Australian Government

Geoscience Australia

# South Pacific Sea Level and Climate Monitoring Project (SPSLCMP)

## Survey Report

EDM Height Traversing
Levelling Survey

# Manus Island,
# Papua New Guinea
# June 2009

This project is sponsored by the Australian Agency for International Development (AusAID), managed by the Bureau of Meteorology (BOM) and supported by the National Geospatial Reference Systems Project, Geospatial Earth Monitoring Division, GEOSCIENCE AUSTRALIA.

Geocat # 69402

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## Introduction

This report outlines the level survey completed during the visit to Manus Island, Papua New Guinea (PNG) from 8 – 12 June 2009.

Personnel: Manoj Deo – Surveyor - **GEOSCIENCE AUSTRALIA**
Andrick Lal – Surveyor - **SOPAC**

This is the third EDM Height Traversing levelling survey of the deep driven bench mark array in Manus Is, PNG. The previous levelling surveys using this technique were performed in January 2006 and August 2007. These surveys follow the previous surveys performed by the National Tidal Centre (NTC) from 1994 to 2003 .

## The Survey

The EDM Height Traversing levelling survey was carried out between the 5 deep driven Bench Marks:

**PNG1**
**PNG2**
**PNG29**
**PNG30**
**PNG3**
**PNG31**

Included in the survey was the SEAFRAME Sensor Bench Mark **PNG14** at the Tide Gauge and **PNG20** a galvanised iron bolt located adjacent to the Tide gauge Hut.
Also included in the survey were temporary holding marks - **PNG34, PNG100, PNG26** and **PNG28** as well as the CGPS Bench Mark - **PNGMBM,** the CGPS Reference Point - **PNGM** and the three CGPS Reference Marks **- RM1, RM2** and **RM3.** The temporary holding mark PNG100 was placed during this survey and consists of a stainless steel bolt drilled in concrete and then glued in place with quality epoxy resin.

All the deep driven bench marks were located and found in good order and undisturbed.

The EDM Height Traversing levelling technique was performed to the Class L2A, as per

the Inter-Government Committee on Surveying and Mapping (ICSM), Standards and Practices for Control Surveys, SP1, Ver. 1.5, May 2002.

After reduction an internal precision of **1mm** $\sqrt{\mathbf{K}}$ or better was achieved, where K is levelled distance in kilometres. This is well within the Project Specification of **2mm** $\sqrt{\mathbf{K}}$

## Bench Mark Locality Diagram

## The Manus Island Datum

The Datum for the survey is Tide Staff Zero (TSZ).
Reduction of the data has been calculated holding **PNG1** fixed at 2.2987675 metres.
This value was determined by the NTC by adopting the Tide Staff Zero (TGZ) from the 1994 survey.

## Equipment

LEICA Total Station Model TCA1800
LEICA Precision Prisms GPH1P (2).
LEICA Rigid Tripod.
Stainless Steel Target Poles supported by LEICA telescopic Bi-Poles (2).
Shortened Stainless Steel Target Pole for the SEAFRAME Sensor BM Connection.
LEICA Cast Iron Change Plates (2).
KESTRAL 4000 Pocket Weather Tracker

## Method

"**Leap-Frog" EDM-Height-Traversing**: "Leap-Frog" EDM-Height-Traversing involves the one target remaining at a particular change point for both sightings. To avoid the possibility of the target being placed on a different point the target is not moved between the back-sight and foresight. Two target/reflectors are employed (on reflector rods with struts). As in spirit levelling, it is imperative that the electronic tacheometer (total station) is set up in the middle between the two reflectors. Recorded are the height differences (between the instrument's trunnion axis and the reflector) that are computed by the electronic tacheometers. In consequence, the ambient temperature and pressure must be input into the instrument since the slope distances must be corrected for temperature and pressure (first velocity correction) on-line. See Rüeger & Brunner (1982) and *The Canadian Surveyor*, 36(1): 69-87.

***All observations were recorded digitally.***

Reduction of the digital data was computed by the Geoscience Australia levelling program "leveling1.exe"

This program computes the height difference between the two reflectors at any one set-up. Results can also be gained with the EDM Height Traversing method by using a single set-up / single rod configuration. To achieve height differences when using this single rod configuration, a simple comment line is added, indicating this is the case before running the program.

This "single set-up / single rod" configuration is particularly useful when levelling between bench marks which are close together e.g. between the Project Plaque BM and the SEAFRAME Sensor BM.

All levelling bays started and finished with the same reflector and reflector rod, ie an even number of setups when the two reflector rod configuration was used – this eliminates any reflector rod zero error.

Atmospheric readings were obtained using a KESTRAL 4000 Pocket Weather Tracker. These atmospheric readings were recorded manually onto the Manus Island Levelling Booking Sheets and entered into the Total Station prior to each level run and approximately every hour thereafter or when ever an obvious change in weather conditions was observed.

## Survey Support

The survey team very much appreciated the assistance from staff of Lombrum Naval base, Manus Provincial Administration and the New Guinea Weather Service.

Personnel consulted during the visit were:
Mr. Kanawi Sindol – Assistant Administrator, Manus Provincial Administration
Mr. Milton Sapac – Chief Petty Officer, Lombrum Naval Base
Mr. Hymson Waffi – Officer In Charge, New Weather Service, Momote

All personnel consulted had a keen interest in the project and were always supportive with any project associated matters.

## Issues

Due to the abundance of rain, the CGPS station area gets overgrown with grass. Contact PO Milton Sapac to arrange grass cutting prior to conducting the survey.

## Description of Marks – Manus Island, PNG

**PNG1** is the bench mark held fixed with **RL = 2.2987675 metres**

The height of **PNG1** was derived by NTC by:

**1994** Adopting the **Tide Staff Zero** RL = 0.0000m

**1996** Adopting the height of **PNG1** as derived from the 1994 survey. RL = 2.29877m.

Bench Marks **PNG1, PNG2, PNG3, PNG29, PNG30, PNG31** are all Deep driven Driven Bench Marks.

**PNG14** is the SEAFRAME Sensor Bench Mark.

**PNG20** is a bolt in wood just below the SEAFRAME Sensor Bench Mark.
**PNG34, PNG26, PNG28** and **PNG100** are Permanent Holding Marks (Stainless Steel bolts).
**PNGMBM** is the CGPS Benchmark, **PNGM** is the CGPS Reference Point and **RM1, RM2, RM3** are the three CGPS Reference Marks.

# Table of Results for 2009 and Comparisons between 2007 and 2009 EDM Surveys

| Manus Island PNG 2009 EDM Height Traversing Levelling Comparison 2007 - 2009 and Table of Results | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **PNG1 - Adopted fixed height 2.2987675 m** | | | | | | | | |
| **Backsight** | **Foresight** | **Levelled Height Difference** | **Reduced Level 2009** | **Misclose (mm)** | **Distance (km)** | **1mm√K** | **Reduced Level 2007** | **Difference (mm) 2007-2009** |
| PNG1 | | | 2.2988 | | | | 2.2988 | 0.0000 |
| PNG100 | PNG100 | 1.0083 | 3.3071 | 0.113 | 0.103 | 0.321 | | |
| | PNG2 | -0.8111 | 2.4960 | -0.100 | 0.159 | 0.399 | 2.4960 | 0.0000 |
| | | | | | | | | |
| PNG1 | | | 2.2988 | | | | 2.2988 | 0.0000 |
| PNG20 | PNG20 | 1.1588 | 3.4575 | 0.075 | 0.146 | 0.382 | 3.4584 | 0.0009 |
| | PNG14 | 1.1226 | 4.5801 | 0.190 | 0.014 | 0.118 | 4.5792 | -0.0009 |
| | | | | | | | | |
| PNG1 | | | 2.2988 | | | | 2.2988 | 0.0000 |
| PNG29 | PNG29 | 2.1809 | 4.4797 | -0.225 | 0.179 | 0.423 | 4.4795 | -0.0002 |
| PNG34 | PNG34 | 4.0241 | 8.5038 | -0.060 | 0.116 | 0.341 | 8.5037 | -0.0001 |
| PNG26 | PNG26 | 17.7842 | 26.2880 | -0.263 | 0.206 | 0.453 | | |
| PNG3 | PNG3 | 7.8584 | 34.1464 | -0.013 | 0.181 | 0.426 | 34.1475 | 0.0011 |
| PNG28 | PNG28 | -3.0162 | 31.1302 | -0.063 | 0.105 | 0.324 | | |
| PNG31 | PNG31 | 1.9759 | 33.1061 | -0.050 | 0.073 | 0.270 | 33.1079 | 0.0018 |
| PNGMBM | PNGMBM | 4.5807 | 37.6868 | 0.075 | 0.069 | 0.263 | 37.6884 | 0.0017 |
| | PNGM | 0.9612 | 38.6480 | 0.013 | 0.017 | 0.132 | 38.6495 | 0.0015 |
| | | | | | | | | |
| PNG34 | | | 8.5038 | | | | 8.5037 | -0.0001 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | PNG30 | -5.2172 | 3.2866 | 0.010 | 0.050 | 0.223 | 3.2865 | -0.0002 |
| | | | | | | | | |
| PNGMBM | | | 37.6868 | | | | 37.6884 | 0.0017 |
| | RM1 | -1.8025 | 35.8842 | 0.088 | 0.025 | 0.159 | 35.8858 | 0.0016 |
| | | | | | | | | |
| PNGMBM | | | 37.6868 | | | | 37.6884 | 0.0017 |
| | RM2 | -0.3755 | 37.3113 | 0.054 | 0.023 | 0.152 | 37.3129 | 0.0016 |
| | | | | | | | | |
| PNGMBM | | | 37.6868 | | | | 37.6884 | 0.0017 |
| | RM3 | -0.0886 | 37.5982 | 0.125 | 0.024 | 0.155 | 37.5996 | 0.0014 |
| | | | **Misclose for all bays levelled =** | -0.031 | 1.491 | 1.221 | *Allowable misclose is 2√K = 2.442mm* | |
| **An internal precision of 1mm√K was achieved for all bays levelled - this is well within the project specification of 2mm√K** | | | | | | | | |

