# ASIA PACIFIC REGIONAL GEODETIC PROJECT (APRGP) EXPANSION OF APRGP TO ALL PACIFIC GROUP MEMBER COUNTRIES

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## 1.0 Introduction

One of the resolutions of the Pacific Group (formerly called the Oceania Group) – PCGIAP Taskforce Workshop held in Suva Fiji on 22 – 25 March 1999 – as priority – to expand the Asia Pacific Regional Geodetic Network to include all Pacific Island countries. It was noted that only Fiji and Papua New Guinea participated in the APRGP 98. This was mainly due to the availability of Geodetic GPS receivers and expertise in the technology in those two countries.

This report has been prepared so that it can be referred to should particular details or any other resource information required by the Working Group 1 – Regional Geodetic Network. The main purpose of the report is to present information and resources available in the 19 island countries that form the Pacific Group.

## 2.0 Member Countries – Pacific Group

The Pacific Group of 19 PCGIAP member countries, 15 of whom were represented at the Suva Workshop in March 1999, comprises:

**1. American Samoa**
**2. Cook Islands**
**3. Fiji**
**4. French Polynesia**
**5. Guam**
**6. Kiribati**
**7. Marshall Islands ***
**8. Micronesia**
**9. Nauru**
**10. New Caledonia ***
**11. Northern Marianas ***
**12. Palau**
**13. Papua New Guinea ***
**14. Samoa**
**15. Solomon Islands**
**16. Tonga**
**17. Tuvalu**
**18. Vanuatu**
**19. Niue**

* Countries not able to participate at the PCGIAP Workshop in Suva, 22 – 25 March 1999:

However, out of the 15 countries that were present at the workshop only 7 replied to our request on geodetic information in their respective island countries. The Development Needs Questionnaire, which has to be filled and returned to AUSLIG by all members of the Pacific Group, would also determine their needs in order to expand the Geodetic Network to include all Pacific islands.

## 3.0 **Equipment – Geodetic GPS Receivers**

From all information gathered we believe that only Fiji, Vanuatu, New Caledonia, Guam and Palau have Geodetic GPS receivers. It is also understood that since Papua New Guinea participated in the APRGP 98, they too would have geodetic receivers. We still need to confirm the above from Vanuatu, New Caledonia and Guam since they did not reply. But knowing that OSTORM is very much involved in a lot of GPS surveys in New Caledonia and Vanuatu the Secretariat of the Pacific Group should seek their co-operation and participation in order to achieve the objective of the PCGIAP.

The Department of Lands and Survey Fiji has just purchased another three geodetic receivers in Leica GPS System 300 and this should enhance Fiji's Participation in the project in the future. To the benefit of the Fiji Lands Department the Leica GPS System 200 Units, which were traded in will not be re – exported out of Fiji but donated to an educational organization/ University of the South Pacific. The receivers are still being used by the Department on GPS survey campaigns. Once the Leica 300 System Units are in place, altogether there will be six (6) geodetic GPS receivers in Fiji.

## 4.0 **Observation Sessions and Funding:**

In order to expand the Geodetic Network to all islands in the Pacific more geodetic GPS receivers plus accessories would be required. It is a possibility that some of the receivers in Fiji accompanied by an operator could be flown to these Pacific Group Member Countries to establish at least one permanent station, to begin with during the survey campaign. We also believe that more geodetic receivers could be borrowed from other organizations to assist other islands, provided operators could be available to "bring back the data".

This operation would be very costly and professional operators should be involved. These operators could provide on the job training to local surveyors on these respective islands too. However, the biggest set back would be funding. We anticipate if funding is possible, equipment could be hired and flown together with operators at the expense of the Funding Agent while the other island countries concerned provide accommodation plus meals. Any allowances payable to all operators should also be covered by the fund mentioned above.

## 5.0 **The South West Pacific GPS Project:**

The South West Pacific GPS Project (SWP) is using GPS to monitor crustal motion across and within a plate boundary complex between the Australian and Pacific Plates. Because of the manner in which the islands are located on both sides of trenches and within the broad interarc of the region, it is only possible to use the GPS Satellites to measure inter – island baselines that straddle many of the major tectonic elements of the region.

To achieve this Project an International consortium comprising of more than twenty–five (25) universities and organizations was formed to carry out this program of measurements. The first SWP field campaign was mounted in 1988 and since has extended to cover more islands in the Southwest Pacific Region.

A cost cutting proposal came into place in 1996 and continuous GPS stations were established on the following islands:

- Fiji
- Tonga
- Samoa
- Niue
- Vanuatu
- Solomons
- New Caledonia

There are also several roving stations established too on the above islands including Rarotonga in the Cook Islands.

This scientific – research project is being monitored by the University of Hawaii under the responsibility of Professor Mr. Michael Bevis.

We believe all these islands would have access to the data from the continuous stations and incorporate in their local network adjustments. We would also appreciate if the PCGIAP could request the University of Hawaii so that we could access the data from all the continuous GPS stations in the Pacific Region and incorporate that data in the APRGP network adjustment.

## 6.0 **The South Pacific Sea Level and Climate Monitoring Project:**

When we look at developing plans for the implementation of an expanded observational campaign for national datum and sea level connections we should study the available resources locally. The above project has been ongoing for the last eight (8) years throughout the South Pacific. In 1991 the National Tidal Facility (NTF) of the Flinders University of South Australia was awarded the contract to undertake the management of this Project. This is an Australian response to concerns raised by member countries of the South Pacific Forum countries over the potential impacts of the Greenhouse Effect on climate and sea levels in the region. There are eleven monitoring stations established to provide a wide coverage across the Southwest Pacific basin.

The participating countries are:

- Cook Islands
- Fiji
- Tonga
- Vanuatu
- Samoa
- Tuvalu
- Kiribati
- Nauru
- Solomon Islands
- Papua New Guinea
- Marshall Islands

All stations were operational by October 1994 and although the Federated States of Micronesia (FSM) and Niue are member countries of the Forum, sea level and climate monitoring stations have not yet been established there as part of this Project. Recently, AUSAID has approved funding for the station in FSM.

This project is another of interest since it is well established in most of the Pacific Group member countries. It is also an AUSAID funded project and there should not be any difficulty in accessing the data. I understand that First Order Leveling has been done on all these islands to connect the Tide gauges with well established Bench Marks inland.

## 7.0 **Survey Datums:**

One of the principal purposes of a world geodetic system is to provide the means whereby local geodetic systems can be referenced to a simple geocentric system. The number of local geodetic systems or local horizontal datum's within the member countries, requiring such referencing is extensive. To accomplish the conversion, local geodetic system and WGS coordinates are both required at one or more sites within the local datum area so that local geodetic system – to – WGS datum shifts can be formed. Situations arise where only Local Geodetic System coordinates irrespective of datum, are available for a site and in such instances that datum - to - WGS 84 Transformation can be used to obtain WGS 84 coordinates for the sites. For those island countries using NAVSTAR GPS but still utilizing local geodetic systems and products, the availability of the more accurate WGS 84 – to- Local Geodetic System Datum Shifts will lead to an improved recovery of local coordinates. It is apparent that all Pacific Group member countries are encouraged to adopt the use of GPS to upgrade their mapping datum.

We, the members of the Pacific Group of Island Countries humbly request the PCGIAP to support this expansion of the Network to the fullest in whichever way possible.

## **SUMMARY:**

A regional GIS needs to be based on a regional geodetic datum. Thus all local horizontal and vertical datums need to be related to the regional datum. And participation of all Pacific Island countries in the PCGIAP geodetic campaigns will not only link them to the regional datum but also improve national coordinates and opportunity for increased expertise.

The future of the surveying and cartography professions is only guaranteed if the Pacific Island Group makes a total commitment to the PCGIAP. I believe all member countries in identifying their needs in the development of GIS - the commitment would relate to the development of geodetic surveying, mapping and GIS systems, cadastral mapping and staff training. With this regional cooperation, we the Pacific member countries humbly seek commitment from PCGIAP funding agencies to sponsor regional students in pursuing further studies in geodetic surveying and GIS.

