



**Australian Government**  

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**Geoscience Australia**

South Pacific Sea Level and Climate Monitoring  
Project (SPSLCMP)

**Survey Report**

EDM Height Traversing  
Levelling Survey

**Tuvalu**

**January 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 # 69407



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## Introduction

This report outlines the level survey completed during the visit to Funafuti, Tuvalu January 2009.

Personnel: Nick Brown – Surveyor - **GEOSCIENCE AUSTRALIA**  
Andrick Lal – Surveyor - **SOPAC**

This is the third EDM Height Traversing levelling survey of the deep driven bench mark array in Funafuti, Tuvalu. These surveys follow the eight previous surveys from 1993 to 2003, undertaken by the National Tidal Centre (NTC) using the Precise Differential Levelling technique.

## The Survey

The EDM Height Traversing level survey was carried out between the six deep driven bench marks:

**BM22**

**BM23**

**BM24**

**BM26**

**BM27**

**BM28**

Included in the survey was the CGPS Station bench mark, **TUVABM**, the SEAFRAME Sensor Bench Mark - **TUV20**, the Project Plaque point – **TUV19**, at the Tide Gauge and Holding Marks **TUV42, TUV100, TUV61, TUV48, TUV74, TUV73 and TUV102**.

Permanent holding mark TUV102 has been destroyed and a new deep driven benchmark (BM28) was put in out the front of the mosque. A benchmark locality diagram for BM28 has been added to the diagrams in this document (pg 17 – 29). All the other deep driven bench marks were located and found undisturbed and in good order.

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  $1\text{mm} \sqrt{K}$  or better was achieved, where K is levelled distance in kilometres. Project Specification precision is  $2\text{mm} \sqrt{K}$

## Bench Mark Locality Diagram





## The Tuvalu Datum

The Datum for the survey is the University of Hawaii Tide Staff Zero (TSZ). Reduction of the data has been calculated holding BM22 fixed at 3.22540 metres TSZ, this value was determined by the NTC in 1993 by :

- 1993 Adopting the height of UH 1  
RL = 3.0072 metres TSZ
- 1994 Adopting the height of BM22 as derived from the 1993 survey  
RL = 3.22540 metres.



## Equipment

LEICA Total Station Model TCA1800 (S/N 424936).

LEICA Precision Prisms GPH1P (2).

LEICA Rigid Tripod.

Stainless Steel Target Poles supported by LEICA telescopic Bi-Poles (2).

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 Tuvalu 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 Director of the Tuvalu Meteorological Service, Ms. Hilia Vavea and her staff provided valuable support during our visit.

A special mention to Mr. Tinapa Faletiuete for his technical assistance when installing the solar panels and wiring them to the battery bank. His willingness and expertise in this field was appreciated.

The Weather Office also collected and provided secure storage for all our survey equipment prior to our arrival.

Other personnel consulted during the visit were:

Mr. Faatasi Mautama – Director, Lands and Survey Department.

The survey team did not require any assistance from the Lands and Survey Department on this visit.

## Issues

No issues or concerns of any importance as regards the level survey were encountered during the 2007 visit.



## Description of Marks – Tuvalu, Funafuti

**BM22** is the bench mark held fixed with an **RL = 3.22540 metres**

The height of **BM22** was derived in 1993 by NTC by means of:

**1993** Adopting the height of UH 1  
RL = 3.0072 metres T.S.Z.

**1994** Adopting the height of **BM22** from the 1993 survey.  
RL = 3.22540

Bench Marks:

**BM22, BM23, BM24, BM26, BM27 and BM28** are all Deep Driven BM's

\* BM25 has been destroyed.

Point:

**TUV20** is the SEAFRAME Sensor Bench Mark

**TUV19** is the Project Plaque point

**TUVABM** is the Reference Bench Mark for the CGPS Pillar.

**TUV42, TUV100, TUV101, TUV61, TUV48, TUV74, TUV73, TUV102** are all permanent stainless steel bolt holding marks, drilled in concrete and glued in place.



## Table of Results and Comparisons between 2007 and 2009

TUVALU 2007 - EDM Height Traversing Levelling Comparison 2007 - 2009 and Table of Results								
BM22 - Adopted fixed height (TSZ)			3.22540					
FROM	TO	Levelled Height Difference	Reduced Level 2009	Misclose (mm)	Distance (Km)	1mm√K	Reduced Level 2007	Difference (mm) 2007 - 2009
BM22	TUV42	0.53737	3.76277	0.29667	0.328	0.57271	3.76369	0.92
TUV42	TUV19	-0.27512	3.48765	0.10575	0.241	0.49092	3.48786	0.21
TUV19	TUV20	0.97110	4.45875	0.04850	0.007	0.08431	4.45962	0.87
BM22	TUV100	-0.29016	2.93524	0.40125	0.258	0.50794	2.93513	-0.11
TUV100	BM23	0.20450	3.13974	-0.11333	0.239	0.48888	3.13931	-0.43
BM23	TUV101	-0.04702	3.09272	-0.00750	0.374	0.61156	3.09258	-0.14
TUV101	TUV61	-0.21435	2.87838	0.56625	0.326	0.57096	2.87807	-0.31
TUV61	TUV48	0.18390	3.06228	0.14000	0.119	0.34496	3.06173	-0.55
TUV48	TUV74	-0.47729	2.58498	-0.02125	0.243	0.49295	2.58421	-0.77
TUV74	BM24	1.21160	3.79659	0.21375	0.107	0.32711	3.7962	-0.39
TUV74	TUV73	-0.28432	2.30067	0.43500	0.199	0.44609	2.29979	-0.88
TUV73	BM28	-0.08358	2.21709	0.67750	0.409	0.63953		
BM28	BM27	-0.00089	2.21620	0.24800	0.357	0.59749	2.21565	-0.55
BM27	BM26	0.89195	3.10815	-0.23500	0.120	0.34641	3.10786	-0.29
BM27	TUVABM	0.52557	2.74177	0.12500	0.147	0.38341	2.74066	-1.11
<b>TUV20</b>	<b>TUVABM</b>	<b>-1.71699</b>	2.74177		<b>3.247</b>	1.80197	<b>2.74066</b>	-1.11