## Combined Comparisons 1994 to 2009

| MANUS ISLAND, PNG - Comparison of the RL's for Precise Differential Levelling (1994 - 2006) and EDM Height Traversing (2006 - 2009) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MARK | | | | | | | | | | | |
| YEAR | PNG1 | PNG2 | PNG3 | PNG14 | PNG29 | PNG30 | PNG31 | PNGBM | PNGM | RM1 | RM2 | RM3 |
| 1994 | 2.2988 | 2.5011 | 34.1461 | 4.5813 | | | | | | | | |
| 1996 | 2.2988 | 2.5010 | 34.1451 | 4.5804 | | | | | | | | |
| 1997 | 2.2988 | 2.5006 | 34.1443 | 4.5786 | | | | | | | | |
| 1999 | 2.2988 | 2.5012 | 34.1451 | 4.5799 | | | | | | | | |
| 2000 | 2.2988 | 2.5010 | 34.1456 | 4.5794 | | | | | | | | |
| 2002 | 2.2988 | 2.5009 | 34.1456 | 4.5794 | 4.4792 | 3.2861 | 33.1049 | 37.6862 | | 35.8836 | 37.3104 | 37.5973 |
| 2003 | 2.2988 | 2.4961 | 34.1457 | 4.5785 | 4.4793 | 3.2866 | 33.1082 | 37.6887 | | 35.8863 | 37.3129 | 37.6004 |
| 2006 | 2.2988 | | 34.1466 | 4.5804 | 4.4798 | | 33.1067 | 37.6876 | | | | |
| | | | | | | | | | | | | |
| 2006 EDM | 2.2988 | | 34.1479 | 4.5797 | 4.4801 | | 33.1083 | 37.6895 | 38.6507 | 35.8869 | 37.3140 | 37.6010 |
| 2007 EDM | 2.2988 | 2.4960 | 34.1475 | 4.5792 | 4.4795 | 3.2865 | 33.1079 | 37.6884 | 38.6495 | 35.8858 | 37.3129 | 37.5996 |
| 2009 EDM | 2.2988 | 2.4960 | 34.1464 | 4.5801 | 4.4797 | 3.2866 | 33.1061 | 37.6868 | 38.6480 | 35.8842 | 37.3113 | 37.5982 |

# Manus Island 2009 Reduced Levels

**Date:** 8 – 12 June 2009

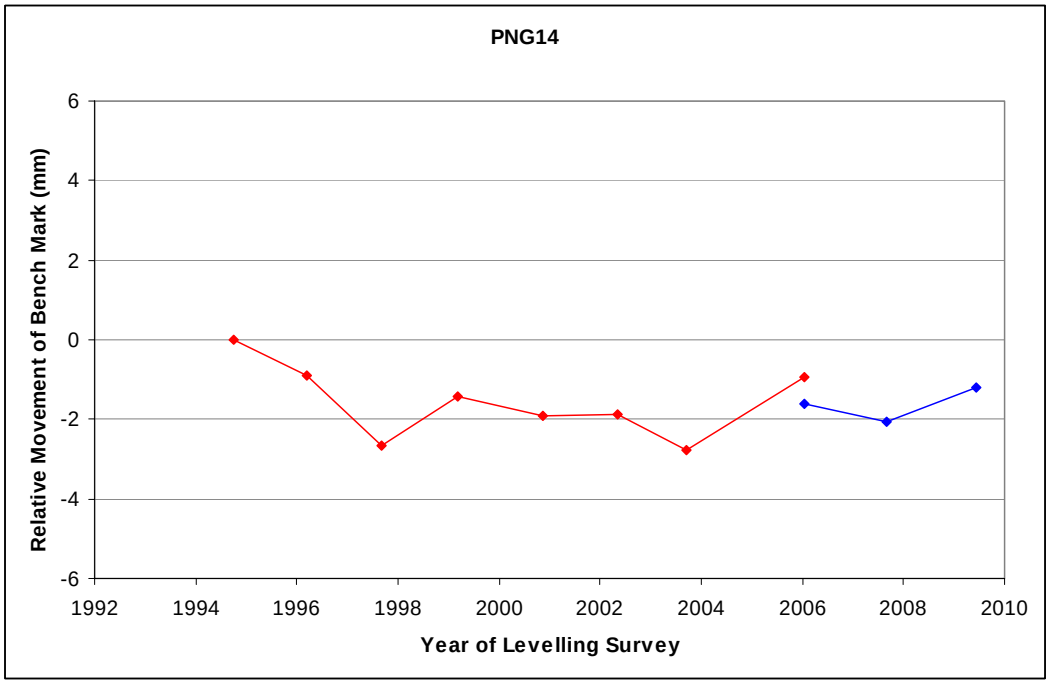
**Datum:** Mean Sea Level

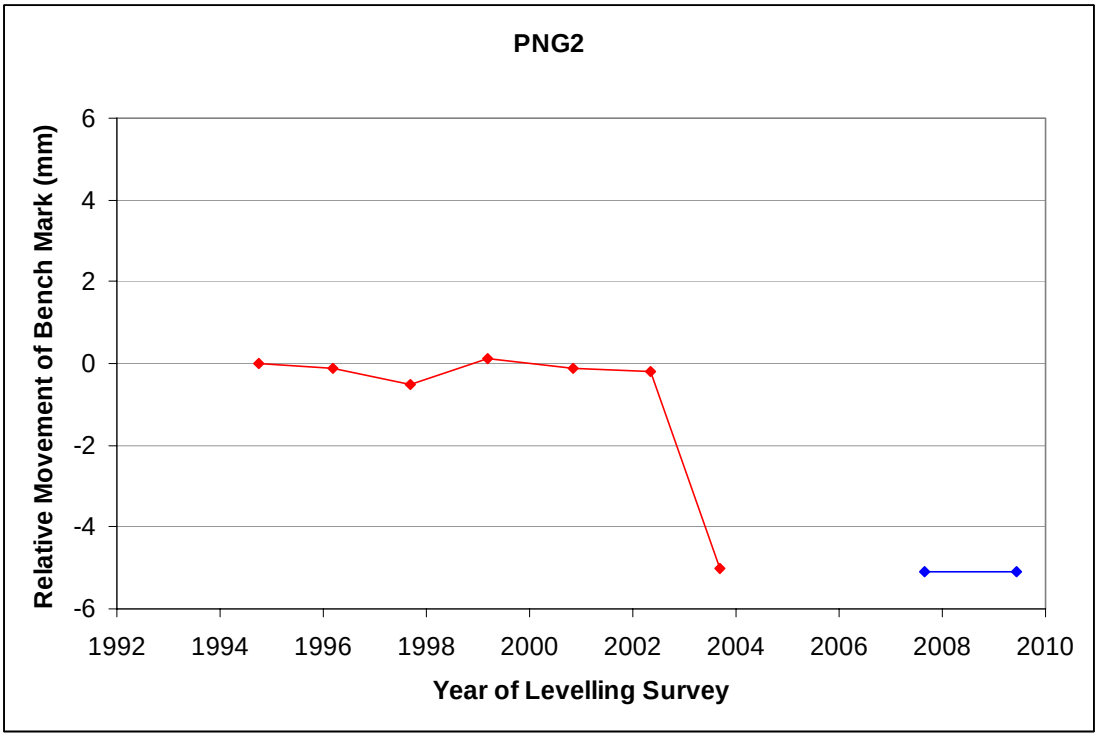
| POINT# | 2009 levelled diff. ht. | 2009 RL |
|---|---|---|
| **PNG1** | **0.0000** | **2.2988** |
| **PNG100** | **+1.0083** | **3.3071** |
| **PNG2** | **+0.1972** | **2.4960** |
| **PNG3** | **+31.8476** | **34.1464** |
| **PNG28** | **+28.8314** | ***31.1302*** |
| ***PNG14*** | **+2.2813** | **4.5801** |
| **PNG20** | **+1.1588** | **3.4575** |
| **PNG29** | **+2.1809** | **4.4797** |
| **PNG34** | **+6.2050** | **8.5038** |
| **PNG26** | **+23.9892** | **26.2880** |
| **PNG31** | **+30.8073** | **33.1061** |
| **PNGBM** | **+35.3880** | **37.6868** |
| **PNGM** | **+36.3492** | **38.6480** |
| **PNG30** | **+0.9878** | **3.2866** |
| **RM1** | **+33.5855** | **35.8842** |
| **RM2** | **+35.0125** | **37.3113** |
| **RM3** | **+35.2994** | **37.5982** |