# Status Report on Geodetic Activities of Papua New Guinea

**Mr. Robert Rosa**
**Geodetic Section**
**National Mapping Bureau**
**Department of Lands & Physical Planning**

## 1. Build Up of Primary Network

Since the gazettal of the PNG94 Geocentric Datum on ITRF92 at epoch 1994.0, the programme of data collection with GPS continues on an opportunity basis. The intention is to build up a database so that when the country requires GPS data at a later date to improve the datum or to determine amount of change within time due to plate motion activities within the region it is already on hand. However, as mentioned in the Canberra paper, the gazetted datum on the reference frame is sufficient for the time being and for general-purpose mapping and other related surveys at less precise order.

Continued GPS surveys for the DCDB capture for towns around the country provide extra data to refine or strengthen the tertiary networks. These are the poor connections from the primary control or no connections at all.

The two permanent base stations in the country, MORE and LAE1, track continuously on 24-hour period if additional data is required.

## 2. Vertical Datum

Vertical datum and the Geoid for PNG was presented at the Canberra WG1 workshop in 1998. The Geoid remains, as it was with no national plans or commitments of improvement in the near future. However, more work on precise levelling with connections from one tide gauge to another and for comparison and connections to the Highlands of PNG and the gravity measurements are taken in addition. The purpose is to refine the Geoid with some parts of the country requiring denser gravity measurements and to reduce the uncertainty of about 5m in the geoid undulation.

## 3. Map Updates

The National Mapping Bureau has set its objective of updating the map series based on the old datum, the AGD66. The 1:500,000 TPC series and the 1:250,000 JOG series of maps are being subjected to updates using the new Micro Station mapping technology provided under the ACLMP (AusAid) support program. The 1:100,000 series may be similarly adjusted after the first two series are completed. However, some map sheets have been adjusted on customer driven demand.

The existing maps on AGD66 spheroid are scanned, vectorised, edited, feature coded and finally the transformation from the AGD66 to WGS84 which is very near to PNG94 to the 6$^{th}$ decimal place of flattening.

The updates include information from the GPS locations now underway from the Village Mapping Project in support of the country's census for year 2000 project.

## 4. GIS of PNG

GIS layers being created include the road infrastructure, social services such as health, schools and villages with updates recorded by handheld GPS. Land-use resource layers such as the soils, forestry and the agricultural are being scanned and updated using satellite images.

The village mapping project in support of the 2000 Census and funded by AusAid offered the opportunity in support of the National Mapping primary objective which is to create maps of national interest and at the minimal cost. A complete GIS of PNG can be achieved given time and resources from within the National Mapping Bureau and from the customer driven demand.

### 4.1 DCDB

DCDB being an additional layer of the GIS covering cities and towns is attractive to customers from both the government and private sector. Demands relate to expansions and urban development planning in major centers and the addition of information on utility development.

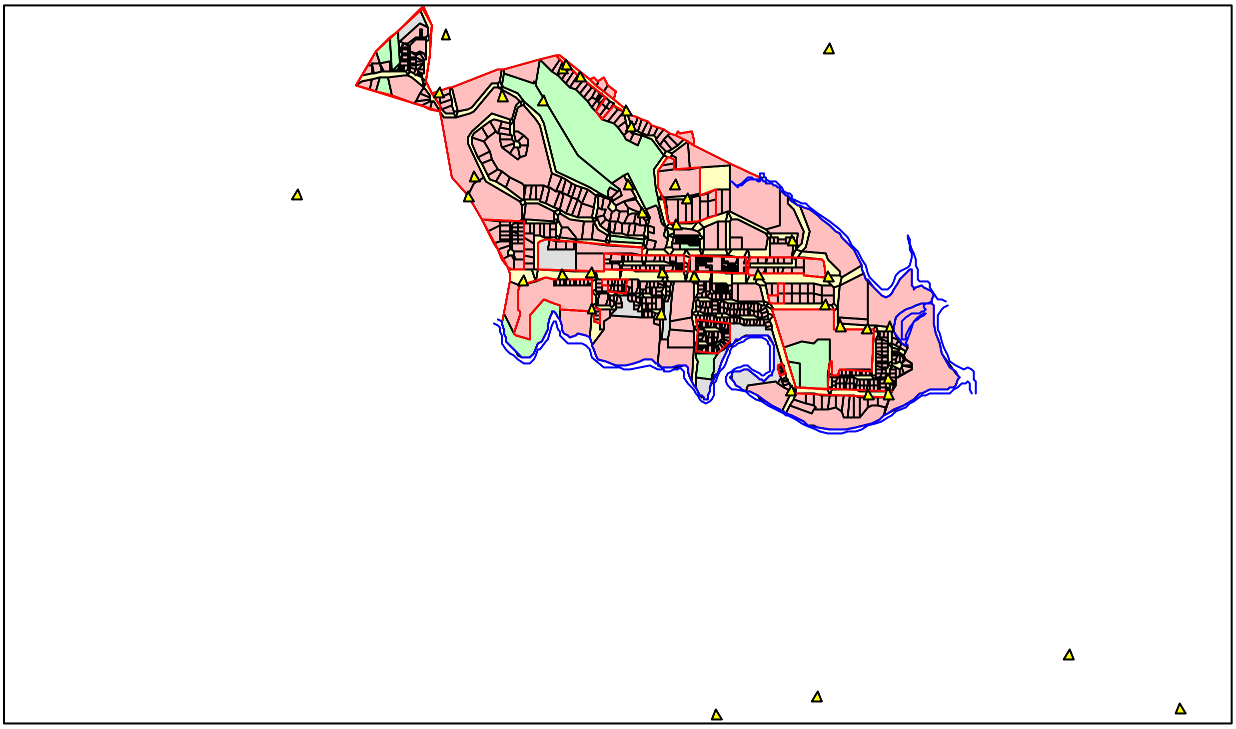


Fig. 2 Shows Kainantu a town in the Eastern Highlands of PNG with in-filled triangles as controls and are connected to the tertiary and the primary network.

The project was commenced as a component of the Australian Contribution to Land Mobilisation Program (ACLMP). The project has been completed but progress is being monitored and happily is progressing well. Commenced in mid 1995 a total of some 40,000 blocks out of the estimated 96,000 have been captured and digitized from the cadastral plans. Accuracy levels are very high, with the result electricity, telephone and water lines match very well.

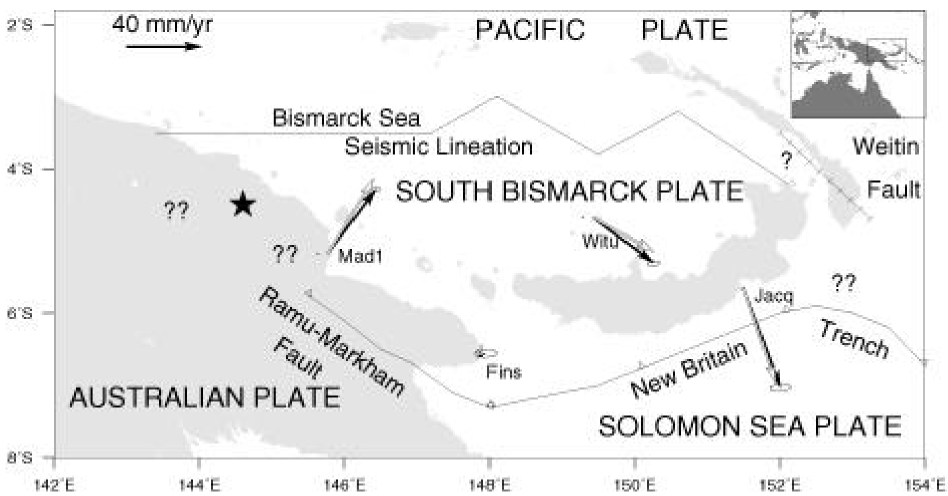
GPS provide the control for the DCDB at the same time strengthens the tertiary networks as described in 1.

**5. Geodynamics of PNG**

The country sits on two major tectonic plates, the Australian and the Pacific plates. Along the major fault line lies the smaller plates, the South Bismarck, Solomon and the trenches within the region. This region is very active with high level of seismic and volcanic activity.

