

SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT (SPSLCMP)



Reference Mark Monitoring Survey Report

June 2004

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SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT (SPSLCMP)

INTRODUCTION

During the 1990's a network of high resolution sea level and climate monitoring stations was established in the South West Pacific and processed and analyzed data from those stations made available to stakeholders.

In Phase III of the Project (2001 – 2005) a significant new environmental monitoring component was added – a **Continuous Global Positioning System network (CGPS)**. CGPS receivers have been established near and linked to the sea level monitoring stations in all partner countries and will measure vertical and horizontal land movements on the islands to help determine absolute sea level change.

Technical support for the GPS geodetic component of the project is provided by Geoscience Australia's Earth Monitoring Group (GEM).

Project Goals and Objectives

The long term goal of the project is to “Provide an accurate long term record of sea levels in the South Pacific for partner countries and the international scientific community, that enables them to respond to and manage related impacts.”

In delivering this goal the key objectives in this phase include:

- Maintaining the investment in existing and new monitoring infrastructure so as to ensure continuity of quality data flow
- Improving information and data flow to a wide group of stakeholders
- Increasing regional and local level participation in project activities
- Enhancing institutional capacity through training and technology transfer

Specific goals in relation to Component 2: Geodetic Surveys are:

- A height time series of at least 3 years duration will have been provided by CGPS measurement, at 10 of the 12 sea level recording stations.
- The raw CGPS data will be securely stored in Australia, if appropriate, a regional and an international GPS archive.
- A height time series for each sea level recording station will be securely stored on the regional and Australian archives and national databases.
- A capacity within each agreed partner country, to maintain a CGPS receiver, to download the data from it, and transfer the data to the GPS Processing Centre.

- **The REFERENCE MARK SURVEYS**

All Reference Mark surveys were performed using a LEICA TC2003, TCA2003 or the TCA1800 Total Stations and a set of 3 LEICA Precision Prisms. These instruments were used to observe all horizontal and vertical angles and slope distances.

Marks were leveled adopting the Total Station Leveling technique using the LEICA Total Stations, and two fixed height rods with corner cube reflectors - with the exception of Samoa in 2001 where the marks were levelled using a TOPCON DL-101C Digital Level.

All reduced observations were corrected for temperature, humidity and pressure. The observations were then put into a least squares adjustment program – GEOLAB to determine final coordinates, and also to evaluate the quality of the measurements.

In all of the 10 South Pacific countries the Reference Mark surveys were completed during the initial installation / commissioning visit and have since been re-observed approximately 12 to 18 months later.

Using these two surveys a comparison table for each country has been drawn up to identify any obvious horizontal or vertical movement of the CGPS reference point. A summary of results follows each comparison table.

1. Cook Islands

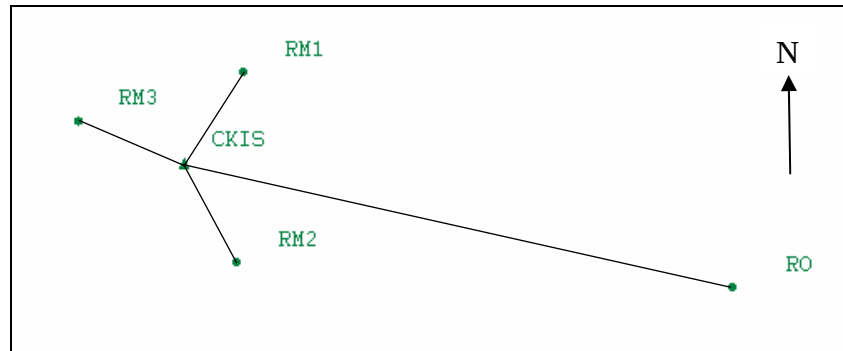


Figure 1.1 Cook Islands networks. To Scale

Site Description

Site consists of a purpose built Hut for the Technical equipment and a 1.5 metre high Antenna Pillar. The site is located within the Cook Islands Airport perimeter fence. Permission and a Security pass are required to visit the site; this can be arranged through Mr. Timoti Tangirua from the Lands and Survey Dept., Ministry of Works, Ph: 682 20034.

1.1 2001 Survey

1.1.1 Details

Location: Cook Islands

Date: 4 – 6 July 2001

Field Book: General Black Field Book # 43 (“Samoa & Cook Is”)

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TC 2003

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

1.1.2 Survey Specific Notes: GPS was observed for Azimuth at Bevis Mark.

*The Stainless Steel Target Pole and Pillar Target Stub Set used was Set No. 1. See Calibration details in Annex A.

1.1.3 2001 Results

Table 1.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at CKIS.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
CKIS	S 21 12 3.70071	0.0000	W159 48 2.19306	0.0000	18.4117	0.0000
RO	S 21 12 4.45249	0.0014	W159 47 58.63318	0.0061	16.3084	0.0003
RM1	S 21 12 3.15024	0.0016	W159 48 1.80694	0.0015	16.5314	0.0003
RM2	S 21 12 4.30168	0.0019	W159 48 1.84434	0.0016	16.3417	0.0003
RM3	S 21 12 3.44471	0.0016	W159 48 2.87297	0.0018	16.7046	0.0003

Table 1.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
CKIS	-5583182.1000	0.0000	-2054143.6377	0.0000	-2292166.7924	0.0000
RO	-5583136.9594	0.0026	-2054236.4319	0.0056	-2292187.5884	0.0013
RM1	-5583182.3554	0.0007	-2054155.5980	0.0015	-2292150.3285	0.0015
RM2	-5583170.5427	0.0010	-2054150.1025	0.0015	-2292183.2761	0.0017
RM3	-5583190.0495	0.0009	-2054125.6676	0.0017	-2292158.8347	0.0015

Table 1.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

From	To	ΔX	ΔY	ΔZ
CKIS01	RO	45.1407	-92.7942	-20.7960
CKIS01	RM1	-0.2554	-11.9603	16.4639
CKIS01	RM2	11.5573	-6.4648	-16.4837
CKIS01	RM3	-7.9495	17.9701	7.9577

1.2 2003 Survey

1.2.1 Details

Location: Cook Islands

Date: 29 – 30 November 2003

Field Book: Yellow Field Book (“Cook Is.”)

Personnel: Andrick Lal (SOPAC Surveyor)

Instrument: LEICA TCA 1800

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

1.2.2 Survey Specific Notes: *The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

The 2003 CKIS survey did not include a siting to the RO so an azimuth was computed between the CKIS Pillar and RM1 from the CKIS01 Adjustment.