An internal precision of 1mm√K was achieved for all bays levelled - this is well within the Project Specification of 2mm√K

\*Note 1 - Mark not included in 2005 survey

\*Note 2 - New mark established in 2007

\*Note 2 - New mark established in 2009



## Combined Comparisons 1993 to 2009

Tuvalu - The comparison of RL's for Precise Differential Levelling (1993 – 2005) and EDM Height Traversing (2005 – 2009)

YEAR	MARK									
	BM22	BM23	BM24	BM25	BM26	BM27	BM28	TUV19	TUV20	TUVABM
1993	3.2254	3.1385	3.7982					3.4813	4.4599	
1994	3.2254	3.1394	3.7968					3.4826	4.4603	
1995	3.2254	3.1392	3.7972					3.4833	4.4609	
1997	3.2254	3.1387	3.7958					3.4834	4.4608	
1998	3.2254	3.1383	3.7953					3.4848	4.4615	
2000	3.2254	3.1386	3.7951					3.4842	4.4600	
2002	3.2254	3.1390	3.7952					3.4848	4.4599	
2003	3.2254	3.1391	3.7960	3.5369	3.1099	2.2165		3.4851	4.4593	2.7414
2005	3.2254	3.1386	3.7959	3.5379	3.1102	2.2176		3.4864	4.4592	2.7425
2005 EDM	3.2254	3.1393	3.7964	3.5373	3.1099	2.2177		3.4867	4.4593	2.7432
2007 EDM	3.2254	3.1393	3.7962	<i>Destroyed</i>	3.1079	2.2157		3.4879	4.4596	2.7407
2009 EDM	3.2254	3.1397	3.7966		3.1082	2.2162	2.2171	3.4877	4.4588	2.7418



## Tuvalu, Funafuti 2009 Reduced Levels

**Date:** January 2009

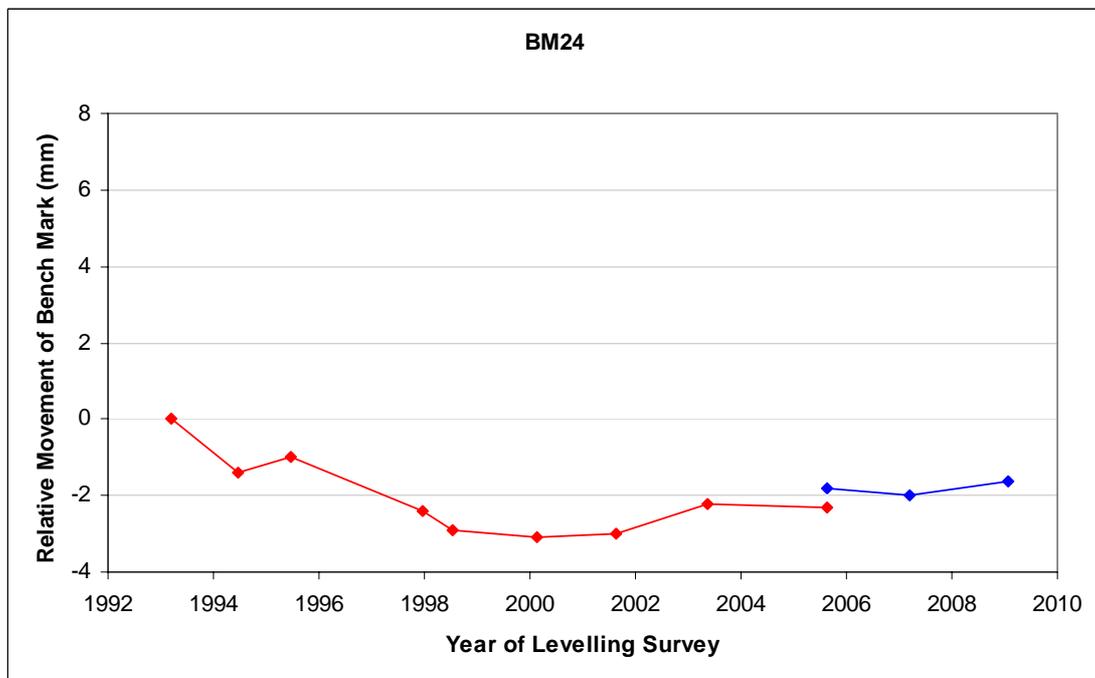
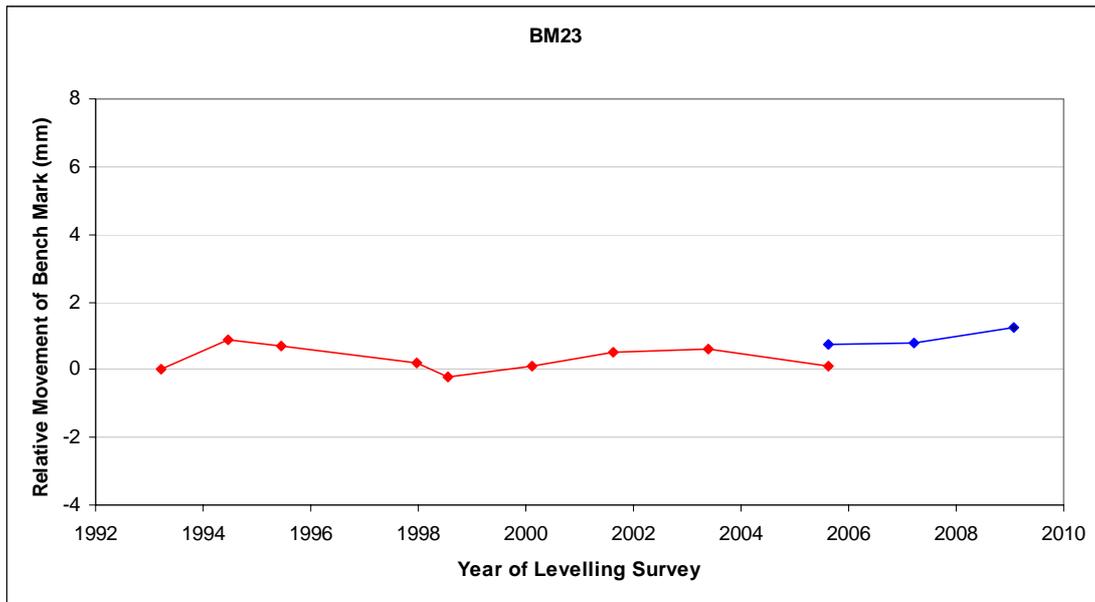
**Datum:** TSZ (University of Hawaii Tide Staff Zero)