The vector motions of the plates are not uniform along the horizontal plane and vertical motions occur almost at all times undetected. Tectonic motions no longer remains an academic issue as the Tsunami on July 17, 1998 has made history in the country as the worst disaster, killing more than 2200 people in a single natural disaster event.

Earth Science studies from interested Australian Surveying and Geodesy groups, the Australian National University (ANU), University of Tokyo and the University of California have contributed much in terms of resources in implementing surveys. Permanent pillars and devices are installed to monitor movements and the volcanic and seismic activities. Geodynamics of PNG is still a very new and fascinating subject for researches and academics from abroad.




**6. Some Considerations**

The paper describes the status of geodetic studies in PNG in respect to our cooperation with our partners in the Asia and the Pacific Regional Geodetic Project (APRGP). Like some other countries in the region we lack the resources but are conscious of the fact that we cannot sit back and let the other countries progress beyond our reach.

Some considerations and area of our shortfalls are:

- PNG does not have the software compatible to other countries such as the GAMIT and GLOBK, therefore our participation in the program is only in data collection.
- The compilation of the PNG94 datum lacked full national participation at the time.
- Staff of the National Mapping Bureau will need basic training on the use of Gravity meter.
- Some basic training on the theory and compilation of the Geoid
- Some considerations for the type of dutum due to the tectonic motion.
- Major national projects will need support from external organizations.

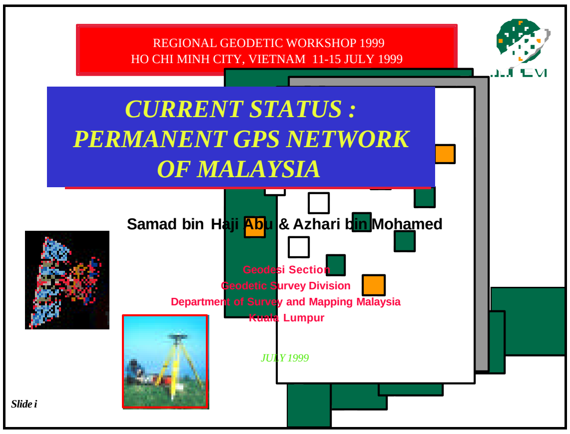
## 7. Conclusion

Technology transfers at levels of technical expertise is very low. Compounded by the country's economic problems this area, Geodesy, is crippled due to the governments restructure programs.
Certainly the country will have to refine the horizontal and vertical datums further.

# Malaysian Permanent GPS Network

**Mr. Samad Binhajiabu**

**Malaysia**




## *Status of GPS Activities in Sarawak*

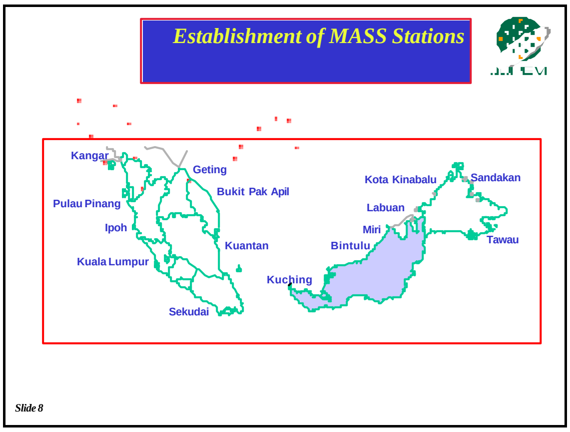
**Summary of Presentation:**

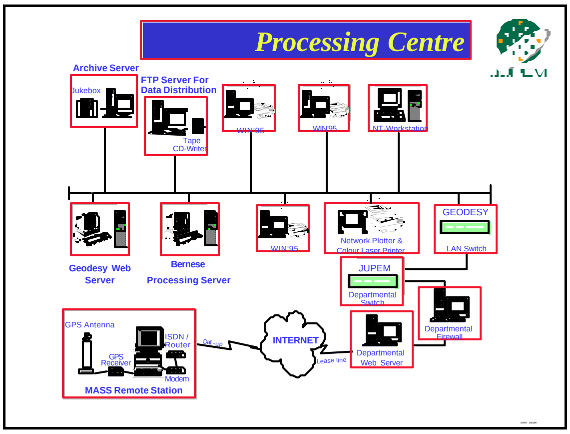
- *GPS at DSMM*
- *Objectives and Applications*
- *Establishment of MASS Stations*
- *Processing Centre*
- *Processing Results*
- *Capability of MASS*
- *Future Outlook*
- *Conclusions*

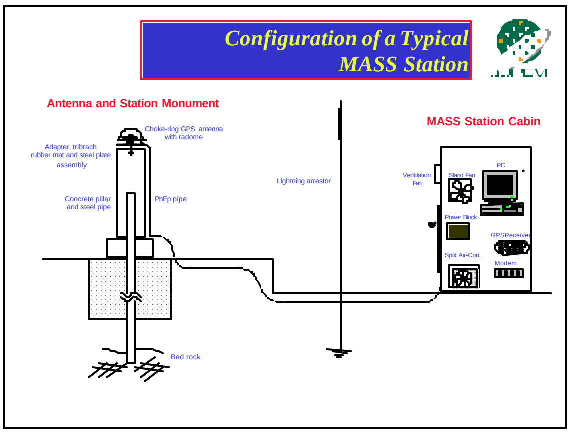
*Slide 1*

## *GPS at DSMM*

- *Nowadays, the advent of Global Positioning System or GPS has prompted DSMM to explore the possibilities of using this new technology in order to keep abreast with the latest development in surveying.*
- *GPS has been introduced at DSMM in 1987. To date, it has been used in the establishment of GPS networks in Malaysia. The presence of these 'passive' networks serve their purpose relatively well, especially in mapping and engineering applications.*
- *However, nowadays most precise applications of GPS make use of 'active' GPS networks. The concept of the Malaysian Active GPS System or MASS for short has been evolving at the DSMM since 1997. In early 1998, the establishment of MASS is launched under the 7th Malaysian Plan.*



## Current Status of MASS Stations

| Location | Type of Station | Antenna / Receiver Type | Progress to Date |
|---|---|---|---|
| Arau | CCP | Choke Ring / Trimble 4000SSI | 100 % ((In operation since 19.11.98 ) |
| Pulau Pinang | CCP | Choke Ring /Trimble 4000SSI | 60% (Awaiting building of the monument) |
| Ipoh | CSP | Choke Ring /Trimble 4000SSI | 100 % (Awaiting Installation of Rcv /Ant) |
| Kuala Lumpur | CSP | Choke Ring /Trimble 4000SSI | 100 % ((In operation since 19.11.98) |
| Skudai | CCP | Choke Ring /Trimble 4000SSI | 100 % ((In operation since 8.2.99) |
| Kuantan | CCP | Choke Ring /Trimble 4000SSI | 100 % (In operation since 19.8.98) |
| Getting | TG | Geodetic / Trimble 4000SSI | 100 % ((In operation since 18.12.98) |
| Bukit Pak Apil | BR | Choke Ring /Trimble 4000SSI | 100 % ((In operation since 15.12.98) |
| Kota Kinabalu | CCP | Geodetic / Trimble 4000SSE | 100 % (In operation since 29.8.98) |
| Sandakan | CCP | Choke Ring /Trimble 4000SSI | 100 % (Awarding electricity supply) |
| Tawau | CCP | Choke Ring /Trimble 4000SSI | 100 % (Awarding telephone connection) |
| Labuan | CCP | Choke Ring /Trimble 4000SSI | 100 % ((In operation since 16.1.99) |
| Kuching | CCP | Choke Ring /Trimble 4000SSI | 100 % ((In operation since 8.12.98) |
| Miri | CSP | Geodetic / Trimble 4000SSI | 100% ((In operation since13.1.99) |
| Bintulu | CSP | Choke Ring /Trimble 4000SSE | 100 % (In operation since19.8.98) |