1.2.3 2003 Results

Table 1.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at CKIS.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
CKIS	S 21 12 3.70071	0.0000	W159 48 2.19306	0.0000	18.4117	0.0000
RM1	S 21 12 3.15022	0.0009	W159 48 1.80693	0.0006	16.5317	0.0001
RM2	S 21 12 4.30173	0.0011	W159 48 1.84430	0.0015	16.3418	0.0002
RM3	S 21 12 3.44474	0.0015	W159 48 2.87297	0.0011	16.7051	0.0001

Table 1.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
CKIS	-5583182.1000	0.0000	-2054143.6377	0.0000	-2292166.7924	0.0000
RM1	-5583182.3557	0.0002	-2054155.5985	0.0007	-2292150.3280	0.0009
RM2	-5583170.5418	0.0007	-2054150.1035	0.0014	-2292183.2776	0.0011
RM3	-5583190.0497	0.0007	-2054125.6675	0.0010	-2292158.8355	0.0014

Table 1.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
CKIS03	RM1	-0.2557	-11.9608	16.4644
CKIS03	RM2	11.5582	-6.4658	-16.4852
CKIS03	RM3	-7.9497	17.9702	7.9569

1.3 Comparison

Table 1.7 Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2001 and 2003 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
CKIS01	RO	102.6736	-23.1219	-2.1042
CKIS01	RM1	11.1365	16.9298	-1.8803
CKIS03	RM1	11.1369	16.9304	-1.8801
CKIS01	RM2	10.0578	-18.4833	-2.0700
CKIS03	RM2	10.0590	-18.4849	-2.0700
CKIS01	RM3	-19.6097	7.8732	-1.7071
CKIS03	RM3	-19.6099	7.8725	-1.7067

1.4 Summary of Results

2. Federated States of Micronesia (Pohnpei)

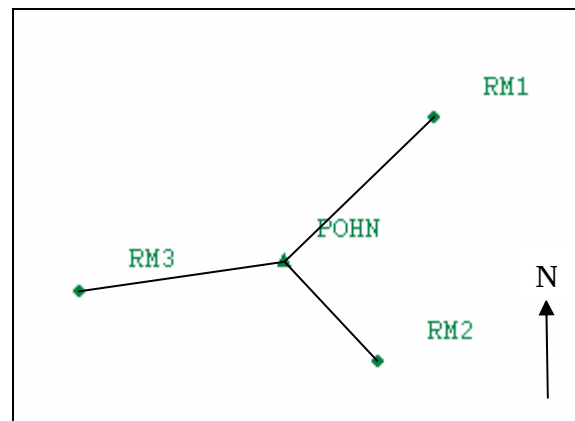


Figure 2.1 Pohnpei network. To Scale

Site Description

Site is located within the Pohnpei Weather Service Office (WSO) perimeter fence, FSM. The Technical equipment is housed within the WSO main building, the Antenna stands on a 1.5 metre high Antenna Pillar approximately 20 metres from this main building. The WSO site contact is Mr. Ceasar Hadley Ph.: 691 320 2248

2.1 2003 Survey

2.1.1 Details

Location: Pohnpei, FSM

Date: 27 – 29 April 2003

Field Book: Yellow Field Book (“FSM Pohnpei”)

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TCA1800

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

2.1.2 Survey Specific Notes: The azimuth used from PHON to RM1 was based on a magnetic bearing adjusted for magnetic declination. The coordinates derived should not be taken as true. However, the deformation observed remains accurate.

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

2.2 2003 Results

Table 2.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at POHN.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
POHN	N 6 57 35.79677	0.0000	E158 12 36.41837	0.0000	90.6641	0.0000
RM1	N 6 57 36.40392	0.0002	E158 12 37.05421	0.0003	89.1431	0.0001
RM2	N 6 57 35.37356	0.0002	E158 12 36.82223	0.0003	88.4900	0.0001
RM3	N 6 57 35.66704	0.0003	E158 12 35.54851	0.0004	88.7469	0.0001

Table 2.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres)

Site	X	Std Dev	Y	Std Dev	Z	Std Dev
POHN	-5879158.7235	0.0000	2350291.7142	0.0000	767748.1642	0.0000
RM1	-5879162.4680	0.0001	2350272.1914	0.0003	767766.4942	0.0002
RM2	-5879162.7842	0.0001	2350279.9868	0.0003	767734.9955	0.0002
RM3	-5879147.4931	0.0002	2350315.9806	0.0004	767743.9760	0.0003

Table 2.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
POHN03	RM1	-3.7445	-19.5228	18.3300
POHN03	RM2	-4.0607	-11.7274	-13.1687
POHN03	RM3	11.2304	24.2664	-4.1882

2.2 2004 Survey

2.2.1 Details

Location: Pohnpei, FSM

Date: 19 – 20 May 2004

Field Book: Yellow Field Book (“FSM Pohnpei”)

Personnel: Bob Twilley

Instrument: LEICA TCA1800

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

2.2.2 Survey Specific Notes: The azimuth used from PHON to RM1 is based on the 2003 magnetic bearing adjusted for magnetic declination. The coordinates derived should not be taken as true. However, the deformation observed remains accurate.

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

2.3 2004 Results

Table 2.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at POHN.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
POHN	N 6 57 35.79677	0.0000	E158 12 36.41837	0.0000	90.6641	0.0000
RM1	N 6 57 36.40391	0.0002	E158 12 37.05421	0.0002	89.1435	0.0000
RM2	N 6 57 35.37357	0.0002	E158 12 36.82225	0.0003	88.4901	0.0000
RM3	N 6 57 35.66701	0.0003	E158 12 35.54852	0.0003	88.7468	0.0001

Table 2.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian

Site	X	Std Dev	Y	Std Dev	Z	Std Dev
POHN	-5879158.7235	0.0000	2350291.7142	0.0000	767748.1642	0.0000
RM1	-5879162.4683	0.0001	2350272.1917	0.0002	767766.4940	0.0002
RM2	-5879162.7845	0.0001	2350279.9863	0.0003	767734.9959	0.0002
RM3	-5879147.4932	0.0001	2350315.9805	0.0003	767743.9751	0.0003

coordinates and associated standard deviations (metres)

Table 2.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
POHN04	RM1	-3.7448	-19.5225	18.3298
POHN04	RM2	-4.0610	-11.7279	-13.1683
POHN04	RM3	11.2303	24.2663	-4.1891

2.3 Comparison

Table 2.7. Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2003 and 2004 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
POHN03	RM1	19.5179	18.6518	-1.5209
POHN04	RM1	19.5177	18.6515	-1.5206
POHN03	RM2	12.3968	-13.0011	-2.1741
POHN04	RM2	12.3974	-13.0007	-2.1739
POHN03	RM3	-26.7014	-3.9853	-1.9171
POHN04	RM3	-26.7012	-3.9862	-1.9172

2.4 Summary of Results

3. Fiji

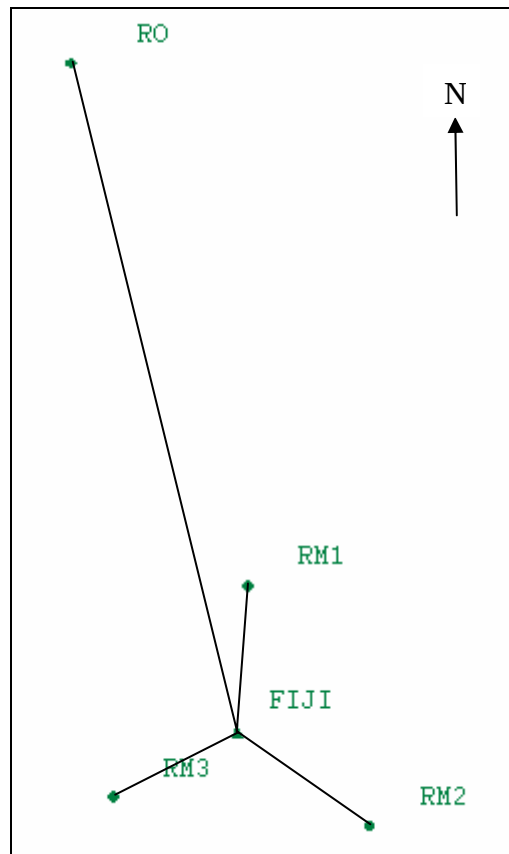


Figure 3.1 Fiji network. To Scale

Site Description

Site consists of a purpose built hut to house the Technical equipment and a 1.5 metre high Antenna pillar. The site is located within the Fiji Sugar Corporation (FSC) grounds in Lautoka. Access is restricted; approval to enter the compound can be done through Vijay at the Lands and Survey Department, Ph.: 679 666 1800 / 1362.