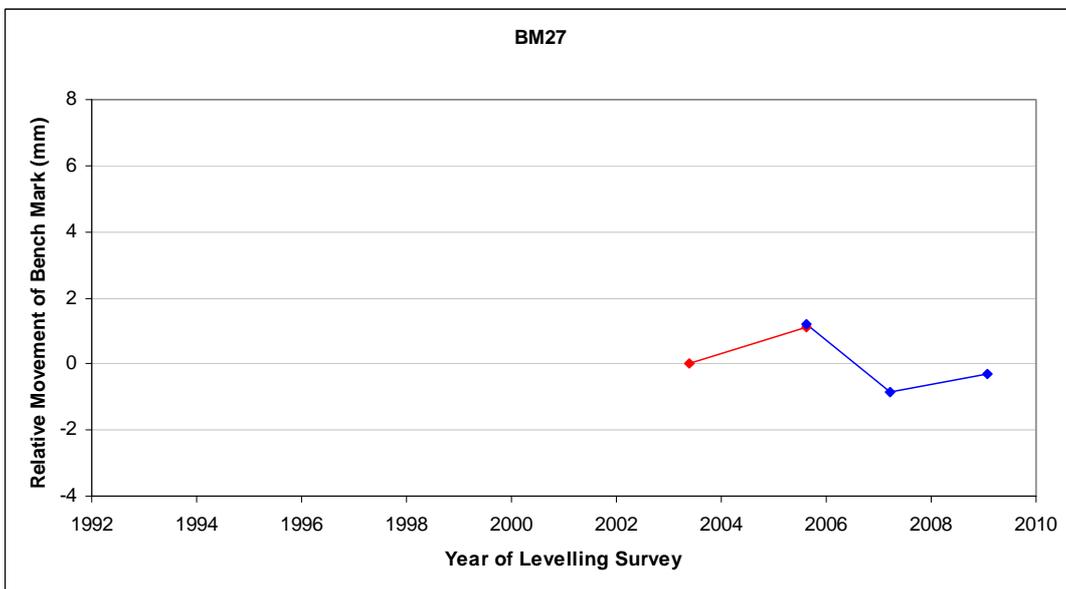
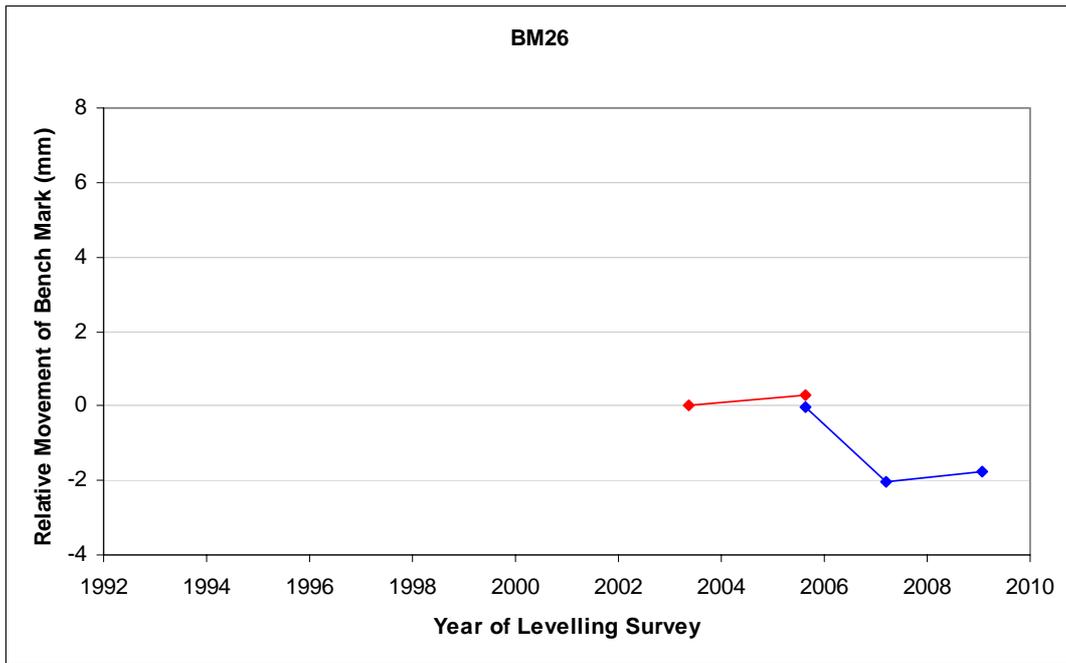
<b>POINT#</b>	<b>2009 levelled diff. ht.</b>	<b>2009 RL</b>
<b>BM22 (fixed)</b>	<i><b>0.000000</b></i>	<i><b>3.22540 (fixed)</b></i>
TUV42	+0.53737	3.76277
TUV19	-0.27512	3.48765
TUV20	+0.97110	4.45875
<b>BM22 (fixed)</b>	<i><b>0.000000</b></i>	<i><b>3.22540 (fixed)</b></i>
TUV100	-0.29016	2.93524
<b>BM23</b>	<b>+0.20450</b>	<b>3.13974</b>
TUV101	-0.04702	3.09272
TUV61	-0.21435	2.87838
TUV48	+0.18390	3.06228
TUV74	-0.47729	2.58498
<b>BM24</b>	<b>+1.21160</b>	<b>3.79659</b>
TUV74		<b>2.58498</b>
TUV73	-0.28432	2.30067
<b>BM28</b>	-0.08358	2.21709
<b>BM27</b>	<b>-0.00089</b>	<b>2.21620</b>
<b>BM26</b>	<b>+0.89195</b>	<b>3.10815</b>
<b>BM27</b>		<b>2.21620</b>
<b>TUVABM</b>	<b>+0.52557</b>	<b>2.74177</b>