Note: CCP : Cylindrical Concrete Pillar, CSP : Cylindrical Steel Pillar, TG : Tide Gauge, BR : Bed Rock

*Slide 9*

## MASS Stations

- OBJECTIVES:
  - To permit maintenance of the National Coordinate System at the 1 cm-level
  - To monitor vertical and horizontal crustal motion
  - To standardise aspects of reference station operation
  - For non-positioning applications such as ionospheric and atmospheric water vapour determination
  - Geodynamic and other scientific studies
- APPLICATIONS:
  - Survey/Mapping - single receiver positioning (post-processed), GIS system integration, CCS, Map completion
  - International Collaboration - support for GEODYSSEA, GIXSEA, APGI
  - Environment - Tide gauge monitoring

*Slide 10*

## MASS Stations in Sarawak




*Slide 10*

## Connection to Local Systems


- Peninsular Malaysia - onnected to 4 existing Doppler stations & 2 tide gauge stations
- East Malaysia - Connected to 3 existing Doppler, 2 primary, 2 tide gauge and 1 GEODYSSEA stations

## GPS Processing by Bernese v 4.0

Connection to IGS Stations in ITRF97

↓

Getting Transformation Parameters for both Peninsular and East Malaysia

↓

Getting Coordinates in Rectified Skew Orthomorphic (RSO)

The derived RSO coordinates are still in two different systems although based from ITRF97.

In order to have one system a new projection system such as UTM projection should be adopted

## Relationship between Global and local

**ITRF97 to BT**

Dx = 570.59429 ± 19.89316 m

Dy = -662.93077 ± 11.85836 m

Dz = 107.84636 ± 33.53176 m

Rx = 1."78707 ± 0."99086

Ry = 0."37657 ± 0."56729

Rz = 3."10724 ± 0."66163

Scale = -8.53257 ± 1.66794 ppm

*Using 7-parameter Bursa Wolf*

Note: BT - Borneo Triangulation

**ITRF97 to MRT**

Dx = 383.77607 ± 53.55985 m

Dy = -774.28054 ± 13.17594 m

Dz = 81.72451 ± 32.82780 m

Rx = 2."40272 ± 1."06787

Ry = 2."04503 ± 0."67491

Rz =-12."21745 ± 1."77945

*Using 6 parameter Bursa Wolf*

Note: MRT - Malayan Revised Triangulation

## Comparison

**Published based on WGS84 & Derived based on ITRF97**

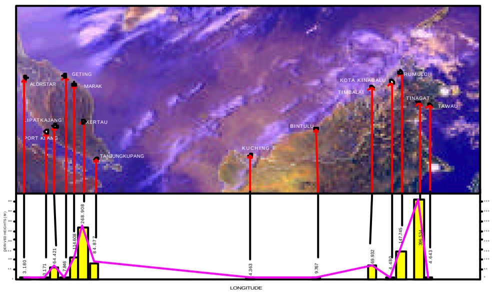
| | Derived | Pub | Diff |
|---|---|---|---|
| Dx | 570.594m | 552.583m | 18.011m |
| Dy | -662.931m | 668.048m | - 5.117m |
| Dz | 107.846m | 90.486m | 17.360m |
| Rx | 1."78707 | 1."23482 | 0."55225 |
| Ry | 0."37657 | 0."25170 | 0."12487 |
| Rz | 3."10724 | 3."72208 | 0."61484 |
| Sc | -8.53257 | -8.61029 | -0.07772 |

For BT , Derived - 5 common points & Published - 49 common points

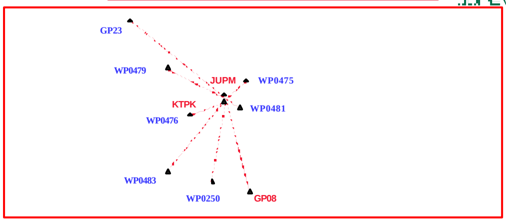
| | Derived | Pub | Diff |
|---|---|---|---|
| Dx | 383.776m | 379.776m | 4.000m |
| Dy | -774.281m | -775.384m | 1.104m |
| Dz | 81.725m | 86.609m | -4.884m |
| Rx | 2."40272 | 2."59674 | - 0."19402 |
| Ry | 2."04503 | 2."10213 | -0."05710 |
| Rz | -12."21745 | -12."11377 | - 0."10368 |

For MRT , Derived - 4 common points & Published - 29 common points

## Malaysian Heights Derived From EGM96

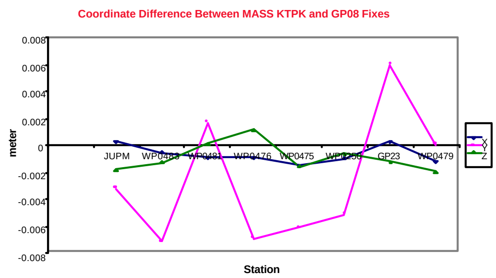


## MASS Capability




- *The objective of the test is to access the validity and accuracy of KTPK MASS Station data*
- *GPS data from 8 stations were collected within Kuala Lumpur area*
- *For processing:*
  - *2-hour's worth of data were used { 4 March 1999 }*
  - *Trimble GPSurvey version 2.0 GPS Post-Processing Software*
- *Results presented in terms of coordinate differences obtained from independent processing from KTPK, JUPM and GP08 stations*

## Results and Analysis




## Future Outlook

**MASS Network**

- **A Fully Automated Operation:** Additional enhanced software including scripts for automatic dialling, data downloading, storage, archive, distribution and processing
- **An Easier User Accessibility:** Station information, raw GPS data, GPS broadcast ephemerides, almanacs and precise ephemerides data to be available in a number of different formats, Internet access, construction of Geodesy Section Homepage / Website
- **An Efficient Data Transfer and Communication:**
  - To date, experience with some MASS stations has exposed a few 'unexpected' issues, such as:
  - System security, functionality and stability:
    - *Firewall against potential hackers, infiltration of viruses etc.*
    - *Software conflicts and compatibility*
    - *Frequent breakdowns and communication / power cut-off*

## Conclusions

- *MASS GPS data and products will offer the public an economical way of carrying out GPS surveys for various type of applications*
- *The degree of accuracy obtained from the preliminary results ensures that MASS can meet geodetic, cadastral and mapping requirements*
- *An extensive testing and quality control of MASS is needed on a continuous basis throughout its period of initial operation to check the stability and functionality of the system*

# Status of existing geodetic networks of iran

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## Introduction :

Geodetic network has been started before Islamic Revolution of Iran (1979) which were done by co-operation of DMA and National Geographical Organization but after revolution, the revolution council gave the responsibility of geodetic network establishment to National Cartographic Center (NCC). From that time, NCC has worked on Horizontal Geodetic Network, Vertical Network (precise levelling), Geoid, Gravity Network and geodynamics.

### *1. Horizontal Geodetic Network :*

During 1979 –1986 a classical triangulation network was established by NCC with 245 stations, with average distance of 60km.This network covered only part of Iran. After 1996, NCC established the 1st order GPS network with distance about 100km, having about 300 stations covering the whole of Iran, Because this network was measured with single frequency GPS receivers so that it had some systematic errors. In 1991, NCC established the Zero order network with 10 stations. These stations are spaced in about 600km and are common with 1st order stations. The zero order network was measured with dual frequency GPS receivers for 3 days after and connected to IGS network . After adjustment we got the accuracy about 10cm and the relative accuracy is better than 1PPM.

After connection the 1st order network to the zero order network, the accuracy of that to 5-10PPM. NCC has also established 2nd order with spacing 25km, with about 2800 stations.

### *2. Vertical network :*

In Iran, NCC has five tide guage beside sea and after analysing the measurement on the level of one of them used as reference height system. There are 3 kinds of levelling networks, 1st order, precise levelling is about 31000 km along major roads with spacing distances of about 2 km with accuracy of 1mm. In Iran also there are 2nd and 3rd order levelling networks which are 27000 km and 25000 km respectively, of which 75% have been completed up to now.

Now NCC is going to re-measure the 1st order one by digital precise levells.