3.1 2001 Survey

3.1.1 Details

Location: Lautoka, Fiji

Date: 22 – 24 November 2001

Field Book: General Black Field Book # 44 (“FIJI CGPS”)

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TC 2003

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

3.1.2 Survey Specific Notes: GPS Observations for azimuth was observed over RO.

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

3.1.3 2001 Results

Table 3.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at LAUT.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
LAUT	S 17 36 31.73221	0.0000	E177 26 47.68774	0.0000	89.6765	0.0000
RO	S 17 36 28.71769	0.0044	E177 26 46.90376	0.0011	81.3164	0.0023
RM1	S 17 36 31.08518	0.0016	E177 26 47.74482	0.0006	86.3918	0.0002
RM2	S 17 36 32.16441	0.0012	E177 26 48.32586	0.0015	87.7172	0.0003
RM3	S 17 36 32.03734	0.0010	E177 26 47.10544	0.0014	87.9708	0.0002

*Note RO was not levelled to.

Table 3.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
LAUT	-6075194.5091	0.0000	270923.9959	0.0000	-1917189.5969	0.0000
RO	-6075213.5269	0.0026	270947.9809	0.0012	-1917098.7325	0.0042
RM1	-6075197.4681	0.0005	270922.4432	0.0006	-1917169.6432	0.0015
RM2	-6075189.4660	0.0004	270904.9388	0.0015	-1917201.6690	0.0012
RM3	-6075189.2851	0.0004	270940.9478	0.0014	-1917198.0220	0.0010

Table 3.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
LAUT	RO	-19.0178	23.9850	90.8644
LAUT	RM1	-2.9590	-1.5527	19.9537
LAUT	RM2	5.0431	-19.0571	-12.0721
LAUT	RM3	5.2240	16.9519	-8.4251

3.2 2003 Survey

3.2.1 Details

Location: Lautoka, Fiji

Date: 15 -16 October 2003

Field Book: General Black Field Book # 44 ("FIJI CGPS")

Personnel: Andrick Lal (SOPAC Surveyor)

Instrument: LEICA TCA 1800

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

3.2.2 Survey Specific Notes:

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

3.2.3 2003 Results

Table 3.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at LAUT.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
LAUT	S 17 36 31.73221	0.0001	E177 26 47.68774	0.0001	89.6765	0.0001
RM1	S 17 36 31.08518	0.0011	E177 26 47.74480	0.0019	86.3918	0.0002
RM2	S 17 36 32.16447	0.0019	E177 26 48.32593	0.0015	87.7165	0.0002
RM3	S 17 36 32.03735	0.0017	E177 26 47.10540	0.0013	87.9711	0.0002

Table 3.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
LAUT	-6075194.5091	0.0001	270923.9959	0.0001	-1917189.5969	0.0001
RM1	-6075197.4680	0.0004	270922.4439	0.0019	-1917169.6432	0.0011
RM2	-6075189.4648	0.0006	270904.9368	0.0015	-1917201.6704	0.0018
RM3	-6075189.2852	0.0005	270940.9487	0.0013	-1917198.0225	0.0017

Table 3.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
LAUT	RM1	-2.9589	-1.5520	19.9537
LAUT	RM2	5.0443	-19.0591	-12.0735
LAUT	RM3	5.2239	16.9528	-8.4256

3.3 Comparison

Table 3.7 Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2001 and 2003 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
LAUT01	RO	-23.1139	92.6776	-8.3608
LAUT01	RM1	1.6830	19.8921	-3.2847
LAUT03	RM1	1.6823	19.8921	-3.2848
LAUT01	RM2	18.8135	-13.2874	-1.9592
LAUT03	RM2	18.8154	-13.2891	-1.9601
LAUT01	RM3	-17.1678	-9.3806	-1.7057
LAUT03	RM3	-17.1687	-9.3811	-1.7054

Note RO ΔU invalid as RO was not levelled to.

3.4 Summary of Results

4. Kiribati

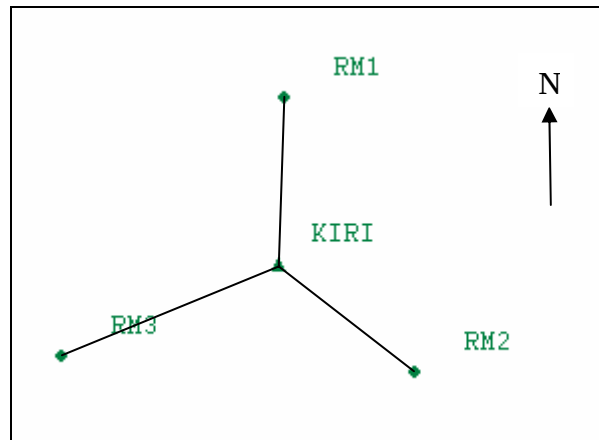


Figure 4.1 Kiribati network. To Scale

Site Description

Site consists of a purpose built hut to house the Technical equipment and a 1.5 metre high Antenna pillar. The site is located within the Weather Service Office (WSO) compound on Betio Island. Information on the access and the key can be obtained from Romano Rio at the Survey and Lands Dept. Ph.: 686 22362.

4.1 2002 Survey

4.1.1 Details

Location: Betio Island, Kiribati

Date: 31 July – 1 August 2002

Field Book: General Black Field Book ("KIRIBATI")

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TCA 1800

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

4.1.2 Survey Specific Notes: The azimuths used from KIRI to RM1 were based on a magnetic bearing adjusted for magnetic declination. The coordinates derived should not be taken as true. However, the deformation observed remains accurate.

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

1.1.3 2002 Results

Table 4.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at KIRI.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
KIRI	N 01 21 16.49194	0.0000	E 172 55 22.43007	0.0000	36.1592	0.0000
RM1	N 01 21 17.19828	0.0012	E 172 55 22.45213	0.0000	34.3408	0.0002
RM2	N 01 21 16.04232	0.0012	E 172 55 23.00671	0.0014	34.3037	0.0002
RM3	N 01 21 16.10563	0.0015	E 172 55 21.52041	0.0014	34.3188	0.0002

Table 4.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
KIRI	-6327822.4695	0.0000	785604.0462	0.0000	149769.0056	0.0000
RM1	-6327820.2404	0.0002	785603.0824	0.0001	149790.6521	0.0012
RM2	-6327823.1488	0.0002	785586.1677	0.0014	149755.1553	0.0012
RM3	-6327817.4572	0.0003	785631.7609	0.0014	149757.0999	0.0015

Table 4.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
KIRI	RM1	2.2291	-0.9638	21.6465
KIRI	RM2	-0.6793	-17.8785	-13.8503
KIRI	RM3	5.0123	27.7147	-11.9057

4.2 2003 Survey

4.2.1 Details

Location: Betio Island, Kiribati

Date: 14 – 15 November 2003

Field Book: General Black Field Book (“KIRIBATI”)

Personnel: Andrick Lal (SOPAC Surveyor)

Instrument: LEICA TCA 1800

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

4.2.2 Survey Specific Notes: The azimuths used from KIRI to RM1 are based on the 2002 magnetic bearing adjusted for magnetic declination. The coordinates derived should not be taken as true. However, the deformation observed remains accurate.