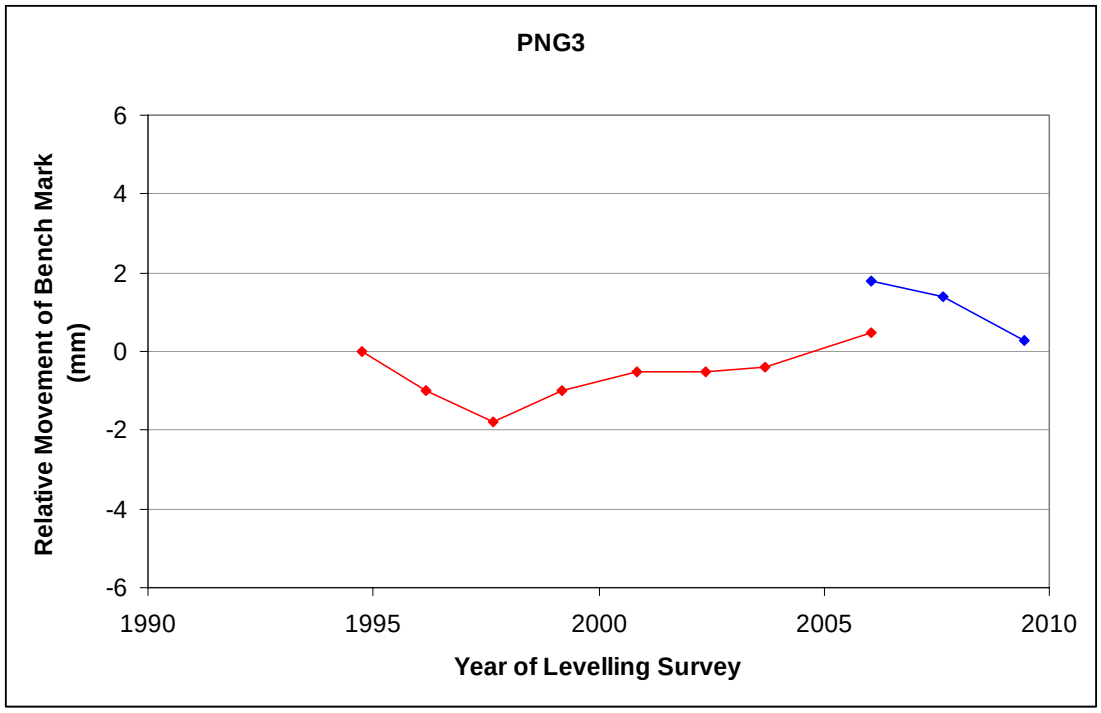
# Time Series of Bench Mark movement relative to the Fixed Deep driven Bench Mark – PNG 1

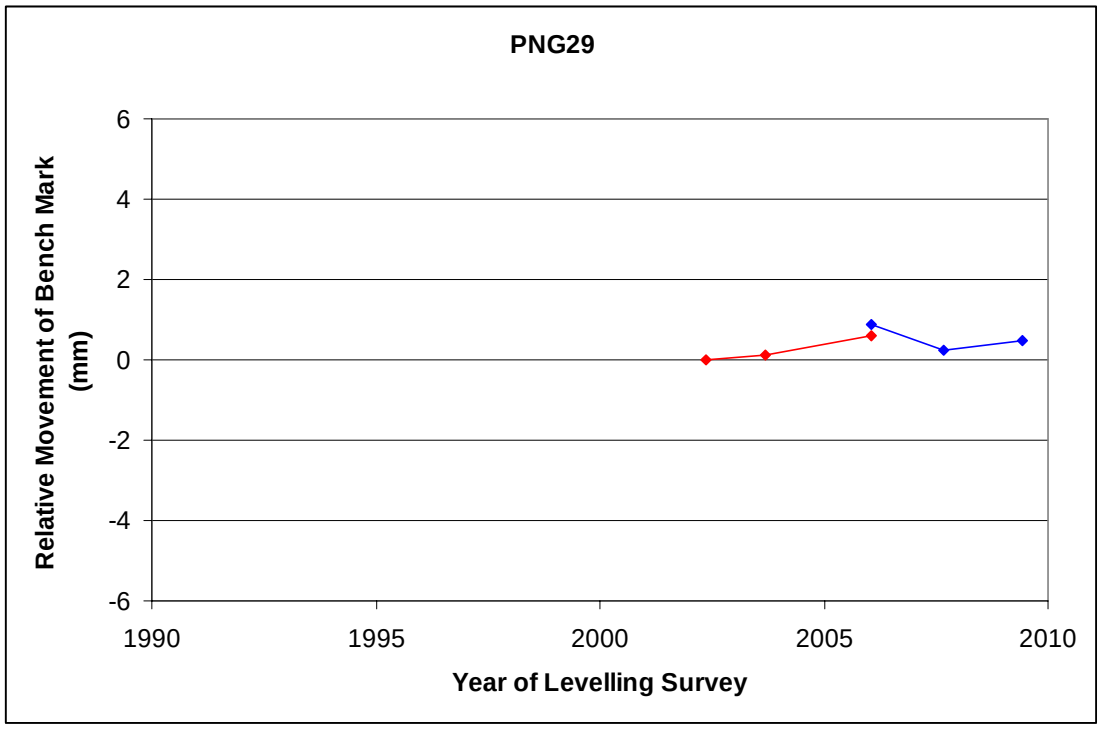
Precise Differential Levelling - 1994 to 2003 (2006)