### *3. Geoid :*

In 1991, NCC determined the Geoid for country with cooperation of IFAG, Germany with OSU89 model in combination with 13000 gavity data. The absolute and relative accuracy is 1.5m and 25cm respectively. Now a group of NCC's scientists are studying on Iranian Geoid and going to determine it with new models and data.

### *4. Gravity network :*

NCC has two relative gravimeters and measure 1st order and 2nd order levelling networks gravity for levelling correction and Geoid determination.

Recently, a base gravity network with 20 stations were designed for Iran. The stations are located in Airports. Some of these stations will be measured by absolute gravity meter with cooperation of foreign country.

### *5. Geodynamics :*

Different geodynamics projects such as Tehran Fault monitoring, Zagros and Caspian Geodynamics Projects are studied with GPS, Gravity and levelling measurements. These projects are done with cooperation of Iran's Geological Survey and Siesmology and Earthquake Institutes.

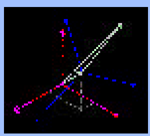
For sudying geodynamical phenomenon and improving reference coordinate system a permanent GPS stations is established and measures continuously. The permanent GPS stations will be increased to 7 up to end of this year.

These stations will also send DGPS corrections to users with cooperation of Radio and Television Organization in RDS-FM Format.

# Transformation from local to regional datum

**Mr. John Manning**
**Australia**

## Transformation from Local to Regional Datum



Permanent Committee for GIS Infrastructure for Asia and Pacific
Regional Geodetic Network Workshop
Ho Chi Minh City, Vietnam
12-13 July 1999

## The Ideal Solution

Re-adjust onto the regional datum

- Rigorous - no transformation required
- Need original, or new, observations
- Usually results in an improved network
- Requires global fiducial points, connected to the local network

## The Practical Solution

Transform onto the regional datum

- Original observations not required
- "Common points" required
  - Points which have both local and regional positions
- No clear-cut guidelines

## Transformation accuracy

Transformation accuracy depends on:

- Number, distribution and accuracy of the common points
  - How well do they represent the local (and regional) network?
  - Are there localised biases in the local network?

## Transformation Methods

- Molodensky's formulae
- 7 parameter (Bursa-Wolf)
- Surface interpolation

## Molodensky's Formulae

- Simple formulae
  - $\Delta X$, $\Delta Y$, $\Delta Z$ and change of ellipsoid
- No coordinate conversion required
  - Directly transforms Latitude & Longitude
- *WGS84* parameters possibly available
  (but probably not very accurate)

## 7 Parameter Transformation

- Minimum 3 common points
  - many more required for accuracy & redundancy
- More complex
  - ΔX, ΔY, ΔZ, Rx, Ry, Rz, Scale change
  - Must use Cartesian coordinates (X Y Z)
  - Need ellipsoidal heights
- Assumes internally consistent networks

## Surface Fitting

- Potentially the most accurate
- Probably the most complex
- Many common points needed
- Examples:
  - Minimum curvature (USA - NadCon)
  - Multiple Regression (Canada)
  - Collocation (Canada - and Australia)

## Australian Experience

- 7 parameter & Molodensky parameters (AGD - GDA94)
  - To cater for different user and software needs
- Solutions used 327 common points (GPS determined with accurate heights)
- Checked with ~1500 common points

## Australian Experience

- 7 parameter transformation
  - ~1 metre accuracy
- Molodensky transformation
  - ~5 metre accuracy
- Collocation
  - <0.1 m accuracy expected

## Possible Strategy

✓ Obtain regional (ITRF) positions at key sites
✓ Propagate ITRF to local network sites (GPS)
✓ Use a common points to compute transformation parameters
✓ Check residuals on common points to assess accuracy
? If necessary, obtain more common points and repeat the process

# Strategy for Computation of Transformation Parameters from Local Datums to Regional Datum

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## 1- Introduction

Working Group 1, Regional Geodetic Network, in 5th PC GIAP meeting in Beijing in April 1999 Reached some conclusions which set general directions of working group.

In one of them WG decided that the reference frame for geodetic applications in the Asia and the Pacific be the International Terrestrial Reference Frame (ITRF) and that the GRS80 ellipsoid be use for horizontal computation within that reference frame, so that all spatial information from individual countries can be readily assembled into a unified regional spatial data infrastructure for GIS purposes.

As there are several local Geodetic datums in the Asia and Pacific that are used by different countries and up to now are used for mapping, Geodetic and GIS applications, so it is necessary to link these local datums to regional datum and transfer all previously produced data in local datums to regional datum.

This paper is tried to discuss on different datum transformation models for Asia and Pacific region.

## 2- Datum Transformation Models :

There are different methods and models for transforming coordinates from one datum to another and depends to accuracy which is needed for example in navigation purposes the needed accuracy is about ±100meter or GIS application about 1-10meter or in surveying application the decimeter accuracy is needed so for each applications and accuracy different methods are proposed.

The best method with high accuracy is to readjust each individual country's geodetic networks on regional geodetic datum(ITRF) for provision of spatial data on this uniform datum.

Several procedures are available to help the users to convert coordinates from local datum to regional datum and vice versa, Featherstone and Langley 1997, Vanicek and Krakiwsky 1986.

These procedures can be divided into three categories: simple block shifts, similarity transformations, and multiple regression equation method.

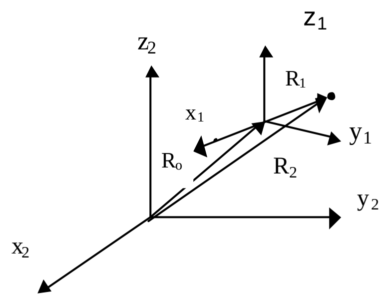
- **Block Shift :** the shift is conceptually the simplest transformation approach and also the coarsest. In this approach the differences of latitude and longitude in regional with local datum is computed in different part of the area and key points. Because of its low accuracy, this approach is used for some application such as navigation.

- **Similarity transformation**: Similarity transformations can be applied by one of two main approaches. The first, known as the Bursa-Wolf transformation, is suited for conducting between satellite derived datums.

Figure 1

$$R_2 = R_0 + (1+m) R_{xyz}(e_x, e_y, e_z) R_1 \qquad (1)$$

This model consists of three axis translation of the system origins given by the vector $R_O$ and involves three small rotations about the coordinates axes $(e_x, e_y \, and e_z)$ and a scale difference




$$R_2 = R_0 + (1+m) R_{xyz}(e_x, e_y, e_z) R_1$$

$$\text{Where } R_{xyz} = \begin{bmatrix} 1 & e_z & -e_y \\ -e_z & 1 & e_x \\ e_y & e_x & 1 \end{bmatrix}$$

Figure 1

The second similarity transformation is Molodensky - Badekas model that here we call Molodensky and is more appropriate for transformations between satellite and terrestrial datums.

The only computational and conceptual differences between these methods is which origin points is used for transformation.

Seven parameters are normally required to carry out similarity transformations using either of the two approaches. The exact implementation of these similarity models usually varies from country to country and depends on availability of common points in both the local and regional datums and the distribution of the points in the country.

Again depending on availability and distribution of common points in both datums may be 3 or 4 or 7 transformation parameters computed in the particular area with a sufficient number of common points. Users can derive their own transformation parameters to attain GPS coordinates that are fully compatible with local geodetic control.

- **Multiple Regression Equation:** This method was initiated to obtain better fits over large areas because of errors that occurred during the original surveys to establish the local geodetic datum.

These errors can now be detected using the more precise GPS surveys.

These method can provide better accuracy than the similarity transformation because of their ability to rectify datum errors, and because they are typically accurate to a few meters. (Featherstone and Langley 1997).