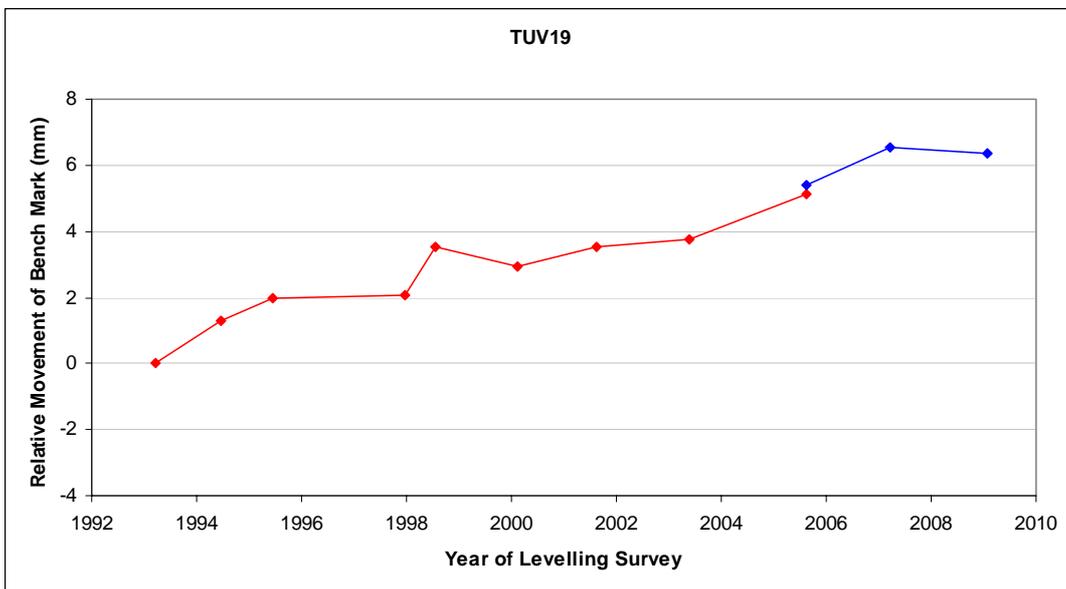
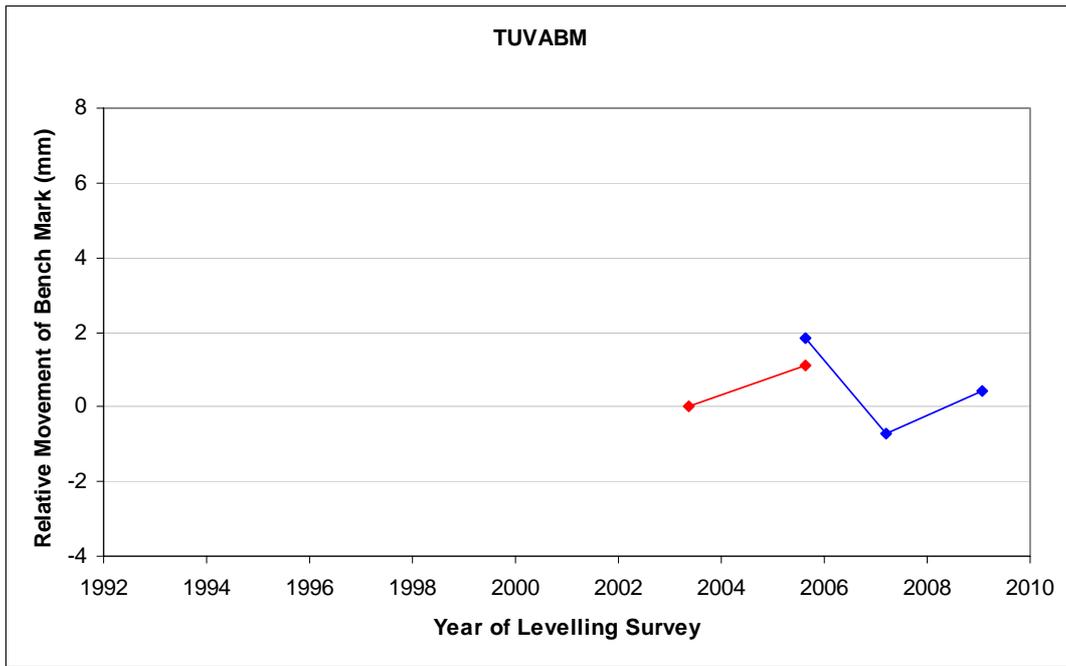


