coordinate system used in Malaysia, and that change will effect not only mapping and spatial data users, but also non-mapping related users. Adopting a geocentric datum will provide a single standard for collecting, storing and applying spatial data. This will ensure compatibility across various geographic systems locally and globally.

The key advantages of the GDM2000 over the existing local datums are that GDM is totally compatible with satellite-based navigation systems such as the GPS and with major international geographic systems. This will also minimise the need for casual users to understand datum transformations and allow more efficient use of spatial data resources by reducing need for duplication and unnecessary translations. The datum will promote GPS, GIS and navigation systems become more widely used in the country.

The current local datums (MRT and BT68 systems) are based on a mathematical surface of the earth design to fit our region. Continuing to work with the existing local coordinates in an international environment where positioning, navigation and information systems relate to a global earth model is becoming increasingly inefficient and difficult. Therefore the use of a globally compatible coordinate system in our country is now inevitable.

3.2 Implication on Implementing Process

3.2.1 Transformation from WGS84, MRT and BT68 to GDM2000

The existing 238 stations of Primary Geodetic GPS Network of Peninsular Malaysia and the **300** stations of Primary Geodetic GPS Network of Sabah and Sarawak were based on approximate World Geodetic System (WGS84). These networks were further strengthened through connection to the MASS stations network which is already on the GDM2000. This has been done through the following steps:

- Re-observation of the well-distributed existing 34 primary GPS stations in Peninsular and 30 primary GPS stations in Sabah and Sarawak for 24 hours and processed with Bernese Software by constraining the 17 MASS stations in ITRF2000
- In order to assess the absolute and relative accuracy, a sufficient number of link and check stations being established
- A network adjustment was later made with vectors from original (existing) primary GPS networks together with the coordinates of the link stations.

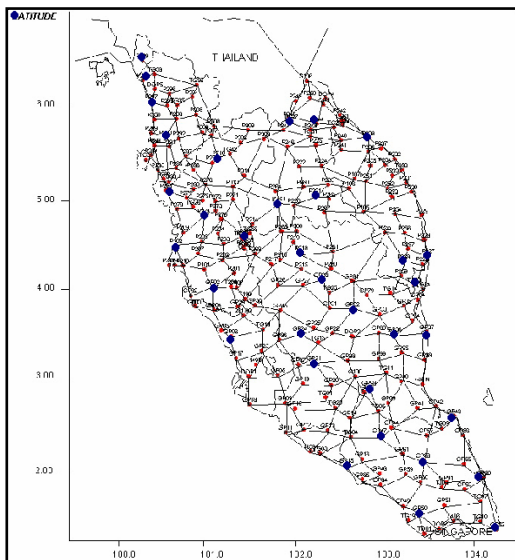


Figure 7: New PMPGN in ITRF2000

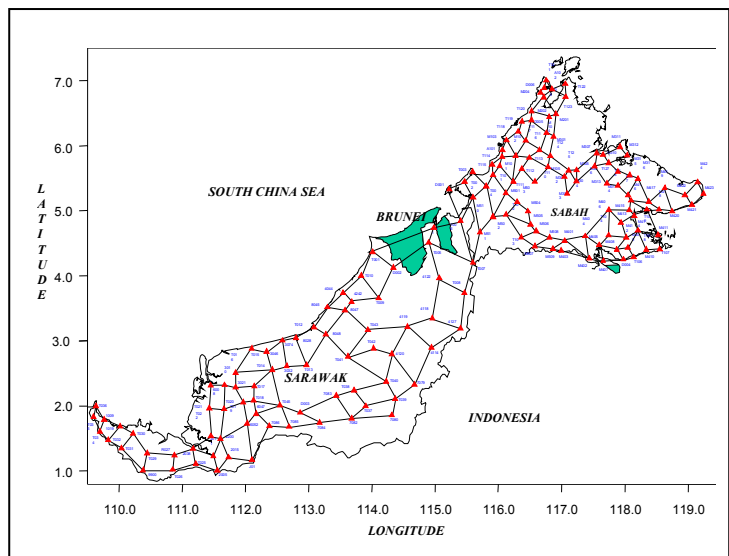


Figure 8: New EMPGN in ITRF2000

The new adjusted networks were later known as the Peninsular Malaysia Primary GPS Network (PMPGN) and East Malaysia Primary GPS Network (EMPGN), respectively. The PMPGN and EMPGN which are now based on GDM2000 compatible with most modern positioning techniques especially GPS (see Figure 7 and 8). The new PMPGN supersedes the MRT and the existing