### 3- Some Experiences

Some studies were done by several people on real data (Deakin and etal 1994, Steed 1998, Tavakoli 1999) These experiences shows that if the Molodensky model with 7 parameters and 3 parameters were used the accuracy of the parameters depending on the number of common points for examples for 16 points of Australia (Deakin and etal 1994) 7 parameter transformation was done with following results and also 3 parameter transformation was done with the same data and the following results were reached :

| | | | | | |
|---|---|---|---|---|---|
| Omega | = | -0.″160 | & | SD (Omega) | = 0. ″372 |
| Phi | = | 0. ″504 | & | SD (Phi) | = 0.″490 |
| Kappa | = | -0.″045 | & | SD (Kappa) | = 0. ″259 |
| Scale | = | 1.000010037018 | & | SD (Scale) | = 0.000001169644 |
| dx | = | -129.811 | & | SD (dx) | = 11.2763 |
| dy | = | -57.269 | & | SD (dy) | = 9.2785 |
| dz | = | 167.046 | & | SD (dz) | = 14.5347 |

3- transformation parameters (Translations) are for transformation of coordinates from AGD66 Coordinate System to WGS84 coordinate system.

| | | | | | |
|---|---|---|---|---|---|
| dx | = | -162.928 | & | SD(dx) = | 0.2500 |
| dy | = | -26.092 | & | SD(dy) = | 0.2500 |
| dz | = | 129.571 | & | SD(dz)= | 0.2500 |

The results show that with decreasing in number of the unknown transformation to 3 translation parameters the standard deviation of the parameters decreased from 4 metre-14 metre to 0.25 metre.

Same result was derieved by 10 common points from Iran's data which are as follows:

7 parameters results :

* * * * * * * *     7 - PARAMETER TRANSFORMATION MODEL * * * * * * * *

-----------------------------------------------------------------------------------------------------

| | | | | |
|---|---|---|---|---|
| Omega | = +0.″660 | & | SD (Omega) | = 0. ″155 |
| Phi | = 1.″792 | & | SD (Phi) | = 0.″148 |
| Kappa | = 2.″020 | & | SD (Kappa) | = 0.″135 |
| Scale | = 1.000047320287 | & | SD (Scale) | = 0.000000538801 |
| dx | = -32.362 | & | SD (dx) | = 4.4887 |
| dy | = -84.820 | & | SD (dy) | = 4.1225 |
| dz | = -206.708 | & | SD (dz) | = 4.8799 |

-----------------------------------------------------------------------------------------------------

3 parameter result:

* * * * * * *  3-  PARAMETER TRANSFORMATION MODEL * * * * * *

3-  Transformation parameters (Translations) are for transformation of coordinates system.

-----------------------------------------------------------------------------------------------------

| | | | | |
|---|---|---|---|---|
| dx | = -192.359 | & | SD(dx) = | 0.3162 |
| dy | = 263.787 | & | SD(dy) = | 0.3162 |
| dz | = -24.450 | & | SD(dz) = | 0.3162 |

-----------------------------------------------------------------------------------------------------

Jim steed(1998) also had a summery of transformation methods used in Australia which was showed in figure 2.

With noting to the number of common points in both datums we can find that in area with few points(such as 5 point ) it is better to use 3 parameter Moldensky models which it and seems that gives better accuracy than 7 parameter model.

**4- Proposal**

In Asia and the Pacific there are more than 20 datums which are used by different countries. With noting that in APRGP98 about 5 points in key points were measured so we have few points in both local datum and regional datum, ITRF, so at this stage we can not use multiple regression equations and we can use only the 3 or 7 parameters models and block shift for Asia and Pacific region.

**5- Conclusion and Recommendation**

1- In 1999 more points of local datums Recommended would be measured by space based systems in ITRF coordinate system.

2- In the first stage for low accuracy applications, differences of coordinates of points in both datums were computed for the area.

3- 7 parameters similarity models is good enough for region but at this stage the number of points are not enough and we can not get accuracy better than several meters.

4- At this stage it is recommended to use 3 parameter Moldensky model.

5- In the next years with increasing the number of common points in both local and ITRF datum we can use 7 parameter similarity transformation or multiple regression equation model.

| Date | Coords | Method | Region | No.points Used | Estimated Accuracy |
|---|---|---|---|---|---|
| 1978 | AGD66&AGD84-WGS84 | Manual graphical | Australia | 106 | 1 Metre |
| 1987 | AGD84 - WGS84 | 7 Parameter - similarity | Australia | 106 | 2 Metre |
| 1987 | AGD66&AGD84-WGS84 | 3 Parameter Molodensky | Australia | 105& 90 | 5-10 metre |
| 1988 | AGD66 - WGS84 | Multipie Regression | Australia | 105 | 2-5 metre |
| 1993 | AGD66 - WGS84 | 7 Parameter - similarity | New Spitj Wales | 30 | 2 metre |
| 1997 | AGD66&84-GDA84 | 3 Parameter Molodensky | Australia | 161 & 327 | 3 metre |
| 1997 | AGD84-GDA94 | 7 Parameter - similarity | Australia | 327 | 1 metre |
| PROPOSED | AGD66 & 84- GDA94 | Surface fit with distortion modelling | Local regions extended as required | Thousands | ∠0.1 metre |

**(Figure 2) Summary of transformation methods used in Australia (Jim Steed 1998)**

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# BRIEF PRESENTATION IN THE REGIONAL GEODETIC NETWORK WORKSHOP 1999

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Ladies and Gentlemen:

On behalf of The Lao National Geographic Department, I would like to express my appreciation to the Permanent Committee for GIS Infrastructure for Asia and The Pacific for inviting us to this Workshop and, AUSLIG for technical assistance. I also would like to express my appreciation to the Research Institute of Land Administration of Vietnam and Finnmap International Oy who are our sponsors, and also Mr. Michael Sheinkman from Management Support Technology Inc. who has been providing the operational funding for our field observation campaign.

Ladies and Gentlemen:

It is the first time in our history of The Lao NGD to have a good opportunity to develop an international relation regarding a Regional Geodetic Network. The 1998 Regional GPS observing campaign contributed significantly for the establishment of The Lao National Geodetic Network, and we expect that the final results of GPS data set can then be used for strengthening of our Geodetic Network which we are awaiting eagerly. More- over, we are very proud since it is the first time the observing campaign is conducted by the NGD staff using seven high precision P-code,dual-frequency GPS receivers which included 3 GPS Trimble 4000Ssi,and 4 Leica series 300. This was a landmark event, as all earlier geodetic network surveys in Lao had been conducted by foreigners.

With regard to the suggestions of AUSLIG and also of the international expert from Department of Administrative and Information Service –South Australia Mr. Andrew Dyson, we selected seven sites, which provided the best coverage over Laos. Even though the field observation was conducted during our late rainy season, we experienced a lot of difficulties to access to the sites particularly in the south of the country because of the road conditions.

Now, I would like to draw your attention to the brief Lao's Geodetic History.

Lao Geodetic infrastructure reflects the international influences that have affected the country during the past century. Essentially, this infrastructure is the result of four waves of activities.

**First came France**. France commenced the first substantial geodetic network in Laos in 1902. It took the form of a first-order triangulation network comprising 47 stations. By 1955, approximately 65 percent of the points had been destroyed. We are uncertain how many of the markers remain today.

**Then the United States.** Between 1963 and 1975, the U.S. Army Map Service and Defense Mapping Agency produced three series of 1:50,000 scale maps based on the remaining French control network. Most of the associated computations were performed on the Indian Datum of 1960 using the Everest Spheroid.

**The Soviets.** In 1982, in cooperation with the Soviet Union, the Lao National Geographic Department initiated a new geodetic survey to provide control for small-scale mapping. Its central core comprised second order traversing, which spanned the western side of the country from Vientiane, the nation's capital, to Southern Lao and also across the country from Savannakhet to Sepon. This survey defined a local geodetic datum, referred to as the Vientiane Datum of 1982. This datum was based on astronomic observations at the Vientiane (Nongteng) survey station. It defined the spheroidal height of the origin as being equal to its mean sea-level height. The survey adopted the Krassovsky ellipsoid as its reference figure.

**Vietnam.** During October and November 1993, the NGD conducted a geodetic survey of Lao. This time, the surveyors used GPS with technical support from the Socialist Republic of Vietnam's Department of Geodesy and Cartography. The GPS geodetic network comprised a primary and two secondary networks. The surveyors used dual-frequency receivers to measure the primary network, which consisted of 25 stations. They also incorporated five of the earlier Soviet stations, including the Vientiane origin. The survey team located the two secondary networks in the Vientiane area and the country's southern region, measuring them with single-frequency receivers. These two secondary networks consisted of 66 stations and incorporated three more of the Soviet stations.