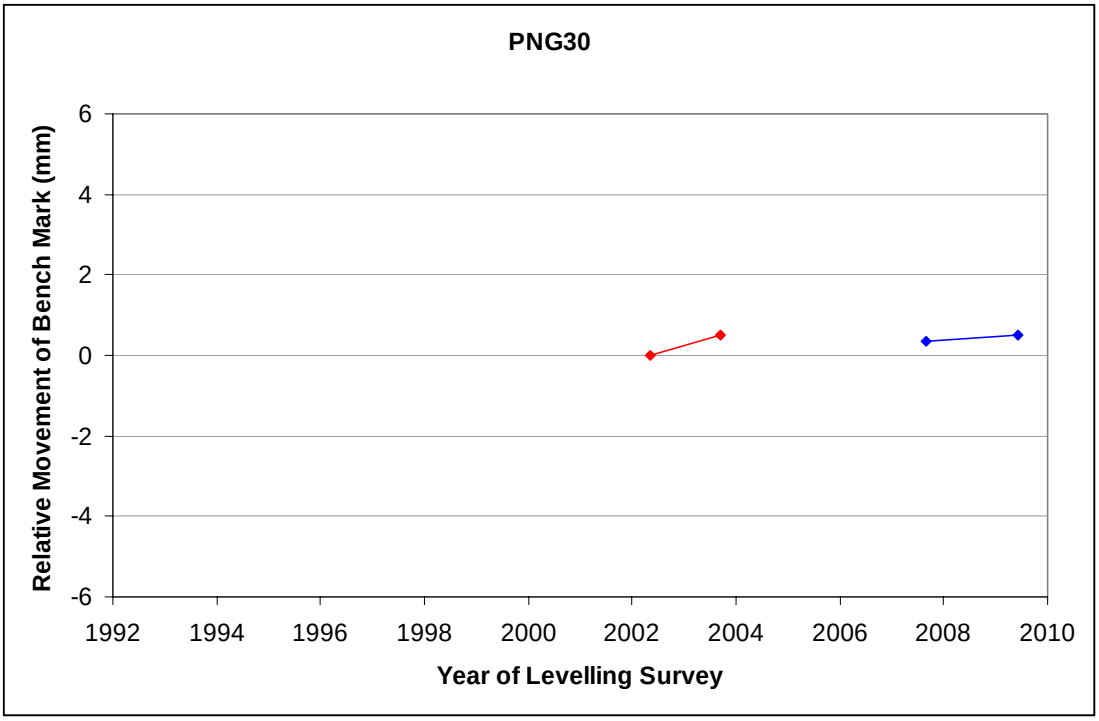
EDM Height Traversing - commenced 2006

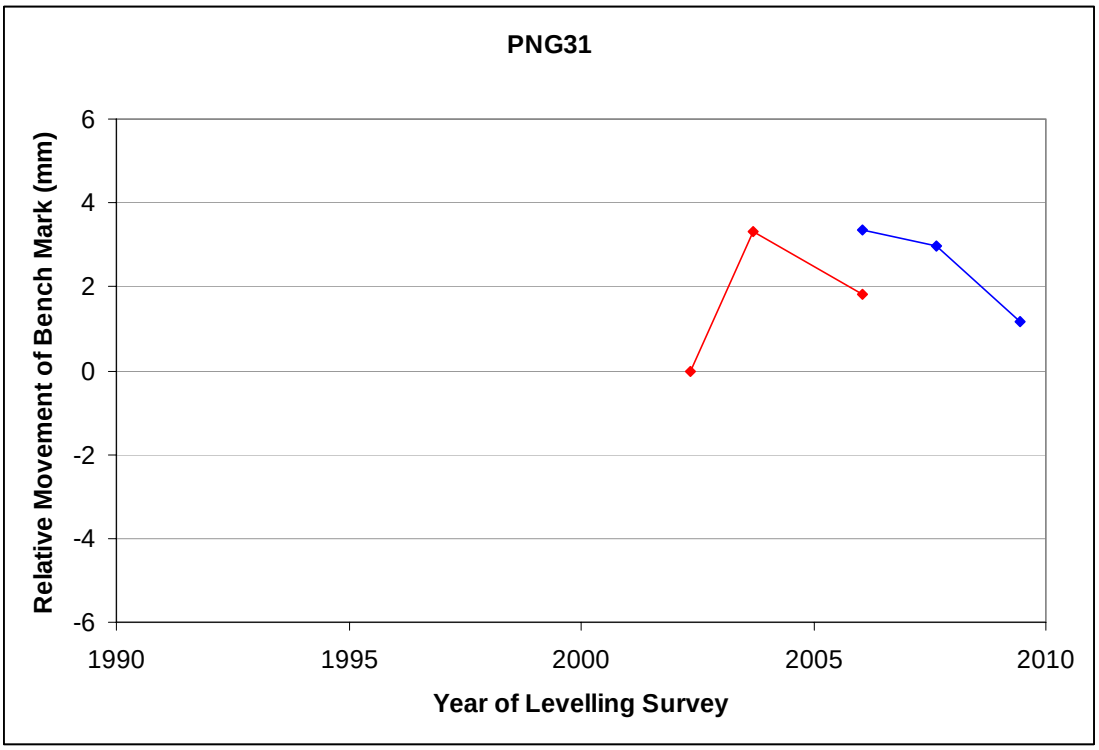


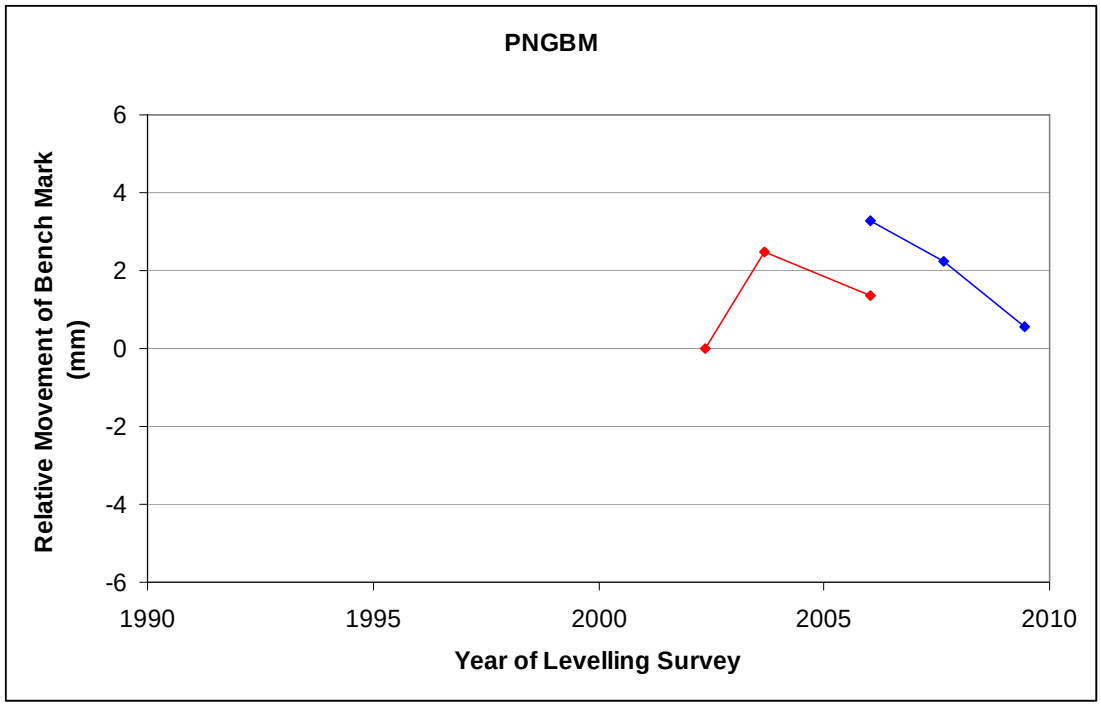



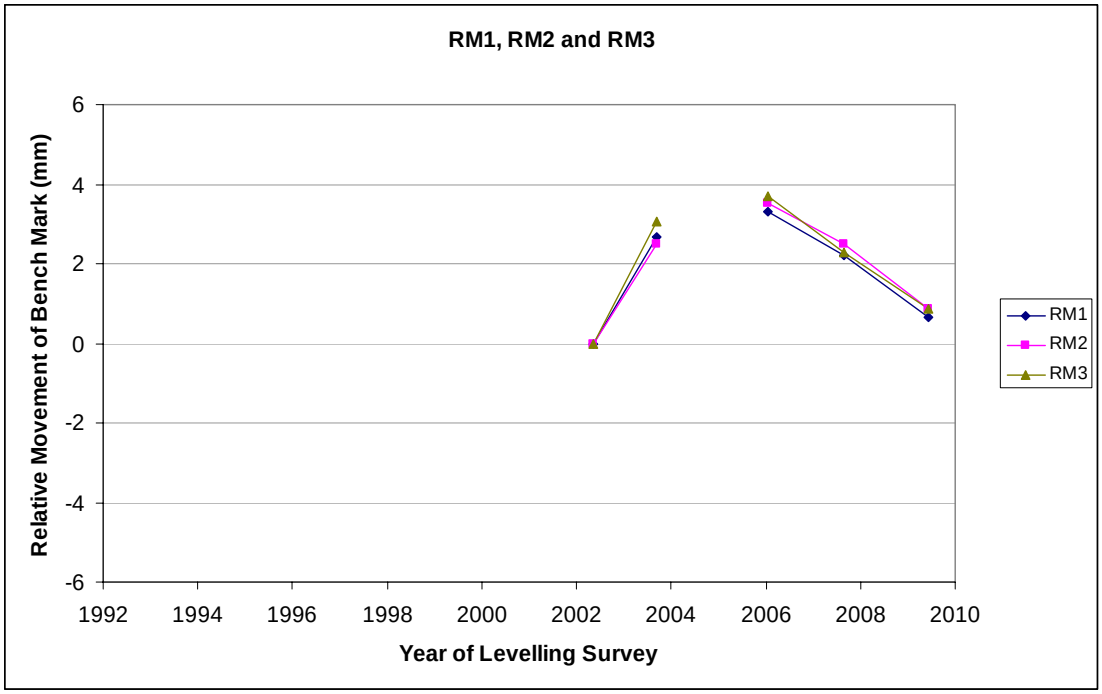






# Deep driven Bench Mark Locality Diagrams

**SOUTH PACIFIC SEA LEVEL**
**&**
**CLIMATE MONITORING PROJECT**

**Survey Bench Mark Record**

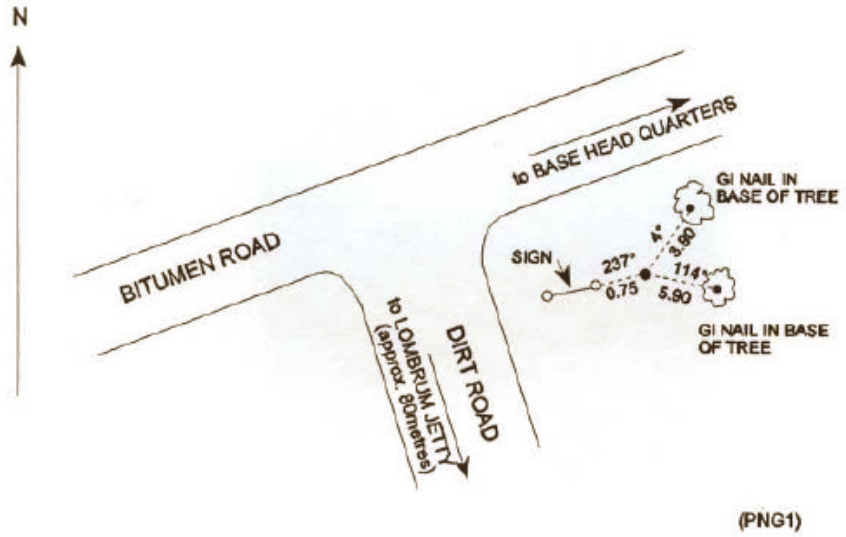
**Bench Mark Number: PNG1**

| | |
|---|---|
| *Original Bench Mark Established by*:<br>National Tidal Centre Australia, Oceanographic Services,<br>Bureau of Meteorology, 25 College Rd, Kent Town, SA. | *Date*: 26-09-94 |
| *Existing Bench Mark Established by*: | *Date*: |
| *Notes / References*: Deep Survey Benchmark<br>This survey mark is not in a good locality GPS occupation. | |
| *Country*: Papua New Guinea<br>*Island*: Manus Island | *City: Lombrum* |