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

4.2.3 2003 Results

Table 4.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at KIRI.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
KIRI	N 01 21 16.49194	0.0000	E 172 55 22.43007	0.0000	36.1592	0.0000
RM1	N 01 21 17.19825	0.0012	E172 55 22.45213	0.0000	34.3409	0.0002
RM2	N 01 21 16.04228	0.0012	E172 55 23.00670	0.0014	34.3037	0.0002
RM3	N 01 21 16.10561	0.0015	E172 55 21.52039	0.0014	34.3187	0.0002

Table 4.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
KIRI	-6327822.4695	0.0000	785604.0462	0.0000	149769.0056	0.0000
RM1	-6327820.2406	0.0002	785603.0825	0.0001	149790.6514	0.0012
RM2	-6327823.1488	0.0002	785586.1682	0.0014	149755.1543	0.0012
RM3	-6327817.4571	0.0003	785631.7613	0.0014	149757.0994	0.0015

Table 4.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
KIRI	RM1	2.2289	-0.9637	21.6458
KIRI	RM2	-0.6793	-17.8780	-13.8513
KIRI	RM3	5.0124	27.7151	-11.9062

4.3 Comparison

Table 4.7 Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2002 and 2003 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
KIRI02	RM1	0.6818	21.6956	-1.8185
KIRI03	RM1	0.6817	21.6948	-1.8183
KIRI02	RM2	17.8260	-13.8103	-1.8556
KIRI03	RM2	17.8255	-13.8113	-1.8555
KIRI02	RM3	-28.1211	-11.8655	-1.8405
KIRI03	RM3	-28.1215	-11.8660	-1.8406

4.4 Summary of Results

5. Manus

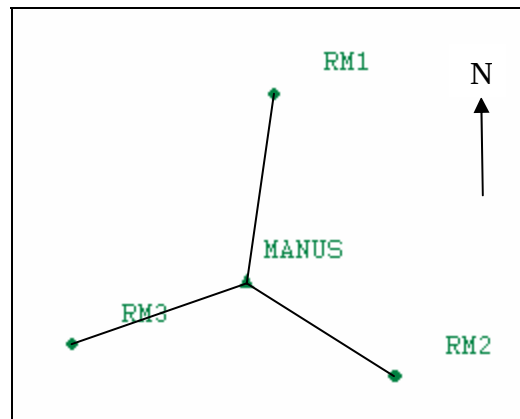


Figure 5.1 Manus network. To Scale

Site Description

Site consists of a purpose built hut to house the Technical equipment and a 1.5 metre high Antenna pillar. The site is located at the Lombrum Naval Base on Manus Island. Information on the access and the key can be obtained from Kanawi Sindol at the Survey and Lands Dept. Ph.: 675 470 9129.

5.1 2002 Survey

5.1.1 Details

Location: Lombrum, Manus Island, PNG

Date: 01 – 02 May 2002

Field Book: General Black Field Book (“MANUS ISLAND”)

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TCA 1800

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

5.1.2 Survey Specific Notes: The azimuths used from MANUS to RM1 were based on a magnetic bearing adjusted for magnetic declination. The coordinates derived should not be taken as true. However, the deformation observed remains accurate.

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

5.1.3 2002 RM Survey Results

Table 5.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at MANUS.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
MANUS	S 02 02 35.63181	0.0000	E 147 21 57.64476	0.0000	116.3471	0.0000
RM1	S 02 02 34.83660	0.0012	E 147 21 57.76147	0.0002	113.5849	0.0002
RM2	S 02 02 36.03384	0.0011	E 147 21 58.27743	0.0014	115.0119	0.0002
RM3	S 02 02 35.89763	0.0012	E 147 21 56.90999	0.0013	115.2986	0.0002

Table 5.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
MANUS	-5367943.2090	0.0000	3437431.1770	0.0000	-225886.0209	0.0000
RM1	-5367943.5628	0.0002	3437427.1205	0.0002	-225861.5122	0.0012
RM2	-5367952.2580	0.0008	3437413.7551	0.0011	-225898.3140	0.0011
RM3	-5367929.8365	0.0007	3437449.5770	0.0011	-225894.1432	0.0012

Table 5.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
MANUS	RM1	-0.3538	-4.0565	24.5087
MANUS	RM2	-9.0490	-17.4219	-12.2931
MANUS	RM3	13.3725	18.4000	-8.1223

5.2 2003 Survey

5.2.1 Details

Location: Lombrum, Manus Island, PNG

Date: 02 – 04 september 2003

Field Book: General Black Field Book (“MANUS ISLAND”)

Personnel: Steve Yates and Andrick Lal

Instrument: LEICA TCA 1800

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

5.2.2 Survey Specific Notes: The azimuths used from MANUS to RM1 were based on the 2002 magnetic bearing adjusted for magnetic declination. The coordinates derived should not be taken as true. However, the deformation observed remains accurate.

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

5.2.3 2003 RM Survey Results

Table 5.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at MANUS.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
MANUS	S 02 02 35.63181	0.0000	E 147 21 57.64476	0.0000	116.3471	0.0000
RM1	S 02 02 34.83660	0.0012	E 147 21 57.76147	0.0002	113.5847	0.0002
RM2	S 02 02 36.03387	0.0011	E 147 21 58.27737	0.0014	115.0116	0.0002
RM3	S 02 02 35.89758	0.0012	E 147 21 56.90998	0.0013	115.2989	0.0002

Table 5.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
MANUS	-5367943.2090	0.0000	3437431.1770	0.0000	-225886.0209	0.0000
RM1	-5367943.5626	0.0002	3437427.1204	0.0002	-225861.5121	0.0012
RM2	-5367952.2569	0.0008	3437413.7563	0.0011	-225898.3150	0.0011
RM3	-5367929.8366	0.0007	3437449.5773	0.0011	-225894.1416	0.0012

Table 5.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
MANUS	RM1	-0.3536	-4.0566	24.5088
MANUS	RM2	-9.0479	-17.4207	-12.2941
MANUS	RM3	13.3724	18.4003	-8.1207

5.3 Comparison

Table 5.7. Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2002 and 2003 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
MANU02	RM1	3.6069	24.4257	-2.7622
MANU03	RM1	3.6069	24.4258	-2.7625
MANU02	RM2	19.5514	-12.3486	-1.3352
MANU03	RM2	19.5498	-12.3496	-1.3355
MANU02	RM3	-22.7066	-8.1649	-1.0484
MANU03	RM3	-22.7068	-8.1633	-1.0482

5.4 Summary of Results

6. NAURU

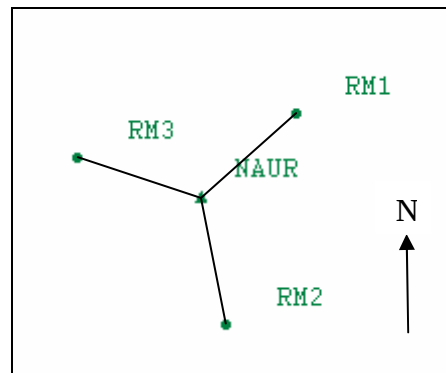


Figure 6.1 Nauru network. To Scale

Site Description

Site consists of a purpose built hut to house the Technical equipment and a 1.5 metre high Antenna pillar. The site is located in the Yaren District, Republic of Nauru. Information on the access and the key can be obtained from Wess Tsitsi at the Survey and Lands Dept. Ph.: 674 444 3760.

6.1 2003 Survey

6.1.1 Details

Location: Yaren District, Republic of Nauru.

Date: 22 – 23 June 2003

Field Book: Yellow Field Book (“NAURU”)

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TCA 1800

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

6.1.2 Survey Specific Notes: The azimuths used from NAUR to RM1 were based on a magnetic bearing adjusted for magnetic declination. The coordinates derived should not be taken as true. However, the deformation observed remains accurate.