Primary Geodetic GPS Network of Peninsular Malaysia (PGGN 95) coordinate systems. On the other hand, the EMPGN supersedes the BT68 coordinate system and the existing Primary Geodetic GPS Network of Sabah & Sarawak. The new GPS networks have an accuracy in the order of 1 to 3cm.

The important fact is that the new primary GPS networks provide a single, uniform and consistent coordinate system within the country that will encourage an efficient exchange of spatial data and products related to information systems. It is inconvenient to keep all mapping activities in the existing local coordinates while positioning, navigation and information systems are referred to a global system. Table 1 shows the properties of the MRT, BT68, WGS84 and ITRF defining parameters. The primary GPS networks will play important role in providing the basic geodetic infrastructure for the densification of GPS points in Malaysia.

The coordinates of a point will change depending on which datum the coordinates are referred to. To change a coordinate from one datum to another, a mathematical process known as transformation is used. This may be done in two or three dimensions and requires a number of points with positions known in terms of both datums. The accuracy of the transformation depends on the method chosen and the accuracy, number and distribution of the common points.

PARAMETER	MRT	BT68	WGS 84	ITRF
Reference Ellipsoid	Modified Everest	Modified Everest	WGS 84	ITRF
Origin	Kertau, Pahang	Timbalai	EFEC	EFEC
Semi-major axis (a)	6 377 304.063	6 377 304.063	6378137.000	6378137.000
Flattening (f)	1/300.8017	1/300.8017	1/298.257223563	1/298.257222101

Table 1: Reference Ellipsoids for MRT, BT68, WGS84 and ITRF

A new set of transformation parameters from the WGS84 and MRT to GDM2000 for Peninsular Malaysia has been derived using Bursa-Wolf seven parameters model and their related values is given in the Technical Manual of the GDM2000 (DSMM, 2003). Transformation parameters from the BT68 to GDM2000 for East Malaysia is also given in the Manual. The new set of transformation parameters which consist of shift (Dx, Dy, Dz), rotation (Rx, Ry, Rz) and Scale is available at JUPEM for the conversion to GDM2000 purposes.

3.2.2 Conversion to Geocentric Cassini Coordinate System

The existing Cassini projection system used for cadastral application in the Peninsular is based on local MRT datum and realized by their published related defining parameters. Conversion to geocentric datum involved changing of projection parameters related to reference ellipsoid. The corresponding reference ellipsoid for geocentric datum is the GRS80.

In the old system, there are ten (10) State Cassini-coordinate systems in the Peninsular with their respective origins. The latitude and longitude of the origins are not referred to a single triangulation system. Maintaining these origins will pose some problems since their geodetic coordinates in GDM2000 need to be transformed from MRT which is inaccurate. Another option is to re-observe the origin points but still problem will arise since some of the points are no longer exist. The most appropriate way in solving this problem is to adopt new origin points using the existing Primary GPS stations in the country. In doing so, the new origins (10 primary GPS stations) are selected in the vicinity of the old origins with their coordinates accurately defined in

the GDM2000. The list of new State origins used in geocentric Cassini coordinate system is given in Appendix A. The mapping equations used for Cassini coordinates in GDM2000 is given in the Technical Manual of the GDM2000.