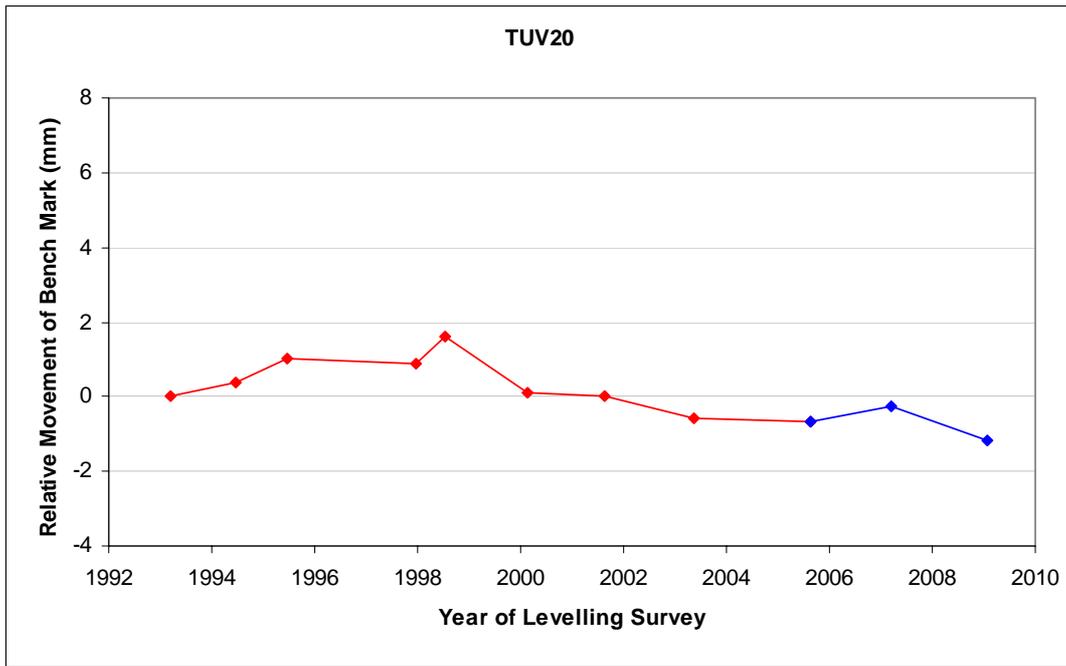
## Time Series of Bench Mark movement relative to the Fixed Deep driven Bench Mark - BM 22

Precise Differential Levelling - 1993 to 2003 (2005) ◆—◆  
 EDM Height Traversing - commenced 2005 ◆—◆









# Deep Bench Mark Locality Diagrams



SOUTH PACIFIC SEA LEVEL AND  
CLIMATE MONITORING PROJECT



AUSTRALIAN  
INTERNATIONAL  
DEVELOPMENT  
ASSISTANCE  
BUREAU

## BENCH MARK RECORD

Bench Mark Number: BM22

Original Bench Mark Established by:		Date: 04-02-92
National Tidal Facility, Flinders University of South Aust.		
Existing Bench Mark Established by:		Date:
References:		
Country: Tuvalu		Island / Atoll: Funafuti
City / Island: Fongafale		
Marking and locality sketch		
Bench Mark: 2.2 m of 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC tube for top 0.6m. Top of mark 0.25m below ground level.		
Locality sketch: Mark approx. 500 m from tide gauge station.		
Not to scale	Distances in metres	Magnetic bearings
Approved by:		Date:





SOUTH PACIFIC SEA LEVEL AND  
CLIMATE MONITORING PROJECT

BENCH MARK RECORD



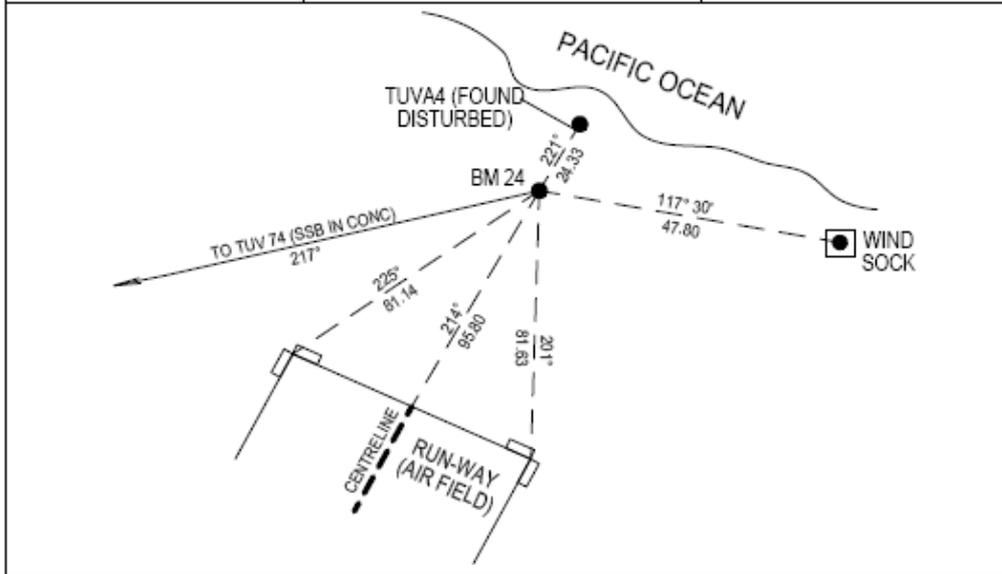
AUSTRALIAN  
INTERNATIONAL  
DEVELOPMENT  
ASSISTANCE  
BUREAU

Bench Mark Number: BM23

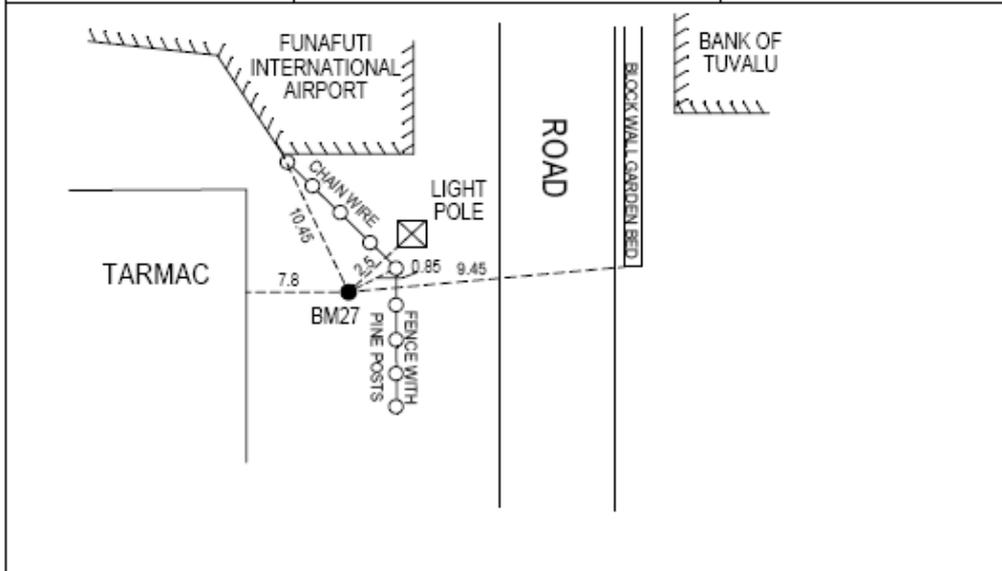
Original Bench Mark Established by:	Date:03-02-92
National Tidal Facility, Flinders University of South Aust.	
Existing Bench Mark Established by:	Date:
References:	
Country: Tuvalu	Island / Atoll: Funafuti
City / Island: Fongafale	
Marking and locality sketch	
Bench Mark: 1.0m of 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC tube for top 0.6m. Top of mark 0.2m below ground level.	
Locality sketch: Mark approx. 1000m from tide gauge station.	
<p>LAGOON</p> <p>concrete base</p> <p>Bitumen Road</p> <p>sharf</p> <p>1.35</p> <p>1.17</p> <p>1.04</p> <p>nail</p> <p>Coconut Palm</p> <p>1m</p> <p>Not to scale</p> <p>Distances in metres</p> <p>Magnetic bearings</p>	
Approved by:	Date:



COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 784 POINT NO. BM 24
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 29-03-07



COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 785 POINT NO. BM 27
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 18-01-07