To support the results of this GPS survey, the NGD adopted a new local datum. Referred as to the Lao Datum 1993, its origin was defined by the Vientiane Datum 1982 coordinates at Paksan. The Krassovsky ellipsoid was again adopted as the reference figure. The datum was aligned so that its *X,Y,Z* Cartesian coordinates axes were parallel with those of WGS 84.

**The Lao National Datum 1997.**

In 1997, under the Land Titling Project the World Bank loan enabled the purchase of four dual-frequency P-code Leica GPS receivers,ancillary equipment, and operational funding, and Australian funded technical assistance provided the training and technical advise for NGD. With this assistance NGD was able to complete the GPS observations to strengthen the 1993 observations and provide the necessary level of redundancy. Additional observations were made to define WGS 84 at the 5-meter level (horizontal) and 10 meter level (vertical). The network was readjusted, a new datum defined and transformation parameters developed to relate the various datums and WGS 84. The geodetic datum was defined to accompany the network. It is referred to as **The Lao National Datum 1997.** The new datum was created to resolve uncertainties, which currently surround existing Lao geodetic datums. It is suitable for all survey and mapping activities.

**Datum Definition.**

The Lao National Datum 1997 is defined by the following parameters:

| | |
|---|---|
| **Spheroid** | **Krassovsky ( a = 6378245.000, b = 6356863.018)** |
| **Origin Station** | **Vientiane (Nongteng) Astronomic pillar (36201)** |
| **Latitude** | **N 18 01 31.3480** |
| **Longitude** | **E 102 30 57.1367** |

**Spheroidal Height 223.824 metres**

**Relating LAO 97 and WGS 84.**

We generated transformation parameters relating LAO 97 to WGS 84 using a three-parameter model. We selected the Cartesian *X,Y,* and *Z* translations relating the centers of the two spheroids as the parameters.We chose this model because of the limited aerial extent of the Lao PDR.

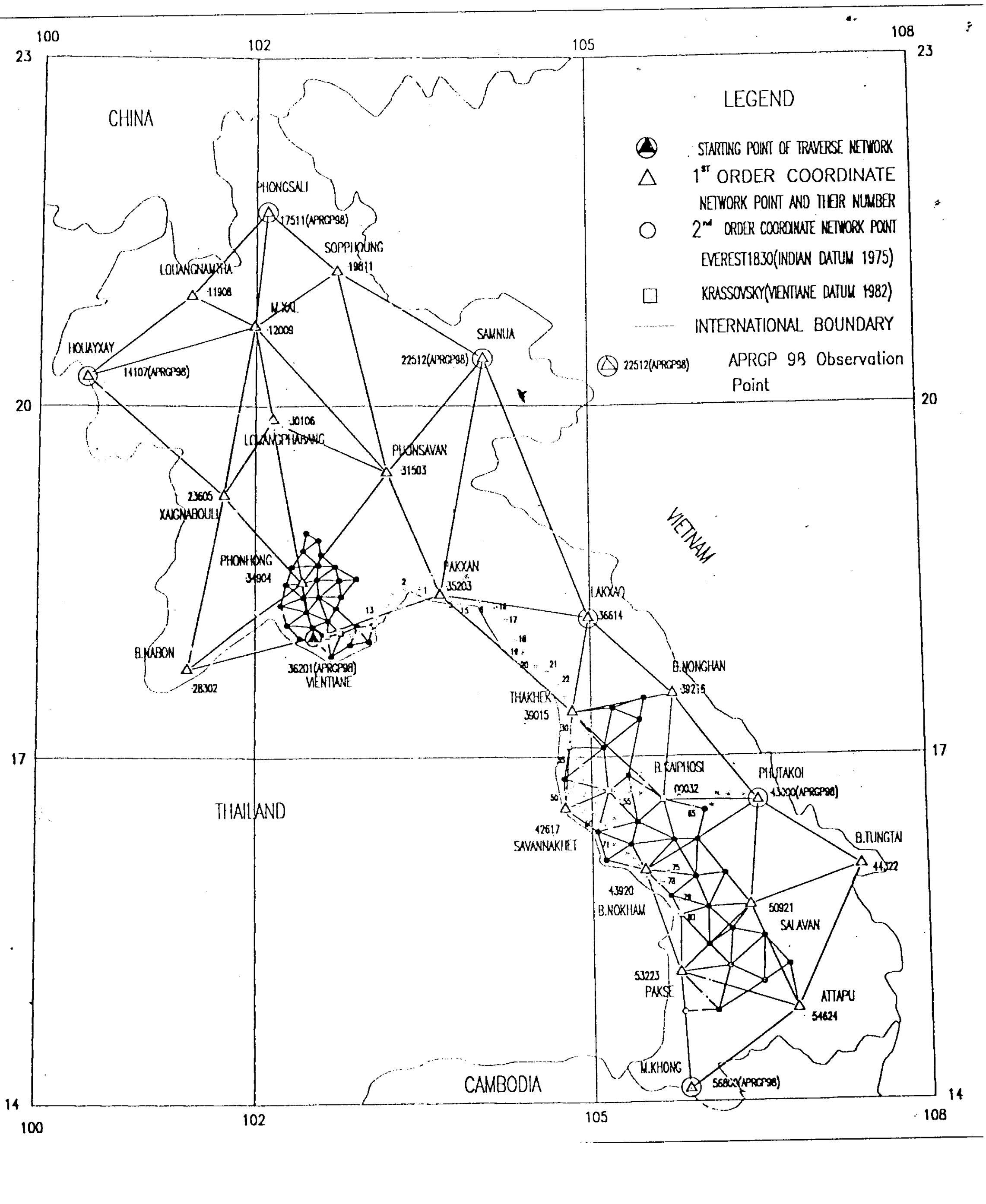
The transformation parameters aaded to LAO 97 geocentric Cartesian coordinates to produce WGS 84 Cartesian coordinates are:

DX = +44.585 meters

DY = -131.212 meters

DZ = - 39.544 meters

## NATIONAL COORDINATE CONTROL NETWORK OF LAO PDR



# REPORT TO IUGG ON GEODETIC NETWORKS IN SE ASIA 1995 -1999

**Mr. John Manning /Australia**
**Mr. Junyong Chen/China**

This is a report to Commission X on Geodetic activities in the Asia Pacific from the Sub Commission on SE Asia which was reformed in 1998.

International co-operation in Geodesy at the national level is coordinated through the Regional Geodetic Network Working Group of the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP).

As the objectives of Commission X are close to the aims of the Regional Geodetic Networks Working Group it was sensible to reform the sub commission from Working Group representatives.

## Background

The Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) was established by the United Nations Regional Cartographic Conference for Asia and the Pacific (UNRCC-AP) at its triennial meeting in Beijing, May 1994. PCGIAP operates under, and reports to, the UNRCC-AP.

There are 55 member nations of the PCGIAP as defined by the United Nations. The countries span a wide part of the globe from Iran and Armenia in the west to French Polynesia in the east; from the Russian Federation and Japan in the north to New Zealand and Australia in the south.

Membership of PCGIAP comprises directorates of national survey and mapping organisations and equivalent national agencies of the nations from Asia and the Pacific. Each nation nominates a single representative but may invite experts as advisers.

**The aims of the PCGIAP are to:**

Maximise the economic, social and environmental benefits of geographic information in accordance with Agenda 21 by providing a forum for the 55 member nations from the Asia and the Pacific region to cooperate in the development of the Asia-Pacific Spatial Data Infrastructure (APSDI) and contribute to the development of the global infrastructure.

***Two of the key PCGIAP objectives are to:***

- ♦ Design a strategy for the development of a regional geodetic framework and topographic data bases as the basis for regional GIS activity.
- ♦ Determine the need for research, training and technology exchange in relation to the beneficial impact of geographic information on the social, economic and environmental objectives of member nations of Asia and the Pacific region.