3.2.3 Conversion to Geocentric RSO Coordinate System

The RSO is an oblique Mercator projection used for topographical mapping application in Malaysia. Hotine (Snyder, 1984) called the projection as "rectified skew orthomorphic". This projection is orthomorphic (conformal) and cylindrical. All meridians and parallel are complex curves. Scale is approximately true along a chosen central line (exactly true along a great circle in its spherical form). The RSO provide an optimum solution in the sense of minimizing distortion whilst remaining conformal for Malaysia. Its scale factor varies from 0.99984 to 1.0016 leading to a maximum scale distortion of 1:6250.

	Peninsular Malaysia RSO	East Malaysia Borneo RSO	Remark
Ellipsoid Parameters			
Ellipsoid	GRS 80	GRS 80	
	6378137.000 Meters	6378137.000 Meters	
Flattening, 1/f	298.2572221	298.2572221	
Category I – Defined Parameters.			
Latitude of Origin, ϕ	4° 00' 00" N	4° 00' 00" N	
Longitude of Origin, λ_o	102° 15' 00" E	115° 00' 00" E	
Azimuth, α	$-\sin^{-1}(0.6)$	$-\sin^{-1}(0.6)$	
Scale factor, k	0.99984	0.99984	
False Origin (Easting)	804,671 Meters E	Nil	
False Origin (Northing)	Nil	Nil	
Category II - Parameter that related to ellipsoid change			
Parameter A	6378137.502 Meters	6378137.502 Meters	$B(\rho_o v_o)^{1/2}$
Parameter B	1.003331484644	1.003331484644	$(1+k'^2 \cdot \cos^4 \phi_o)^{1/2}$
Parameter C	0.000003016721	0.000003013554	$\cosh^{-1}(A/\rho_o) - B\psi_o$
Basic Longitude. ω_o	105° 14' 10.587"	109° 41' 08.948"	$\sin B \cdot (\omega_o - \omega) = 0.75 \sinh(B\psi + C)$

*Note: Formulae for Basic longitude for Borneo RSO is $= 0.75 \sin (B (115^\circ - \omega_o)) = \sinh (B\psi + C)$

Table 2 : The New Geocentric RSO Projection Parameters for Peninsular and East Malaysia

RSO based on the local MRT datum has been used for topographical mapping in Peninsular Malaysia. This projection system has also been used in Sabah and Sarawak (called Borneo RSO) for topographical mapping based on the local BT68 datum. The defining parameters for

these local RSO projection systems have been published and being used in Malaysia over the years. Conversion to geocentric datum involved changing of projection parameters related to reference ellipsoid. The corresponding reference ellipsoid for geocentric datum is the GRS80. Thus, the new defining parameters for the RSO projection system (both for Peninsular and East Malaysia) based on the geocentric datum (GDM2000) is given in Table 2.

3.3 Implication on Practice

3.3.1 GPS Positioning

The widespread use of GPS has further highlighted the need to adopt geocentric datum in this country. Position determination using various GPS techniques have been increasingly being practiced for various survey related applications. The existing GPS networks in Peninsular and East Malaysia which have been strengthened and referenced to the GDM2000 will certainly provide better control for GPS positioning activities carried out by various mapping related agencies. The new primary GPS networks having accuracy of better than 2cm are now referred to the geocentric datum. The current spacing of the GPS primary stations which is about 30km satisfies most GPS survey related application such as providing control for large engineering surveying and construction purposes.

WGS84 is the coordinate reference frame of the GPS which is based on GRS80 reference ellipsoid. With GDM2000, ellipsoidal or geodetic coordinates of a point in the country could be determined using GPS positioning with respect to geocentric datum. This datum is based on GRS80 reference ellipsoid which is having its center coincident with earth center of the mass. Current practice in this country is the geodetic coordinates (latitude and longitude) determined using GPS in geocentric datum (on the GRS80 ellipsoid) need to be converted to the MRT or BT68 systems which is based on the Modified Everest reference ellipsoid. This is due to the existing map projection systems that have been used in Malaysia are based on MRT and BT68 systems. For non map user, the WGS84 coordinates obtained from GPS positioning is compatible with the new GDM2000. The difference between WGS84 and GDM2000 is negligible for most applications and this is due to slight different between the parameters used in defining the GRS80 ellipsoid in both systems. However for scientific applications such as in tide gauge stations monitoring in the country, proper conversion from WGS84 to GDM2000 is needed since very precise GPS measurement is required. In that case, conversion could be done using the new set of transformation parameters given in the Technical Manual of the GDM2000.