Marking and locality sketch

Bench Mark: 4.0m of 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level.

Locality sketch: Mark approximately 150m from the tide gauge station.




Not to scale | Distances in Metres | Magnetic bearings

Approved by: Geoscience Australia / SOPAC | Date: April 2006

**SOUTH PACIFIC SEA LEVEL**
**&**
**CLIMATE MONITORING PROJECT**

## Survey Bench Mark Record

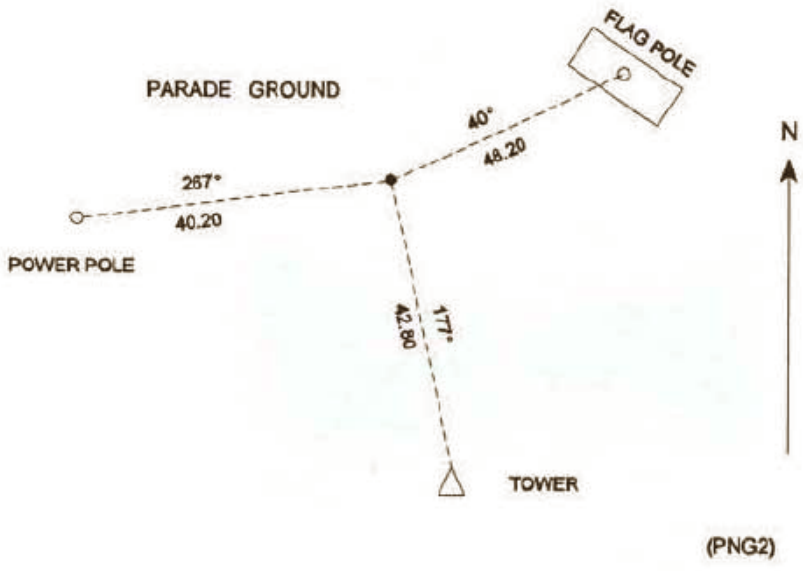
**Bench Mark Number: PNG2**

| | |
|---|---|
| *Original Bench Mark Established by*:<br>National Tidal Centre Australia, Oceanographic Services,<br>Bureau of Meteorology, 25 College Rd, Kent Town, SA. | *Date*: 26-09-94 |
| *Existing Bench Mark Established by*: | *Date*: |
| *Notes / References*: Deep Survey Benchmark<br>This survey mark is in a good locality for GPS occupation. | |
| *Country*: Papua New Guinea<br>*Island*: Manus Island | *City: Lombrum* |

Marking and locality sketch

Bench Mark: 2.0m of 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.1m below ground level.

Locality sketch: Mark approximately 500m from the tide gauge station.




Not to scale | Distances in Metres | Magnetic bearings

Approved by: Geoscience Australia / SOPAC | Date: April 2006

**SOUTH PACIFIC SEA LEVEL**
**&**
**CLIMATE MONITORING PROJECT**

## Survey Bench Mark Record

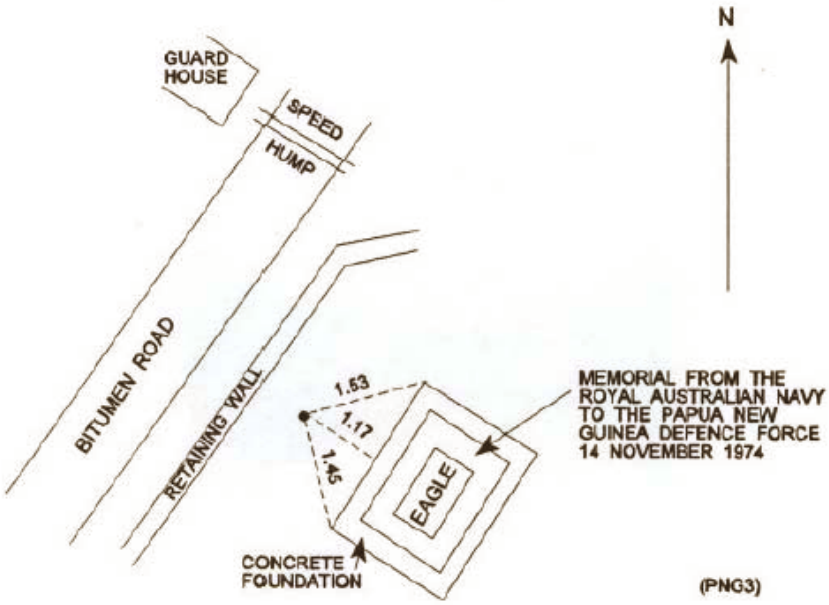
**Bench Mark Number: PNG3**

| | |
|---|---|
| *Original Bench Mark Established by*:<br>National Tidal Centre Australia, Oceanographic Services,<br>Bureau of Meteorology, 25 College Rd, Kent Town, SA. | *Date*: 27-09-94 |
| *Existing Bench Mark Established by*: | *Date*: |
| *Notes / References*: Deep Survey Benchmark<br>This survey mark is in a good locality for GPS occupation. | |
| *Country*: Papua New Guinea<br>*Island*: Manus Island | *City: Lombrum* |

Marking and locality sketch

Bench Mark: 3.0m of 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level.

Locality sketch: Mark approximately 800m from the tide gauge station.




Not to scale | Distances in Metres | Magnetic bearings

Approved by: Geoscience Australia / SOPAC | Date: April 2006

**SOUTH PACIFIC SEA LEVEL**
**&**
**CLIMATE MONITORING PROJECT**

## Survey Bench Mark Record

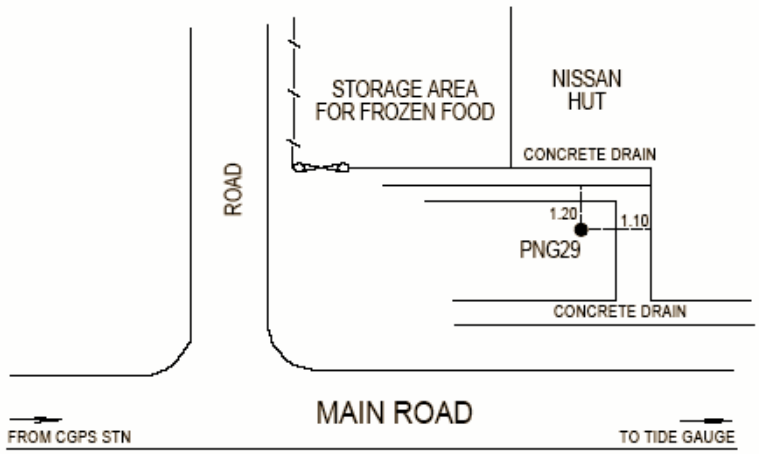
**Bench Mark Number: PNG29**

| | |
|---|---|
| *Original Bench Mark Established by*:<br>National Tidal Centre Australia, Oceanographic Services,<br>Bureau of Meteorology, 25 College Rd, Kent Town, SA. | *Date*: 09-05-02 |
| *Existing Bench Mark Established by*: | *Date*: |
| *Notes / References*: Deep Survey Benchmark<br>This survey mark is not in a good locality for GPS occupation. | |
| *Country*: Papua New Guinea<br>*Island*: Manus Island | *City: Lombrum* |

Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal.
Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level.

Locality sketch: Mark approximately 320m from the tide gauge station.