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

6.1.3 2003 RM Survey Results

Table 6.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at NAUR.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
NAUR	S 0 33 6.23238	0.0000	E166 55 31.98521	0.0000	46.2153	0.0000
RM1	S 0 33 6.03298	0.0014	E166 55 31.35218	0.0011	44.4915	0.0001
RM2	S 0 33 5.80909	0.0008	E166 55 32.48101	0.0009	44.5560	0.0001
RM3	S 0 33 6.89881	0.0011	E166 55 32.12439	0.0014	44.3936	0.0002

Table 6.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
NAUR	-6212555.1135	0.0000	1442786.6012	0.0000	-61006.8007	0.0000
RM1	-6212557.0873	0.0003	1442771.3210	0.0009	-60993.7840	0.0008
RM2	-6212554.1206	0.0004	1442781.9525	0.0014	-61027.2519	0.0011
RM3	-6212549.0640	0.0003	1442805.2910	0.0011	-61000.6598	0.0014

Table 6.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
NAUR	RM1	-1.9738	-15.2802	13.0167
NAUR	RM2	0.9929	-4.6487	-20.4512
NAUR	RM3	6.0495	18.6898	6.1409

6.2 2004 Survey

6.2.1 Details

Location: Yaren District, Republic of Nauru.

Date: 27 – 28 March 2004

Field Book: Yellow Field Book (“NAURU”)

Personnel: Steve Yates

Instrument: LEICA TCA 2003

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

6.2.2 Survey Specific Notes: The azimuths used from NAUR to RM1 are based on the 2003 magnetic bearing adjusted for magnetic declination. The coordinates derived should not be taken as true. However, the deformation observed remains accurate.

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

6.2.3 2004 RM Survey Results

Table 6.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at NAUR.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
NAUR	S 0 33 6.23238	0.0000	E166 55 31.98521	0.0000	46.2153	0.0000
RM1	S 0 33 5.80908	0.0002	E166 55 32.48102	0.0002	44.5560	0.0001
RM2	S 0 33 6.89881	0.0003	E166 55 32.12438	0.0003	44.3936	0.0001
RM3	S 0 33 6.03293	0.0003	E166 55 31.35216	0.0003	44.4916	0.0001

Table 6.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
NAUR	-6212555.1135	0.0000	1442786.6012	0.0000	-61006.8007	0.0000
RM1	-6212557.0874	0.0001	1442771.3206	0.0002	-60993.7837	0.0002
RM2	-6212554.1205	0.0001	1442781.9528	0.0003	-61027.2519	0.0003
RM3	-6212549.0640	0.0001	1442805.2915	0.0003	-61000.6585	0.0003

Table 6.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
NAUR	RM1	-1.9739	-15.2806	13.0170
NAUR	RM2	0.9930	-4.6484	-20.4512
NAUR	RM3	6.0495	18.6903	6.1422

6.3 Comparison

Table 6.7 Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2003 and 2004 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
NAURU03	RM1	15.3306	13.0013	-1.6593
NAURU04	RM1	15.3310	13.0016	-1.6592
NAURU03	RM2	4.3036	-20.4697	-1.8218
NAURU04	RM2	4.3033	-20.4697	-1.8217
NAURU03	RM3	-19.5738	6.1246	-1.7238
NAURU04	RM3	-19.5743	6.1257	-1.7236

6.4 Summary of Results

7. SAMOA

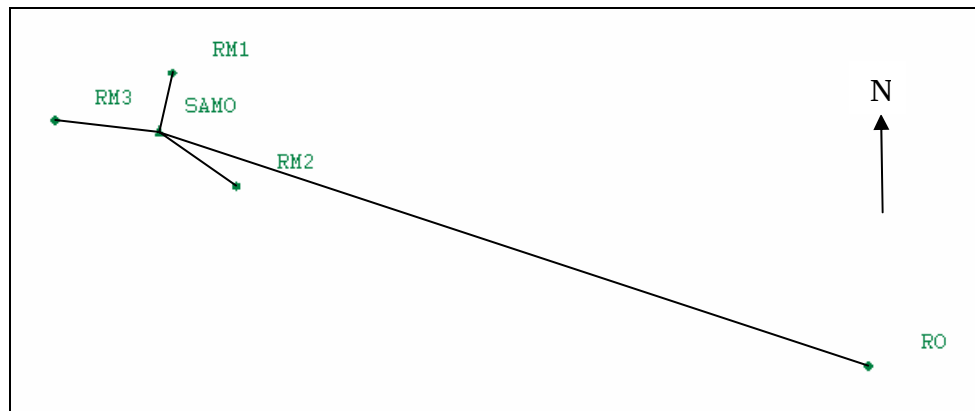


Figure 7.1 Samoa network. To Scale

Site Description

Site consists of a purpose built hut to house the Technical equipment and a 1.5 metre high Antenna pillar. The site is located within the Fagalii Airport perimeter fence, Fagalii Village. Access is restricted; the access information and the key can be obtained from Pele Futai at the Survey and Lands Dept. Ph.: 685 25155.

7.1 2001 Survey

7.1.1 Details

Location: Fagalii Airport, Samoa.

Date: 27 – 28 June 2001

Field Book: Black Field Book (“SAMOA and COOK ISLANDS”)

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TC 2003 Total Station and TOPCON DL-101C Digital Level.

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, TOPCON Fibreglass Staff.

Heighting Technique: Spirit Levelling.

7.1.2 Survey Specific Notes: The azimuths used from NAUR to RO were based on GPS observations.

No Pillar BM was in place for the 2001 survey.

7.1.3 2001 Results

Table 7.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at SAMO.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
SAMO	S 13 50 57.16198	0.0000	W171 44 18.31264	0.0000	76.8739	0.0000
RO	S 13 50 59.13553	0.0010	W171 44 12.22477	0.0031	76.6379	0.0003
RM1	S 13 50 56.68307	0.0015	W171 44 18.19052	0.0011	74.4138	0.0002
RM2	S 13 50 57.62882	0.0015	W171 44 17.64900	0.0018	75.3764	0.0003
RM3	S 13 50 57.08186	0.0012	W171 44 19.20082	0.0021	74.9230	0.0002

Table 7.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
SAMO	-6129702.2310	0.0000	-890029.4566	0.0000	-1516807.4832	0.0000
RO	-6129661.3645	0.0008	-890208.2536	0.0031	-1516866.3170	0.0010
RM1	-6129702.8267	0.0004	-890033.2488	0.0011	-1516792.6040	0.0014
RM2	-6129694.5298	0.0006	-890048.4759	0.0017	-1516821.0553	0.0015
RM3	-6129704.7722	0.0005	-890002.8746	0.0021	-1516804.6255	0.0012

Table 7.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
SAMO	RO	40.8665	-178.7970	-58.8338
SAMO	RM1	-0.5957	-3.7922	14.8792
SAMO	RM2	7.7012	-19.0193	-13.5721
SAMO	RM3	-2.5412	26.5820	2.8577

7.2 2002 Survey

7.2.1 Details

Location: Fagalii Airport, Samoa.

Date: 29 November – 1 December 2002

Field Book: Yellow Field Book (“SAMOA”)

Personnel: Steve Yates

Instrument: LEICA TCA 2003

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station Levelling Method.

7.2.2 Survey Specific Notes:

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

During the 2002 visit a Pillar BM was installed.

7.2.3 2002 Results

Table 7.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at SAMO.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
SAMO	S 13 50 57.16198	0.0000	W171 44 18.31264	0.0000	76.8739	0.0000
RO	S 13 50 59.13553	0.0010	W171 44 12.22477	0.0030	76.6134	0.0029
RM1	S 13 50 56.68307	0.0011	W171 44 18.19053	0.0010	74.4165	0.0001
RM2	S 13 50 57.62880	0.0013	W171 44 17.64904	0.0013	75.3784	0.0002
RM3	S 13 50 57.08192	0.0013	W171 44 19.20079	0.0013	74.9250	0.0002

*Note RO was not levelled to.