The primary role of the PCGIAP working group is to facilitate a single regional datum through a linkage of compatible geodetic datums. This is fundamental to the development of an Asia Pacific Spatial Data Infrastructure (APSDI) which requires that:

- A reference regional datum be established, and

- Transformation values be determined between the regional datum and the local geodetic datums of the individual countries.

These then permit a homogeneous spatial data set to be readily assembled from national spatial data sets based on local datums.

### Working Group activities 96-99

At the inaugural meeting of the Working Group in 1996 in Sydney a number of project responsibilities were identified and a program of regional geodetic activities endorsed. The initial activity of the Geodesy Working Group was to establish a precise regional geodetic network as a high-level reference framework.

Another area of activity identified was the investigation of techniques, which can be used to transform national spatial data into a single spatial data set in the region.

An additional role for the Working Group has been to gather information on geodetic datums used within the region. Australia has listed best known information on existing geodetic datums for all countries in the UN Asia Pacific Cartographic region on the PCGIAP Web site at URL www.percom.apgis.gov.au. A feedback mechanism has been established on the Web page to amend any incorrect, or out of date, entries.

### Asia Pacific Regional Geodetic Network (APRGP' 97)

One of the core projects in the region has been the establishment of a Regional Geodetic Network with a geographical spread covering the Asia and the Pacific Region, from Central Asia to the Western Pacific.

In October 1997 an Asia Pacific Regional Geodetic Project (ARGP97) campaign observed to establish an overarching geodetic frame work for the integration of national geodetic datums in the region. In the ARGP97campaign both the Radio Techniques (GPS, DORIS), and space techniques (SLR, VLBI) were employed. The data acquired by participating countries during this campaign was assembled in Australia, which distributed the data for immediate use by Asia Pacific member countries.

A results workshop was subsequently hosted by AUSLIG in Canberra 2-4 July1998. Representatives from ten member countries of the PCGIAP attended the workshop, presenting and analysing results from the 1997 campaign, thus concluding the core component of the project, leading to the finalisation of a set of results. (AUSLIG 1998, papers available through PCGIAP web site) The observational data set was then made available to regional scientific researchers.

### GPS Results from ARGP97

Four members presented independent results from processing the APRGP97 GPS data set:

- Indonesia
- Japan
- China

- Australia

The first three countries used GAMIT to process the data set utilising the final IGS orbit product. Solutions were then generated using GLOBK producing SINEX files as outputs. Australia computed precise global orbits in the Regional GPS solution process using MicroCosm and generated a campaign solution using the SOLVE program. The results presented showed good agreement and demonstrated a significant achievement in technology for those involved. It was noted that Malaysia and Iran are also close to also establishing high precision GPS processing capability in their analysis centres whilst smaller countries such as Vietnam and PNG were working with receiver manufacturers proprietary software such as PRISM.

The workshop examined the options for definition of a regional geodetic datum in a global setting and recommended an interim ITRF product based on a combined GPS solution, pending further work on an integrated solution of all techniques utilising ground ties at collocated sites. The APRGP97 campaign produced significant results, but also has achieved a degree of technology transfer for participating members in the development of a regional capability for high level processing of GPS data.

Further the workshop considered the need for a strategy to link individual vertical datums, such as

- Land locked countries
- isolated island
- chart datums,
- as well as scientific sea level determinations.

**It recommended the concept of a unified vertical datum using data stored in earth centred cartesian coordinates or related to the GRS80 ellipsoid in the ITRF system.**

Plans were developed for the implementation of an expanded observational campaign in November 1998 (APRGP98). A cooperative strategy was developed with the GEODYSSEA project for a common observational campaign and sharing of data from key sites.

A second APRGP field campaign was subsequently held in November 1998 (ARGP98) at the same time as the GEODYSSEA98 campaign. There was greater participation in this campaign compared to APRG97 but there are still significant areas to be infilled when countries gain access to GPS resources. Seventeen nations were able to participate and GPS observations from some 87 sites in addition to the existing IGS sites were achieved. The GPS data (except from four sites in India) was collated by AUSLIG and distributed on CD ROMs to all countries for processing, analysis and presentation of results. A VLBI campaign was again arranged by China (Shanghai Observatory) through APSG cooperation and SLR (through WPLTN) with DORIS observations also made at that time.

The ARGP98 results computed by individual countries will be analysed with view to a combined solution at the Regional Geodetic at a results Workshop hosted by Vietnam in 12-14th July 1999.

**Future Activities**

For the Regional Geodetic Network to best contribute to the Regional Spatial Data Infrastructure and furthermore to the Global Spatial Data Infrastructure through a regional densification of ITRF, a lot of work still needs to be done. By taking into account the existence of various international scientific effort in establishing a Global Geodetic Network, such as those by IAG, IGS/ITRF, DORIS, PRARE, GEODYSSEA and Asia Pacific Space Geodynamic Program (APSG),

The aim for the establishment of a Regional Geodetic Network is to provide a common datum for all nations in the Asia Pacific region and to densify ITRF. To be able to provide data to a homogeneous spatial data base individual countries whose datum is not in ITRF and on GRS80 need to be able to transform from their individual datum. To develop these transformations the individual datums need to be well defined and have sufficient common stations in both individual and regional systems to determine datum transformations.

A new cooperation strategy will be required to promote a strong cooperation in setting campaign linkages and data sharing across the region. In addition the issue of regional sea level connections to a universal vertical datum and a related regional geoid must also be addressed. Enhanced linkages need to be formed between national Geodetic bodies represented by the PCGIAP and scientific bodies such as represented by APSG together with individual scientific researchers funded from outside the region.

Since the individual datums within the Asia and Pacific Region differ from country to country, some country might need assistance to perform the datum transformation. This assistance ranges from GPS equipment, survey expertise, datum definition to the definition of datum transformation parameters.

John Manning AUSLIG

Junyong Chen SBSM

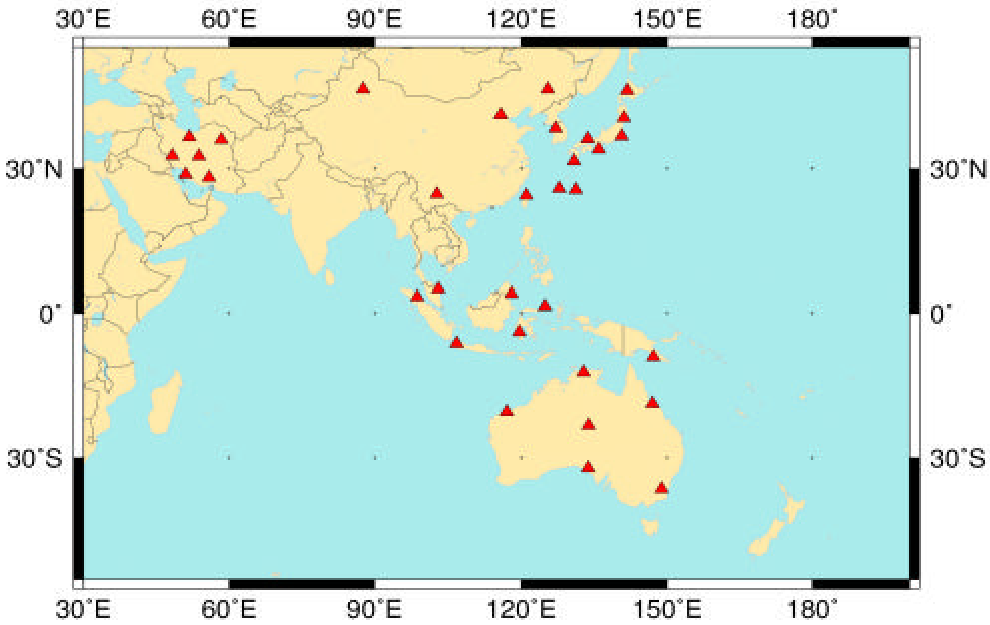
Co Chairs

SE Asia

Sub Commission X

8 July 1999

## APGP97 GPS




## APGP98 GPS