Not to scale | Distances in Metres | Magnetic bearings

Approved by: Geoscience Australia / SOPAC | Date: September 2006

**SOUTH PACIFIC SEA LEVEL**
**&**
**CLIMATE MONITORING PROJECT**

## Survey Bench Mark Record

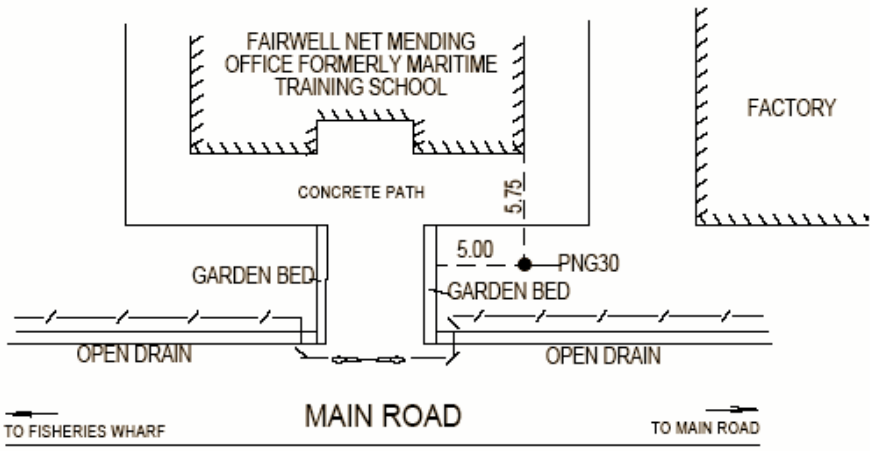
**Bench Mark Number: PNG30**

| |
|---|
| *Original Bench Mark Established by*: National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA. *Date*: 09-05-02 |
| *Existing Bench Mark Established by*: *Date*: |
| *Notes / References*: Deep Survey Benchmark<br>This survey mark is not in a good locality for GPS occupation. |
| *Country*: Papua New Guinea<br>*Island*: Manus Island *City: Lombrum* |

Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level.

Locality sketch: Mark approximately 500m from the tide gauge station.




Not to scale Distances in Metres Magnetic bearings

Approved by: Geoscience Australia / SOPAC Date: September 2006

**SOUTH PACIFIC SEA LEVEL**
**&**
**CLIMATE MONITORING PROJECT**

## Survey Bench Mark Record

**Bench Mark Number: PNG31**

*Original Bench Mark Established by*:
National Tidal Centre Australia, Oceanographic Services,
Bureau of Meteorology, 25 College Rd, Kent Town, SA.

*Date*: 09-05-02

*Existing Bench Mark Established by*:

*Date*:

*Notes / References*: Deep Survey Benchmark
This survey mark is in a good locality for GPS occupation.

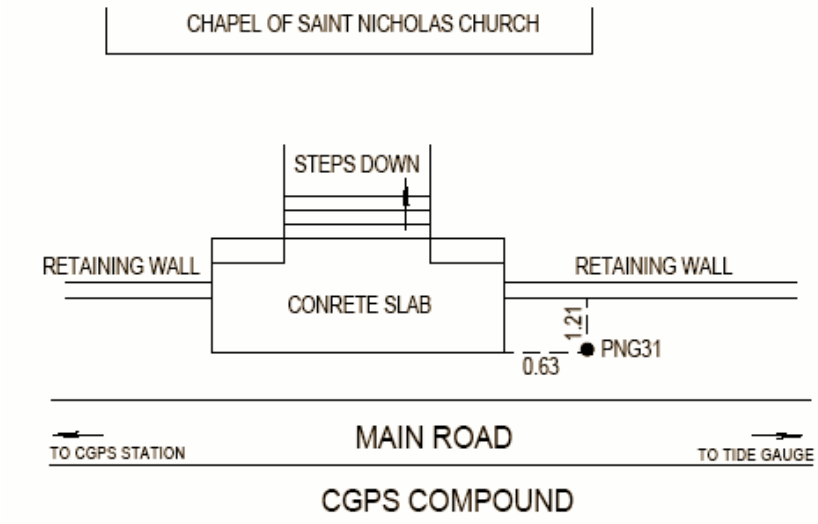
*Country*: Papua New Guinea
*Island*: Manus Island

*City: Lombrum*

Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal.
Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level.

Locality sketch: Mark approximately 1000m from the tide gauge station.