Table 7.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
SAMO	-6129702.2310	0.0000	-890029.4566	0.0000	-1516807.4832	0.0000
RO	-6129661.3410	0.0029	-890208.2502	0.0030	-1516866.3111	0.0012
RM1	-6129702.8294	0.0003	-890033.2488	0.0010	-1516792.6046	0.0010
RM2	-6129694.5320	0.0004	-890048.4751	0.0013	-1516821.0551	0.0012
RM3	-6129704.7735	0.0004	-890002.8757	0.0013	-1516804.6278	0.0012

Table 7.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
SAMO	RO	40.8900	-178.7936	-58.8279
SAMO	RM1	-0.5984	-3.7922	14.8786
SAMO	RM2	7.6990	-19.0185	-13.5719
SAMO	RM3	-2.5425	26.5809	2.8554

7.3 Comparison

Table 7.7 Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2001 and 2002 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
SAMO01	RM1	3.6672	14.7182	-2.4601
SAMO02	RM1	3.6669	14.7183	-2.4574
SAMO01	RM2	19.9285	-14.3477	-1.4975
SAMO02	RM2	19.9274	-14.3470	-1.4956
SAMO01	RM3	-26.6713	2.4623	-1.9509
SAMO02	RM3	-26.6704	2.4604	-1.9490

7.4 Summary of Results

8. Tonga

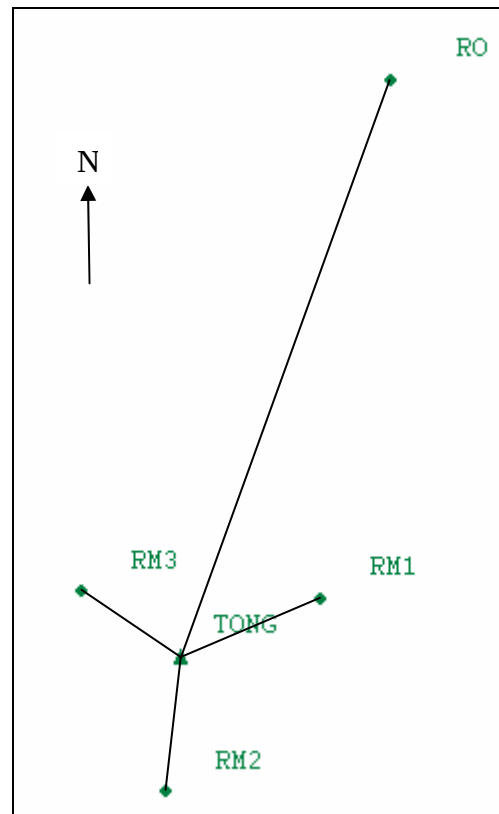


Figure 8.1 Tonga network

Site Description

Site consists of a purpose built hut to house the Technical equipment and a 1.5 metre high Antenna pillar. The site is located within the Apifo'ou College, Nuku'alofa, Tonga. Access information and the key can be obtained from Francis Latu at the Survey and Lands Dept. Ph.: 676 27364.

8.1 2002 Survey

8.1.1 Details

Location: Apifo'ou College, Nuku'alofa.

Date: 15 – 16 February 2002

Field Book: Black Field Book ("TONGA CGPS")

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TCA 2003 Total Station.

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station levelling Method.

8.1.2 Survey Specific Notes:

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

8.1.3 2002 Results

Table 8.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at TONG.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
TONG	S 21 08 40.96692	0.0000	W175 10 45.20720	0.0000	56.3168	0.0000
RO	S 21 08 37.41726	0.0021	W175 10 43.80643	0.0008	54.2501	0.0002
RM1	S 21 08 40.61347	0.0010	W175 10 44.27433	0.0011	54.1131	0.0002
RM2	S 21 08 41.79830	0.0011	W175 10 45.29471	0.0009	54.1773	0.0002
RM3	S 21 08 40.57229	0.0009	W175 10 45.85092	0.0010	54.2700	0.0002

Table 8.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
TONG	-5930303.7219	0.0000	-500147.1080	0.0000	-2286366.2034	0.0000
RO	-5930337.6450	0.0007	-500190.5291	0.0009	-2286263.6364	0.0020
RM1	-5930303.3191	0.0004	-500174.0857	0.0011	-2286355.2700	0.0009
RM2	-5930292.7546	0.0004	-500143.6494	0.0009	-2286389.2798	0.0010
RM3	-5930307.7431	0.0004	-500128.8081	0.0010	-2286354.1452	0.0009

Table 8.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
TONG	RO	-33.9231	-43.4211	102.5670
TONG	RM1	0.4028	-26.9777	10.9334
TONG	RM2	10.9673	3.4586	-23.0764
TONG	RM3	-4.0212	18.2999	12.0582

8.2 2003 Survey

8.2.1 Details

Location: Apifo'ou College, Nuku'alofa.

Date: 11 – 12 October 2003 February 2002

Field Book: Black Field Book ("TONGA CGPS")

Personnel: Bob Twilley and Andrick Lal

Instrument: LEICA TCA 2003 Total Station.

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station levelling Method.

8.2.2 Survey Specific Notes:

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

The 2003 did not include a siting to the RO, so an azimuth was computed between the TONG Pillar and RM1 from the TONG 2002 adjustment results.

8.2.3 2003 Results

Table 8.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at TONG.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
TONG	S 21 08 40.96692	0.0000	W 175 10 45.20720	0.0000	56.3168	0.0000
RM1	S 21 08 40.61348	0.0005	W175 10 44.27434	0.0011	54.1134	0.0002
RM2	S 21 08 41.79830	0.0012	W175 10 45.29475	0.0013	54.1774	0.0002
RM3	S 21 08 40.57228	0.0013	W175 10 45.85091	0.0011	54.2702	0.0002

Table 8.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
TONG	-5930303.7219	0.0000	-500147.1080	0.0000	-2286366.2034	0.0000
RM1	-5930303.3193	0.0002	-500174.0855	0.0012	-2286355.2703	0.0004
RM2	-5930292.7549	0.0005	-500143.6483	0.0013	-2286389.2797	0.0011
RM3	-5930307.7433	0.0005	-500128.8084	0.0011	-2286354.1452	0.0012

Table 8.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
TONG	RM1	0.4026	-26.9775	10.9331
TONG	RM2	10.9670	3.4597	-23.0763
TONG	RM3	-4.0214	18.2996	12.0582

8.3 Comparison

Table 8.7 Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2002 and 2003 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
TONG02	RO	40.4166	109.1713	-2.0679
TONG02	RM1	26.9161	10.8703	-2.2038
TONG03	RM1	26.9159	10.8701	-2.2035
TONG02	RM2	-2.5247	-25.5697	-2.1396
TONG03	RM2	-2.5258	-25.5696	-2.1394
TONG02	RM3	-18.5731	12.1370	-2.0469
TONG03	RM3	-18.5728	12.1370	-2.0467