Certainly the new GDM2000 will provide better platform for most GPS positioning applications in future for the country. This will encourage the use of GPS as an effective positioning tool without going through the lengthy process of conversion to the old local datums of MRT and BT68. This will also support the function of future Real Time Kinematic (RTK) GPS Network in the country. Real time application of GPS positioning technology, especially in RTK GPS, is an emerging trend in many countries taking advantage of the GPS to its maximum capabilities. The DSMM is establishing such infrastructure which is known as the RTK Network for Peninsular Malaysia (PMRTKNet) and RTK Network for Sabah and Sarawak (SSRTKNet). When the system is installed and operational, it will support concurrent GPS positioning in both real time and post-processing modes. Providing the country with the most advance RTK GPS infrastructure requires modern geocentric datum such as GDM2000 that will support every aspect of their future real time applications on horizontal and vertical positioning both in static and dynamic conditions.

3.3.2 Cadastral Survey

Cassini projection system for the Peninsular is based on several local datums and realized by their published equations and coordinate of their respective State origin. The existing Cassini projection for cadastral mapping was based on the MRT system referenced to the Modified

Everest ellipsoid. The corresponding reference ellipsoid for geocentric datum of GDM2000 is the GRS80. The list of new State origins used in geocentric Cassini coordinate system is given in Appendix A. The mapping equations used for Cassini coordinates in GDM2000 is given in the Technical Manual of the GDM2000. This map projection is now being termed as the geocentric Cassini. By using equations from the Manual, corresponding geocentric Cassini coordinates of a marker could be directly computed.

The existing procedure of converting WGS84 coordinates to their corresponding values in local Cassini system involves several transformation steps such as the following:

$$WGS84 \rightarrow MRT \rightarrow RSO \rightarrow Cassini$$

Quality of the resulting coordinates derived from such conversion procedure depends mainly on the parameters being used in the transformations. For example conversion from RSO to Cassini is being done using conversion table derived over the years and never been revised.

For cadastral surveyor, geodetic coordinates of a point determined in GDM2000 (on the GRS80 ellipsoid) using GPS can now be projected directly to their related geocentric Cassini plane coordinate values (using equations and new origin given in Appendix A) without converting first to the MRT and RSO systems.

3.3.3 Topographical Mapping

For national mapping, the introduction of a global datum will have a significant effect particularly on the map projection being used. The existing map projection used for topographical mapping in Malaysia is the RSO based on the MRT and BT68 systems. The procedure of converting WGS84 coordinates to their corresponding values in local RSO system involves several transformation steps such as the following:

$$WGS84 \rightarrow MRT/BT68 \rightarrow RSO$$

Resulting coordinates derived from such conversion procedure depends on the reliability of the parameters being used in the transformations. The defining parameters for these local RSO projection systems have been published and being used in Malaysia since 1950's.

With GDM2000, geodetic coordinates of a point determined in geocentric datum (on the GRS80 ellipsoid) using GPS could be directly projected to their related plane coordinate values (for this case geocentric RSO) without converting first to the MRT or BT68 systems. Reducing the step of coordinates transformation will reduce any defect caused by imperfection in the value of defining parameters being used. The new defining parameters for the geocentric RSO projection system (both for Peninsular and East Malaysia) based on the GDM2000 is given in the Technical Manual of the GDM2000.