Not to scale | Distances in Metres | Magnetic bearings

Approved by: Geoscience Australia / SOPAC

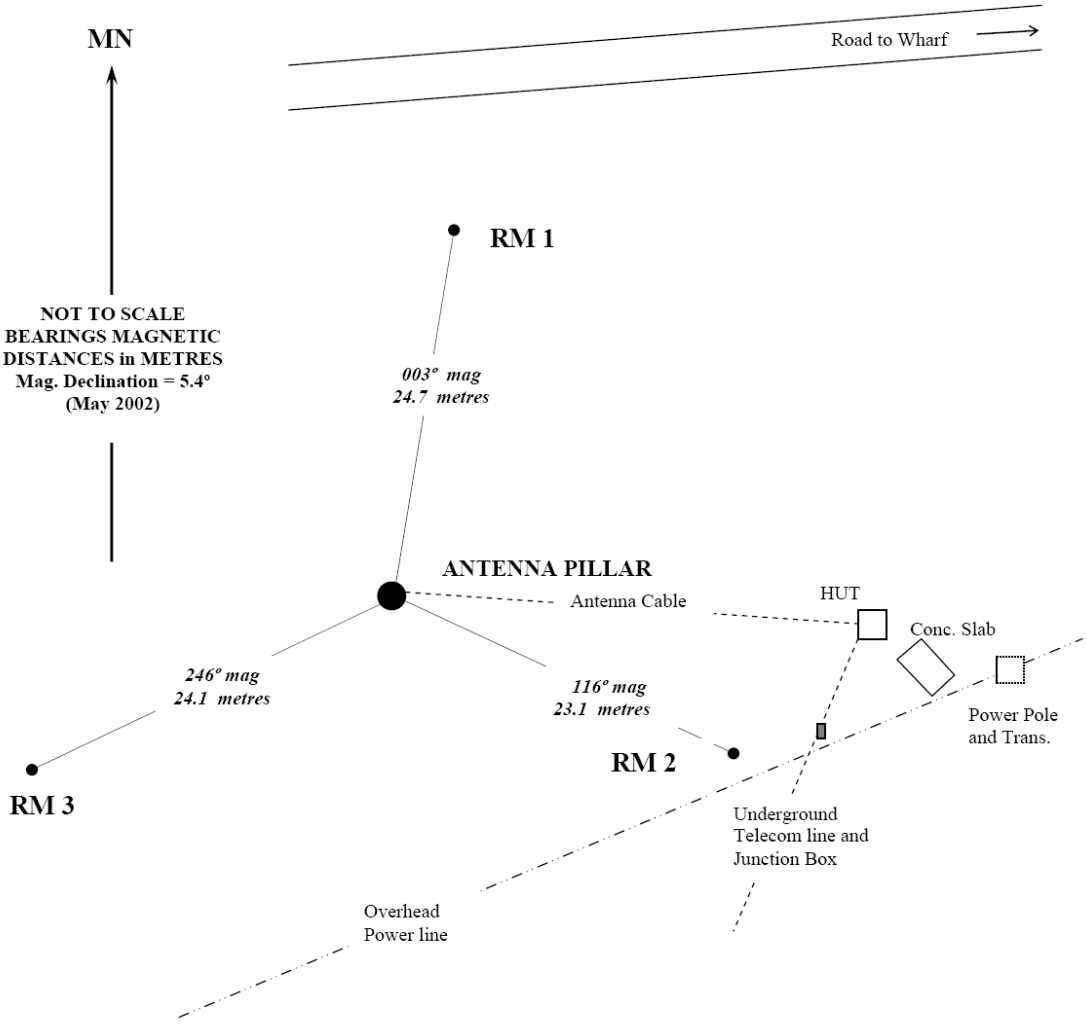
Date: September 2006

# PNGMBM and PNGM Reference Mark Locality Diagrams

## PNG CGPS Station, Lombrum, Manus Is. – Reference Marks

**REFERENCE MARKS**

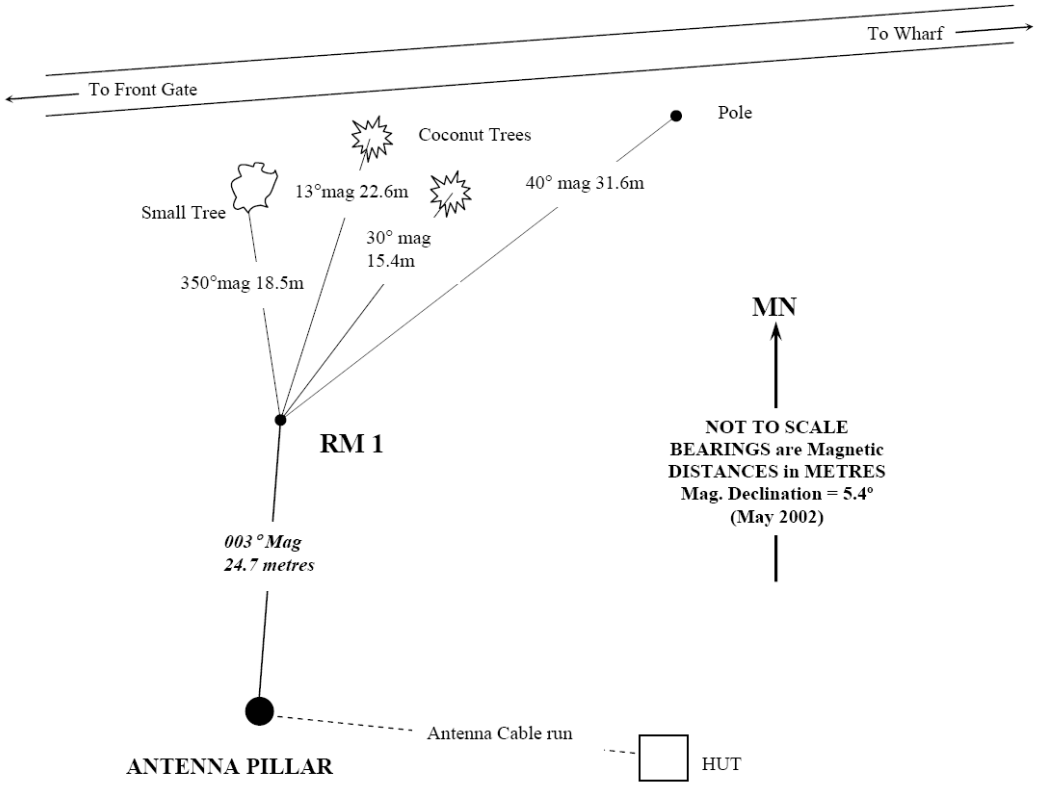
**All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.**



## PNG CGPS Station, Lombrum, Manus Is. – RM 1

### REFERENCE MARKS

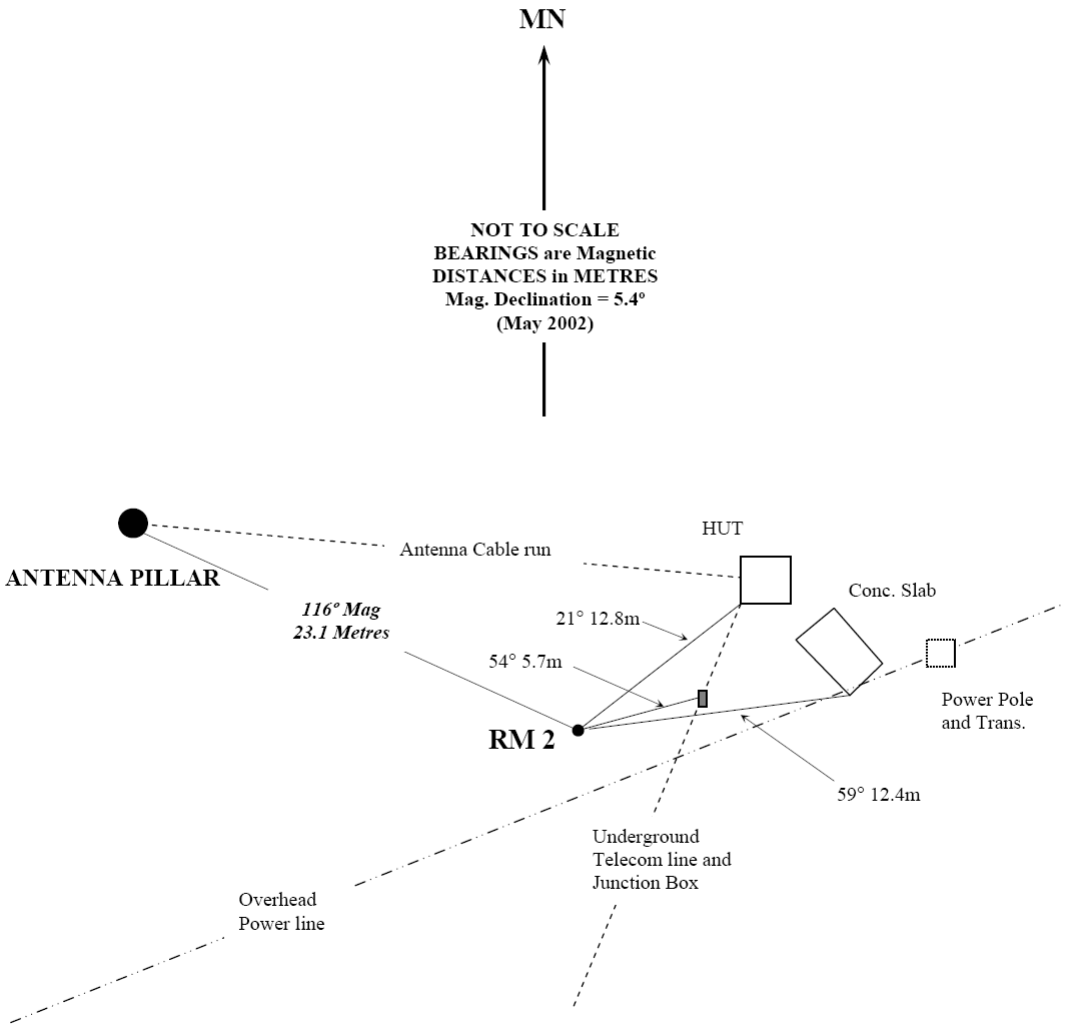
**All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.**



## PNG CGPS Station, Lombrum, Manus Is. – RM 2

### REFERENCE MARKS

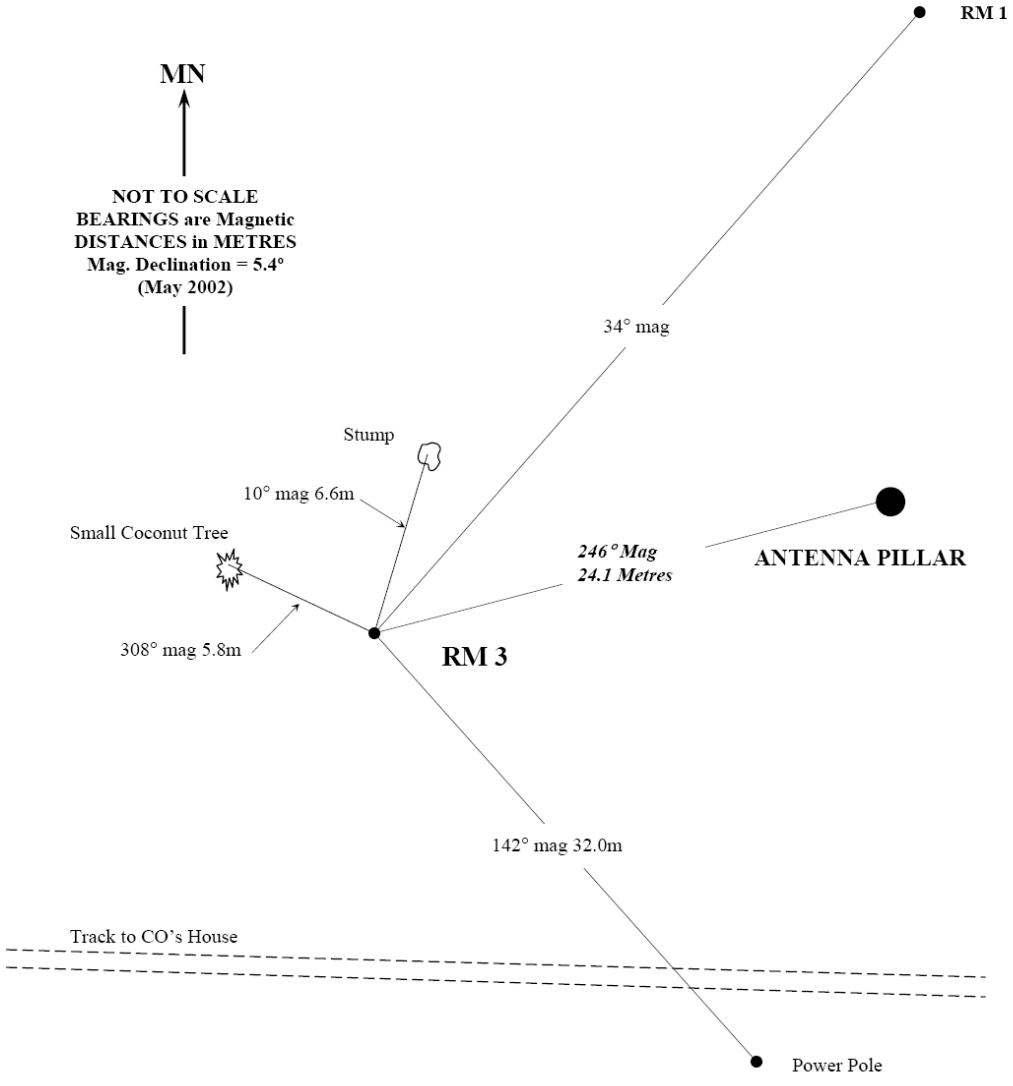
**All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.**