8.4 Summary of Results

9. Tuvalu

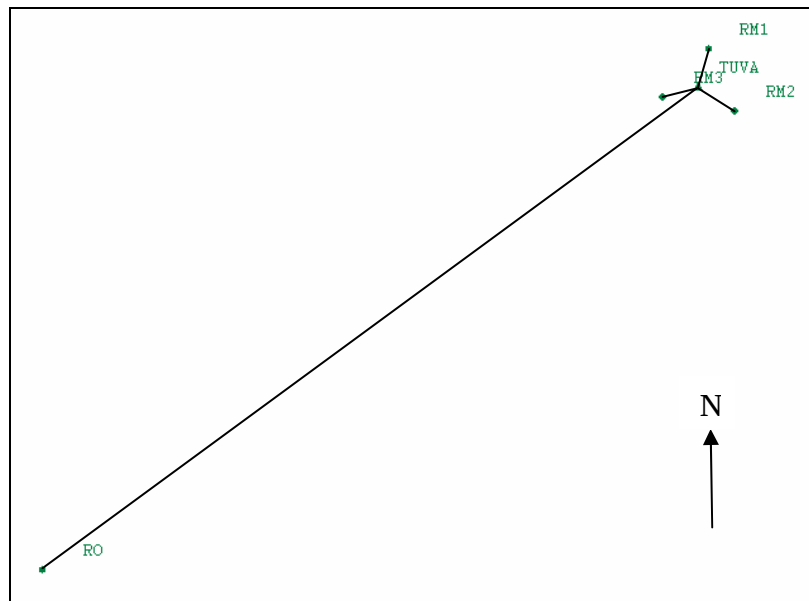


Figure 9.1 Tuvalu network. To Scale

Site Description

Site located within the perimeter fencing at the Tuvalu Weather Station Office (WSO), Funafuti, the Technical equipment is housed in an existing building at the WSO and a 1.5 metre high Antenna pillar is located approximately 30 metres away. Access information and the key can be obtained from Faatasi Malologa at the Survey and Lands Dept. Ph.: 688 20097 or directly from the WSO director Ms Hilia Vavae.

9.1 2001 Survey

9.1.1 Details

Location: Funafuti, Tuvalu.

Date: 28 November – 1 December 2001

Field Book: Black Field Book ("TUVALU")

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TC 2003 Total Station.

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station levelling Method.

9.1.2 Survey Specific Notes:

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

Azimuth to RO was determined from GPS observations from previous APRGP campaigns.

9.1.3 2001 RM Survey Results

Table 9.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at TUVA.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
TUVA	S 08 31 31.05048	0.0000	E 179 11 47.62083	0.0000	38.4067	0.0000
RO	S 08 31 42.34229	0.0023	E 179 11 32.06878	0.0030	39.2389	0.0090
RM1	S 08 31 30.18260	0.0012	E 179 11 47.88609	0.0012	36.7880	0.0002
RM2	S 08 31 31.62528	0.0012	E 179 11 48.49883	0.0013	36.8596	0.0002
RM3	S 08 31 31.29945	0.0012	E 179 11 46.77483	0.0012	36.6325	0.0002

*Note RO was not levelled to.

Table 9.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
TUVA	-6307543.7422	0.0000	88454.2756	0.0000	-939278.1585	0.0000
RO	-6307486.4459	0.0089	88929.1411	0.0030	-939621.3548	0.0026
RM1	-6307546.2076	0.0002	88446.1971	0.0012	-939251.5501	0.0012
RM2	-6307539.9711	0.0003	88427.3684	0.0013	-939295.3933	0.0012
RM3	-6307540.4911	0.0003	88480.1057	0.0012	-939285.4600	0.0012

Table 9.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
TUVA	RO	57.2963	474.8655	-343.1963
TUVA	RM1	-2.4654	-8.0785	26.6084
TUVA	RM2	3.7711	-26.9072	-17.2348
TUVA	RM3	3.2511	25.8301	-7.3015

9.2 2003 Survey

9.2.1 Details

Location: Funafuti, Tuvalu.

Date: 7 – 8 October 2003

Field Book: Black Field Book (“TUVALU”)

Personnel: Bob Twilley and Andrick Lal

Instrument: LEICA TCA 1800 Total Station.

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station levelling Method.

9.2.2 Survey Specific Notes:

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

Azimuth to RO was determined from GPS observations from previous APRGP campaigns.

9.2.3 2003 Results

Table 9.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at TUVA.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
TUVA	S 08 31 31.05048	0.0000	E 179 11 47.62083	0.0000	38.4067	0.0000
RM1	S 08 31 30.18260	0.0011	E 179 11 47.88609	0.0003	36.7878	0.0002
RM2	S 08 31 31.62531	0.0013	E 179 11 48.49887	0.0015	36.8594	0.0002
RM3	S 08 31 31.29945	0.0013	E 179 11 46.77483	0.0013	36.6323	0.0002

Table 9.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
TUVA	-6307543.7422	0.0000	88454.2756	0.0000	-939278.1585	0.0000
RM1	-6307546.207	0.0002	88446.197	0.0003	-939251.5502	0.0011
RM2	-6307539.971	0.0003	88427.3673	0.0015	-939295.394	0.0012
RM3	-6307540.491	0.0003	88480.1056	0.0013	-939285.4598	0.0013

Table 9.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
TUVA	RM1	-2.4651	-8.0786	26.6083
TUVA	RM2	3.7714	-26.9083	-17.2355
TUVA	RM3	3.2513	25.8300	-7.3013

9.3 Comparison

Table 9.7 Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2001 and 2003 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
TUVA01	RO	-475.6222	-346.9102	0.8049
TUVA01	RM1	8.1123	26.6630	-1.6187
TUVA03	RM1	8.1124	26.6629	-1.6190
TUVA01	RM2	26.8517	-17.6593	-1.5472
TUVA03	RM2	26.8528	-17.6600	-1.5474
TUVA01	RM3	-25.8731	-7.6490	-1.7743
TUVA03	RM3	-25.8731	-7.6489	-1.7745

*Note RO ΔU invalid as RO was not levelled to.

9.4 Summary of Results

10. Vanuatu

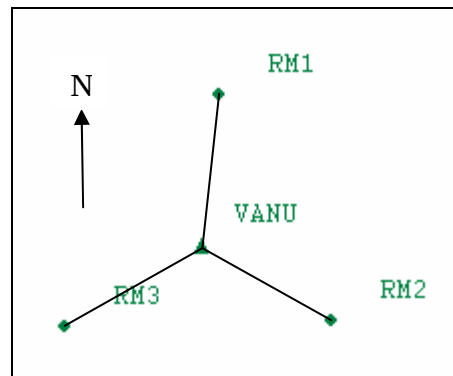


Figure 10.1 Vanuatu network. To Scale

Site Description

Site consists of a purpose built hut to house the Technical equipment and a 1.5 metre high Antenna pillar. The site is located within the Parliament House grounds, Port Villa, Vanuatu Access is restricted; the access information and the key can be obtained from Tony Kanas at the Survey and Lands Dept. Ph.: 678 22427.

10.1 2002 Survey

10.1.1 Details

Location: Port Vila, Vanuatu.

Date: 8 – 9 September 2002

Field Book: Yellow Field Book (“Vanuatu”)

Personnel: Bob Twilley and Steve Yates

Instrument: LEICA TCA 2003 Total Station.

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station levelling Method.

10.1.2 Survey Specific Notes:

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

10.1.3 2002 Results

Table 10.1 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at VANU.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
VANU	S 17 44 38.31099	0.0000	E168 18 54.54333	0.0000	97.6002	0.0000
RM1	S 17 44 37.67439	0.0012	E168 18 54.63276	0.0002	95.6044	0.0001
RM2	S 17 44 38.62945	0.0012	E168 18 55.12468	0.0013	95.9622	0.0002
RM3	S 17 44 38.65864	0.0012	E168 18 53.95150	0.0014	95.8442	0.0001

Table 10.2 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
VANU	-5950766.6783	0.0000	1230703.5583	0.0000	-1931445.0901	0.0000
RM1	-5950771.1916	0.0004	1230701.8013	0.0001	-1931425.8411	0.0011
RM2	-5950765.6972	0.0005	1230685.8660	0.0013	-1931453.9159	0.0011
RM3	-5950758.3193	0.0004	1230719.6343	0.0014	-1931454.7348	0.0012

Table 10.3 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
VANU	RM1	-4.5133	-1.7570	19.2490
VANU	RM2	0.9811	-17.6923	-8.8258
VANU	RM3	8.3590	16.0760	-9.6447

10.2 2004 Survey

10.2.1 Details

Location: Port Vila, Vanuatu.