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



**BENCH MARK RECORD**

Bench Mark Number: BM 26

Original Bench Mark Established by: National Tidal Facility Australia Flinders University of South Australia	Date: 15-05-2003
Existing Bench Mark Established by:	Date:
References:	
Country: Tuvalu	
Island/ Atoll: Funafuti	City / Island: Fongafale
<u>Marking and locality sketch</u>	
Bench Mark: 3.3m of 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.5m. Top of mark 0.1m below ground level.	
Locality sketch: Mark approximately 3100m from tide gauge station.	
<p style="font-size: small;">p:\artwork\geodesy\jpeg\bm 26.jpg</p>	
Not to scale	Distances in metres
Approved by:	Magnetic bearings
	Date:





SOUTH PACIFIC SEA LEVEL  
&  
CLIMATE MONITORING PROJECT



Survey Bench Mark Record

**Bench Mark Number: BM28**

Original Bench Mark Established by: Geoscience Earth Monitoring Geodetic Operations Geoscience Australia, Cnr Jerrabomberra Ave & Hindmarsh Drive, Australia		Date: 17-01-09
Existing Bench Mark Established by:		Date:
Notes / References: Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.		
Country: Tuvalu Island: Funafuti		Atoll: Fongafale
<u>Marking and locality sketch</u>		
Bench Mark: 2.14m of 13mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 200mm diameter PVC pipe, Top of mark 0.1m below ground level.		
Locality sketch: Mark approximately 600m from the CGPS station.		
<p>The diagram shows a plan view of the locality. At the top is a 'MOSQUE' with a hatched roof. Below it is a 'MESH WIRE FENCE'. A dashed line indicates a distance of 12.15 from the mosque to a point on the fence. From that point, a distance of 3.33 leads to a 'LIGHT CONCRETE BASE' containing a 'STAINLESS STEEL BOLT IN CONCRETE (TV102)'. A distance of 1.00 leads from the bolt to the 'BM 28' mark. From the bolt, a distance of 14.60 leads to another point on the fence. Below the fence is a 'BITUMEN ROAD' with a 'HUMP' in the center. Below the road is a 'RUN-WAY (AIR FIELD)'. Arrows indicate directions 'TO AIRPORT' and 'TO DBM 24'.</p>		
Not to scale		Magnetic bearings
Distances in Metres		Date: January 2009
Approved by: Geoscience Australia / SOPAC		