## PNG CGPS Station, Lombrum, Manus Is. – RM 3

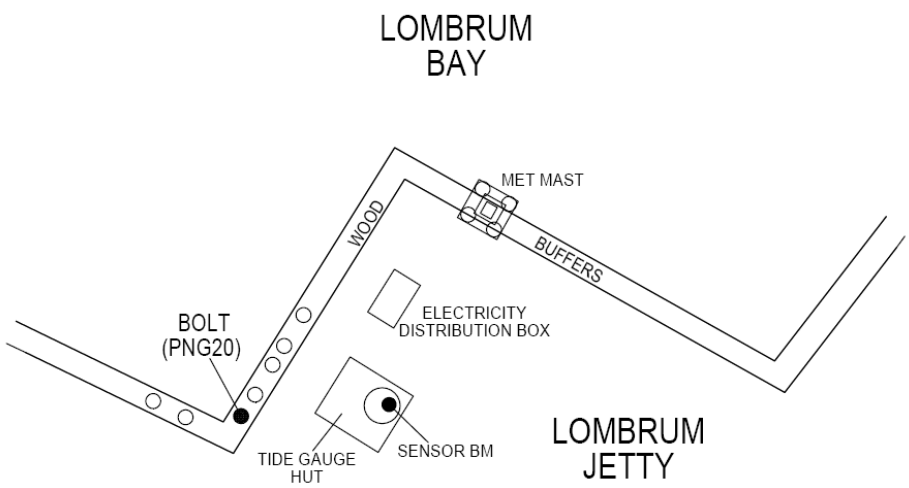
### REFERENCE MARKS

**All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.**

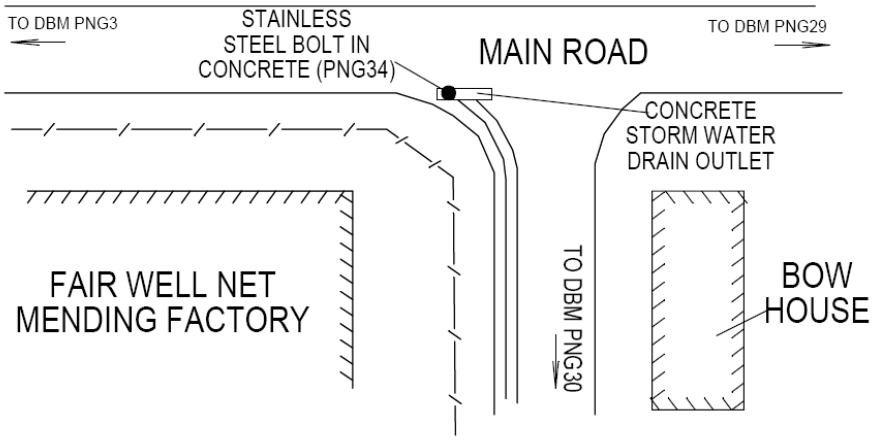


# Temporary Holding Mark Locality Diagrams

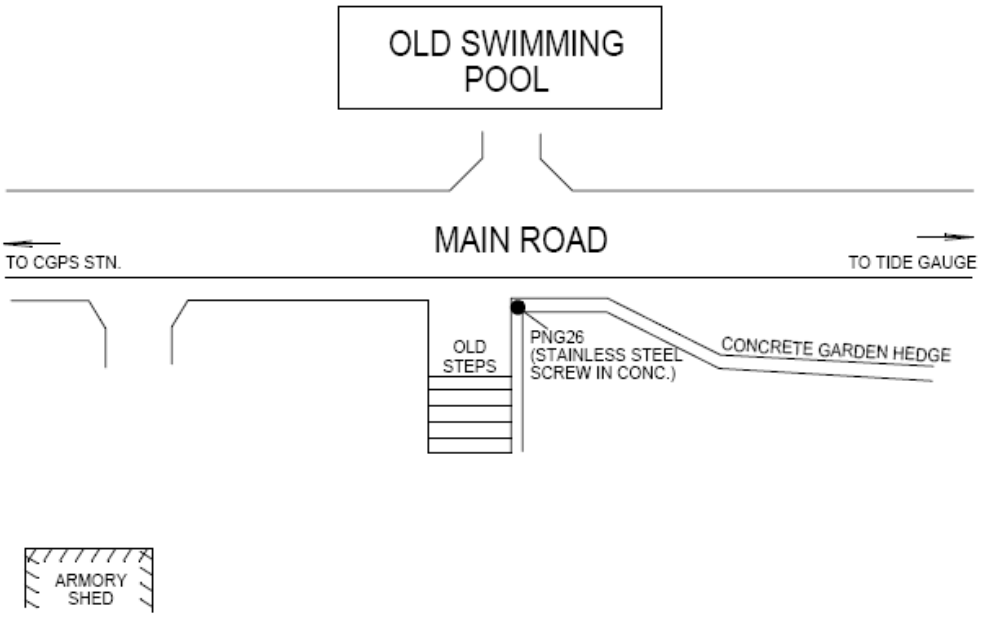
| COUNTRY: Papua New Guinea | ISLAND: Manus Is<br>CITY: Lombrum | L. D. P. 805<br>POINT NO. PNG14 & 20 |
|---|---|---|
| PROJECT: SPSLCMP | SURVEYOR: M Deo & A Lal | DATE: 24-09-94 |



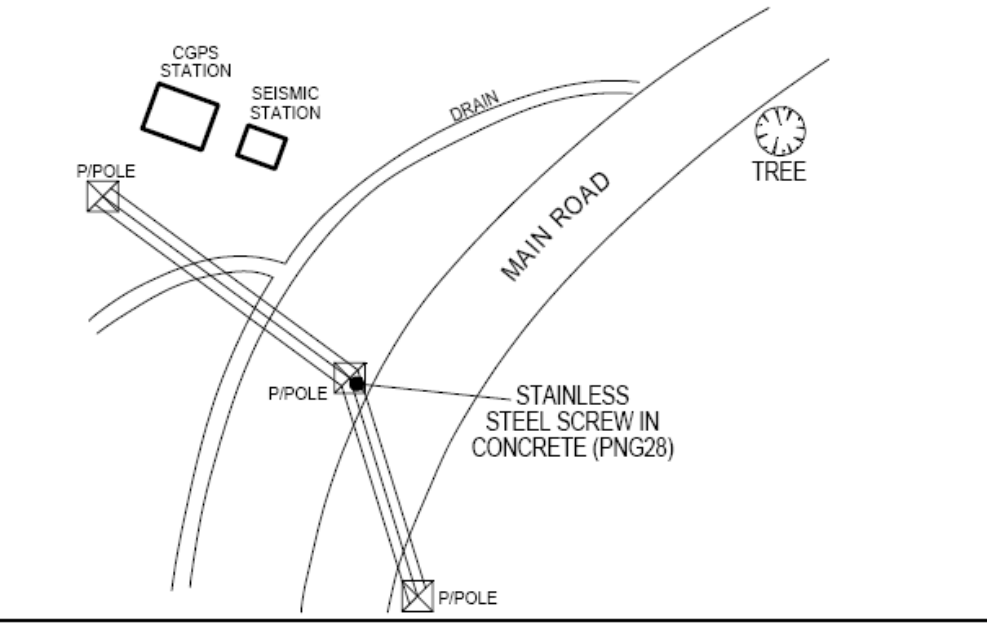

| COUNTRY: Papua New Guinea | ISLAND: Manus Is<br>CITY: Lombrum | L. D. P. 804<br>POINT NO. PNG34 |
|---|---|---|
| PROJECT: SPSLCMP | SURVEYOR: M Deo & A Lal | DATE: 07-09-03 |



| COUNTRY: Papua New Guinea | ISLAND: Manus Is<br>CITY: Lombrum | L. D. P. 892<br>POINT NO. PNG26 |
|---|---|---|
| PROJECT: SPSLCMP | SURVEYOR: M Deo & A Lal | DATE: 09-05-02 |




| COUNTRY: Papua New Guinea | ISLAND: Manus Is<br>CITY: Lombrum | L. D. P. 893<br>POINT NO. PNG28 |
|---|---|---|
| PROJECT: SPSLCMP | SURVEYOR: M Deo & A Lal | DATE: 09-05-02 |



| | | |
|---|---|---|
| COUNTRY:<br>Papua New Guinea | ISLAND: Manus Is<br>CITY: Lombrum | L. D. P. 894<br>POINT NO. PNG100 |
| PROJECT: SPSLCMP | SURVEYOR: M Deo & A Lal | DATE: 09-06-09 |