Date: 23 – 24 March 2004

Field Book: Yellow Field Book (“Vanuatu”)

Personnel: Steve Yates

Instrument: LEICA TCA 2003 Total Station.

Ancillary Equipment: LEICA GPH1P Precision Prisms, and Telescopic Tripods, Bi Pole with Stainless Steel Target Pole and Pillar Target Stub*.

Heighting Technique: Total Station levelling Method.

10.2.2 Survey Specific Notes:

*The Stainless Steel Target Pole and Pillar Target Stub Set - No.2 was used. See Calibration details in Annex A.

10.2.3 2004 Results

Table 10.4 Latitude, Longitude and Ellipsoidal Height and associated standard deviations (metres) for the RM stations. ITRF2000@2003.00 coordinates adopted at VANU.

Mark	Latitude	Std Dev	Longitude	Std Dev	height (m)	Std Dev
VANU	S 17 44 38.31099	0.0000	E168 18 54.54333	0.0000	97.6002	0.0000
RM1	S 17 44 37.67436	0.0003	E168 18 54.63276	0.0000	95.6045	0.0001
RM2	S 17 44 38.62932	0.0012	E168 18 55.12478	0.0000	95.9622	0.0001
RM3	S 17 44 38.65877	0.0000	E168 18 53.95154	0.0003	95.8443	0.0001

Table 10.5 GPS station and RMs ITRF2000@2003.00 Earth Centred Cartesian coordinates and associated standard deviations (metres).

Mark	X	Std Dev	Y	Std Dev	Z	Std Dev
VANU	-5950766.6783	0.0000	1230703.5583	0.0000	-1931445.0901	0.0000
RM1	-5950771.1916	0.0004	1230701.8013	0.0001	-1931425.8411	0.0011
RM2	-5950765.6972	0.0005	1230685.8660	0.0013	-1931453.9159	0.0011
RM3	-5950758.3193	0.0004	1230719.6343	0.0014	-1931454.7348	0.0012

Table 10.6 Difference in XYZ coordinates between the GPS pillar and surrounding RMs (metres).

FROM	TO	ΔX	ΔY	ΔZ
VANU	RM1	-4.5135	-1.7570	19.2497
VANU	RM2	0.9794	-17.6951	-8.8221
VANU	RM3	8.3599	16.0746	-9.6486

10.3 Comparison

Table 10.7 Topocentric vectors showing Delta East, Delta North and Delta Up between each GPS pillar and the RM (metres). Both 2002 and 2004 results are listed for comparison purposes.

FROM	TO	ΔE	ΔN	ΔU
VANU02	RM1	2.6347	19.5718	-1.9958
VANU04	RM1	2.6347	19.5725	-1.9958
VANU02	RM2	17.1270	-9.7908	-1.6380
VANU04	RM2	17.1301	-9.7869	-1.6380
VANU02	RM3	-17.4358	-10.6883	-1.7560
VANU04	RM3	-17.4346	-10.6924	-1.7559

10.4 Summary of Results

ANNEX A

Prism Pole Calibration – Set No. 2

Prism Pole and Pillar plate prism holder Calibration 20th September 2001 (Stromlo ACT)

Temperature: 16.4 C Pressure: 932.5 Mbar Humidity: 0.67800

Leica TC2003 Observations corrected for atmospheric

Setup A	Face left	Face right	Face right	Face left
Pillar Prism holder	-0.95410	-0.95457	-0.95458	-0.95413
Pillar Prism holder	-0.95418	-0.95457	-0.95458	-0.95411
Pillar Prism holder	-0.95413	-0.95457	-0.95459	-0.95413
Mean	-0.95414	-0.95457	-0.95458	-0.95412
	-0.95435		-0.95435	
	-0.95435			
SR BM Prism pole	0.23099	0.23061	0.23043	0.23083
SR BM Prism pole	0.23089	0.23059	0.23041	0.23089
SR BM Prism pole	0.23094	0.23060	0.23044	0.23089
Mean	0.23094	0.23060	0.23043	0.23087
	0.23077		0.23065	
	0.23071			
Diff Pole - Holder (1)	-1.18506			

Setup C	Face left	Face right
Pillar Prism holder	-0.93697	-0.93746
Pillar Prism holder	-0.93693	-0.93753
Mean	-0.93695	-0.93750
	-0.93722	
	Face right	Face left
Pole on Tribrac	0.48337	0.48337
Pole on Tribrac	0.48337	0.48337
Mean	0.48337	0.48337
	0.48337	

Levelling	Back Site	Inter.	Fore sight	Diff Height
Pillar plate	0.93968			
	0.93955			
Mean	0.93962			
Tribrac		0.98082		
		0.98075		
		0.98085		
		0.98080		-0.04119
SR BM	1.18533		1.21658	
	1.18523		1.21646	
	1.18528		1.21652	-0.27691
Pillar plate			0.90853	
			0.90841	
			0.90847	0.27681
Total	2.12490		2.12499	
Misclose	-0.00009			-0.00009

Setup B	Face left	Face right	Face right	Face left
Pillar Prism holder	-0.93676	-0.93738	-0.93745	-0.93692
Pillar Prism holder	-0.93676	-0.93734	-0.93742	-0.93691
Pillar Prism holder	-0.93675	-0.93734	-0.93741	-0.93694
Mean	-0.93676	-0.93735	-0.93743	-0.93692
	-0.93706		-0.93718	
	-0.93712			
SR BM Prism pole	0.24806	0.24753	0.24775	0.24798
SR BM Prism pole	0.24804	0.24752	0.24771	0.24799
SR BM Prism pole	0.24805	0.24751	0.24772	0.24804
Mean	0.24805	0.24752	0.24773	0.24800
	0.24779		0.24787	
	0.24783			
Diff Pole - Holder (2)	-1.18494			

Setup D	Face left	Face right
Pole on Pillar	0.38555	0.38502
Pole on Pillar	0.38553	0.38495
Mean	0.38554	0.38499
	0.38526	
	Face right	Face left
Prism holder on Tribrac	-1.11641	-1.11666
Prism holder on Tribrac	-1.11643	-1.11669
Mean	-1.11642	-1.11668
	-1.11655	

Mean Pole - Holder (1-2) -1.18500
Mean Pillar plate - SR BM -0.27686

Diff pole - prism holder -1.46186

Measure of Prism holder 0.15980

Calibrated Height Difference between Heighting Poles Set 1 and Set 2

HEIGHT DIFFERENCE - Heighting Poles Set No.1 and Set No.2

Heighting Pole Set No.	Observed Height Difference Instrument to Prism	Mean Height Difference Instrument to Prism	Cal. Difference Set No. 1 - Set No. 2
Set No. 1 Heighting Pole	0.0996		
Set No. 1 Heighting Pole	0.0997	0.09968	
Set No. 1 Heighting Pole	0.0996		
Set No. 1 Heighting Pole	0.0998		-0.00195
Set No. 2 Heighting Pole	0.1016		
Set No. 2 Heighting Pole	0.1017	0.10163	
Set No. 2 Heighting Pole	0.1016		
Set No. 2 Heighting Pole	0.1016		

*Set No. 2 is 19.5 mm higher than Set No. 1