The introduction of GDM2000 will have a significant effect on the topographical mapping products because it will change the coordinates (shift) of points by up to approximately 200 meters in northeasterly and northwesterly directions for Peninsular and East Malaysia, respectively. There is no doubt that this would cause some inconvenience for users in the short term. This change will vary according to the map scale. A shift of 200 meters in coordinate will correspond to a shift of 4mm on the topography map of 1:50,000 scale and consequently 20mm on the town sheet of 1:10,000.

The working out of a transformation strategy for mapping products to be based on the new GDM2000 need to be planned and implemented with no complication and confusion. The use of mapping products based on the GDM2000 need to be encouraged. Consequently in future, all mapping products will be based on the new GDM2000. The new geocentric datum will also

generate greater benefit in the application of GPS positioning in all mapping related activities in the country.

3.3.4 GIS Users

GIS is an integrated system of computer hardware, software and trained personnel linking topographic, demographic, utility, image and other resource data that is geographically referenced. One aspect of the government's move to empower the population through the use of information and communication technology (ICT) is by promoting the use of the GIS.

The GDM2000 results from an international movement to adopt a geocentric datum to make mapping and spatial data coordinates compatible with satellite-based coordinates. The GDM2000 provides coordinates that are appropriate for applications at all levels (local through to international) and allows the easy integration with other information technologies such as GIS. Ideally, the future development of National Spatial Data Infrastructure (NSDI) is being planned to provide consistent national datasets to users on the same coordinate system, that is GDM2000. The type and number of spatial data users is increasing with the development of information system technologies, where nearly every industry sector will ultimately use these technologies. The GDM2000 is important in this respect as it simplifies the capture and integration of spatial information.

The NSDI will be based on the GDM2000 and all datasets will be supplied to users in GDM coordinates. This will allow users of the NSDI to integrate the NSDI with other ICT such as GIS and GPS. GDM2000 is the datum to use to minimize confusion for all users and provide maximum accuracy where high precision is required.

3.3.5 Navigation Applications

Application of GPS technology in land transportation sector is the largest compared to other sectors such as maritime and air navigation applications. Intelligent Transportation System (ITS) which integrates GPS positioning technology, ICT and electronic technology is a new dimension in the modern transportation system. For example an autonomous ITS integrates GPS positioning equipments with electronics map in a vehicle that is able in giving an effective travel direction since its position is always shown on the map. The fleet management, on the other hand, is a system where the location of a group of vehicles could easily be managed and monitored efficiently by the controller.

Application of satellite positioning technology in maritime navigation has been practiced by commercial ships and liners, NAVY and port authorities. Integration of GPS positioning technology and electronics charts enable the safety and efficient maritime navigations. Meanwhile the location of an aircraft, including height, could be determined using combination of GPS positioning technology and satellite communication system. Other information such as speed, flight direction and attitude of the aircraft could also be obtained so that flight duration could be optimized. This integrated system is also being utilized for aircraft take off and landing control purposes.

GDM2000 will provide better coordinate system infrastructure which is compatible with GPS positioning technology used for navigation applications. With GDM2000, geodetic coordinates of a point determined in WGS84 using GPS could be directly projected to their related geocentric RSO plane coordinate values. This is an advantage of adopting new geocentric datum that will spur the use of GPS for navigation applications in this country.

3.4 Socio-economic Implications

The user segment of GDM2000 will be mainly from various government department agencies, non-government organizations, as well as the public. Government agencies such as JUPEM, Land Departments, Planning Department, Local Governments and Municipalities will be most affected by the adoption of GDM2000 as a based for mapping products in this country. Non-government user such as private surveyors will be most affected since they directly involve in cadastral survey practice and the main user of the topographical mapping products.

Private and public organizations which produce or use geographic information in any form, will need to assess both the impact and benefits of adopting GDM2000. Organizations will need to understand both their current and future operational requirements as well as the financial, administrative and managerial issues. The existing and future spatial data requirements and use need to be highlighted. Spatial data collection, storage and management practices is another issue which involved for example migration from paper to electronic documents, access and distribution of information. All these need to be considered in the context of GDM2000.

The adoption of GDM2000 will accommodate the integration of spatial datasets and consequently will provide better data sharing, handling and management of the related datasets. The new datum will also encourage consistent or uniform spatial data standard across the country. The initial benefit of GDM2000 implementation is solely on the intangible aspects. However, the tangible benefit of its implementation will surface over the years.

4.0 CONCLUSIONS

The new Geocentric Datum for Malaysia (GDM2000) has been established by the DSMM using GPS space geodetic technology based on International Terrestrial Reference Frame (ITRF2000) and Geodetic Reference System 1980 (GRS80) reference ellipsoid. GDM2000 is connected to ITRF2000 by the inclusion of 17 International GPS Service (IGS) sites from the nearby regions in the precise baselines processing and adjustment of a network of existing Malaysian Active GPS System (MASS) stations. Accuracy estimate for the stations in the network that define GDM2000 is found to be in the order of 3mm and 5mm for the horizontal and vertical components, respectively. In the process of implementing GDM2000, matters related to datum transformations and map projections have been addressed. New sets of transformation parameters concerning conversion from the existing local datum to the new GDM2000 have been developed. Implication of the new GDM2000 on the existing cadastral and mapping practices have also being addressed focusing on its impact to their related current and future products. It has been proposed that the future product for both topography and cadastral mappings will be based on the GDM2000. Implementation of GDM2000 will further encourage the use of GPS positioning technology by various mapping related agencies in this country. Private and public organizations which produce or use geographic information in any form, will need to assess both the impact and benefits of adopting GDM2000. The new datum will also encourage consistent or uniform spatial data standard across the country.

REFERENCES

DSMM. (2003), Technical Manual of the GDM2000, Dept. of Survey and Mapping Malaysia.

Kadir, M., Desa, G., Ses, S. and K. Omar (2002), Studies toward the development of implementation plan of Coordinated Cadastral System for Malaysia, Executive Summary Report submitted to DSMM.

Lithen, T. (1993), The Peninsular Malaysia GPS survey. Final report of the joint survey project DSMM-Swedsurvey, Dept. of Survey and Mapping Malaysia.

Hotine, M. (1947), The orthomorphic projection of the spheroid. Empire Survey Review, No.64, Vol. 9.

Richardus, P. and Adler R.K. (1974). Map Projections. Netherland: North Holland Publishing Company.

Rothacher , M. and L. Mervart, (1996), Bernese GPS Software version 4.0. Astronomical Institute, University of Berne, Switzerland.

Appendix A

Coordinates of States Origin used in Cassini

State	GPS Station	Coordinates of State Origins				
		Station Location	GDM2000		Cassini	
			Latitude (N)	Longitude (E)	Northing	Easting
Johor	GP58	Institut Haiwan,Kluang	2°07'18.04708"	100°25'40.57045"	0.000	0.000
N.Sembilan & Melaka	GP12	Lubuk China, Melaka	2°26'53.59844"	102°04'19.67919"	0.000	0.000
Pahang	GP31	Kuala Mai, Jerantut	3°46'09.79712"	102°22'05.87634"	0.000	0.000
Selangor & Wilayah Persekutuan K. Lumpur	MASS Station	Wisma Tanah, Jalan Semarak, Kuala Lumpur	3°10'15.39787"	101°43'3.39045"	0.000	0.000
Terengganu	P253	Kg. Matang, Hulu Terenganu	4°58'34.62672"	103°04'12.99225"	0.000	0.000
P.Pinang & S. Perai	P314	TLDM Georgetown	5°25'15.46315"	100°20'39.75707"	0.000	0.000
Kedah & Perlis	TG35	Gunung Perak, Kuala Muda	5°57'52.82177"	100°38'10.93600"	0.000	0.000
Perak	TG26	Gunung Larut Hijau, Taiping	4°51'32.62688"	100°48'55.47811"	0.000	0.000
Kelantan	P222	Ulu kelantan	5°17'59.72675"	102°01'13.26240"	0.000	0.000