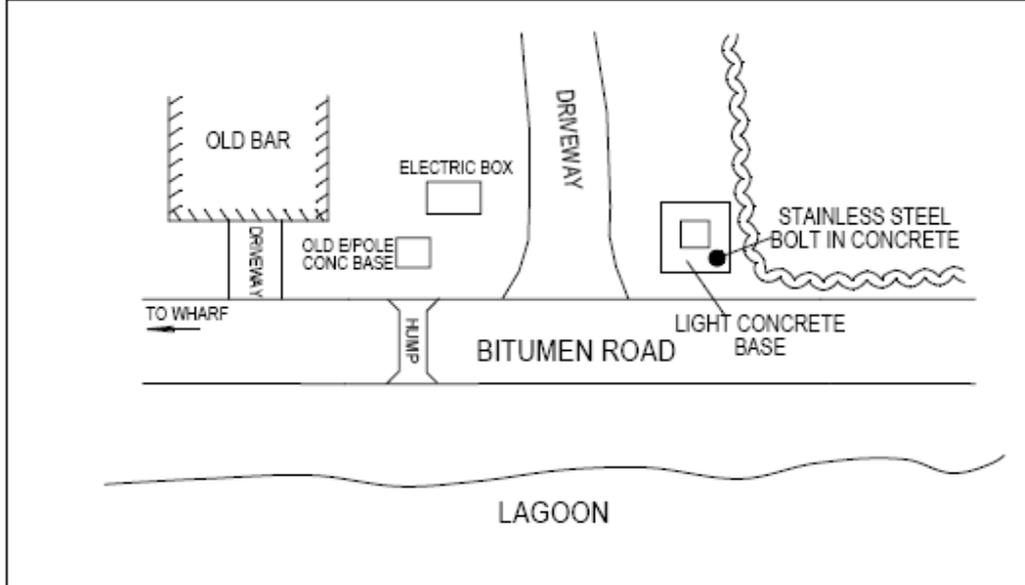


## Permanent Holding Marks – Locality Diagrams

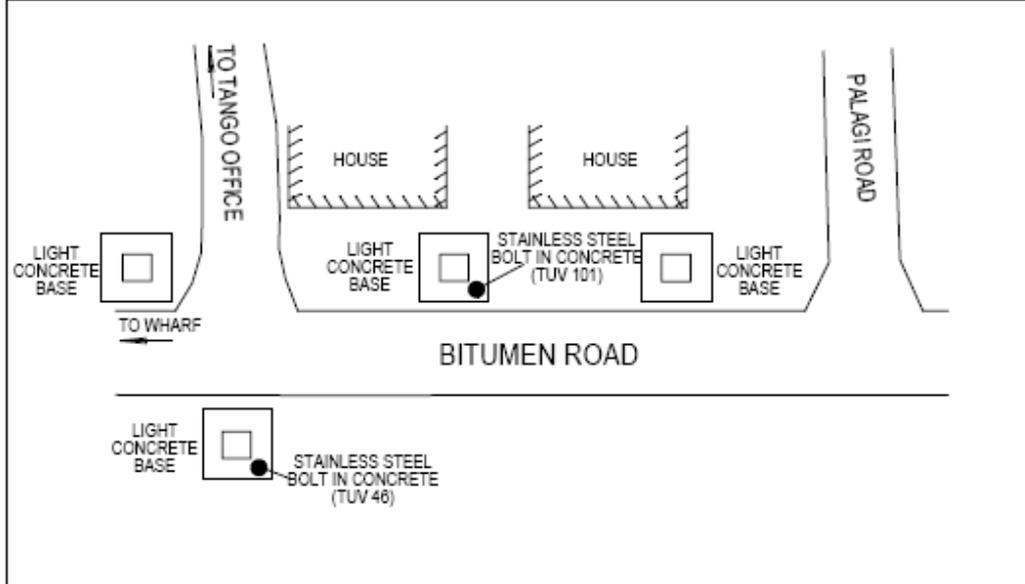
COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 775 POINT NO. TUV 19 & 20
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 29-03-07
COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 776 POINT NO. TUV 42
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 18-01-07



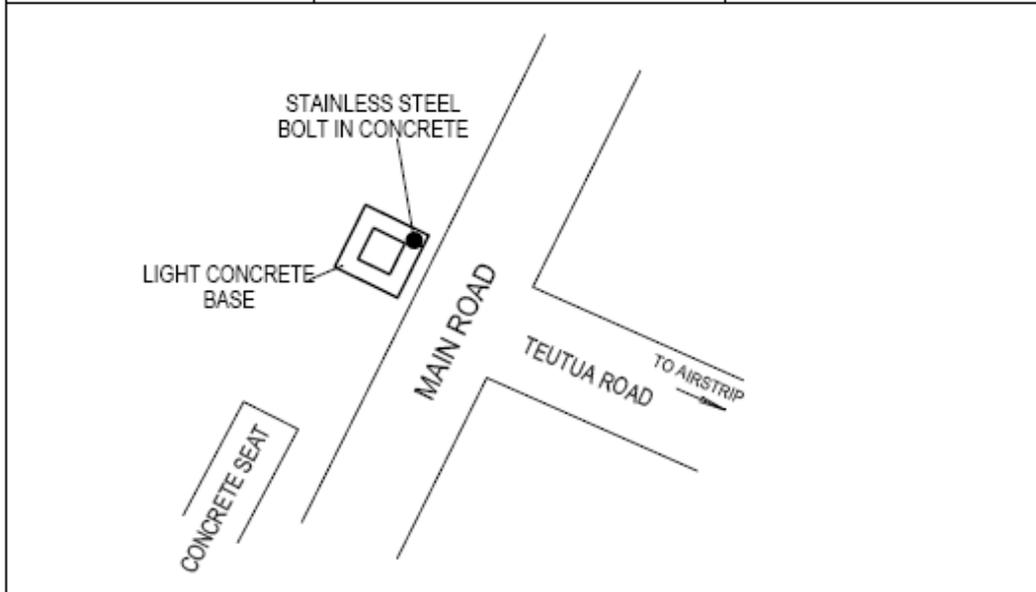
COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 781 POINT NO. TUV 100
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 29-03-07



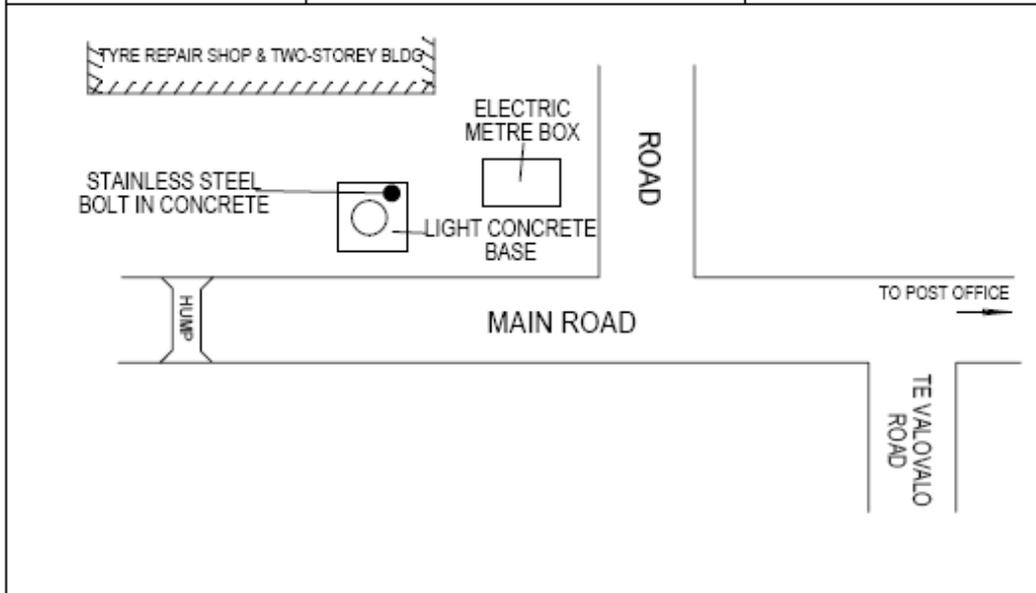
COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 782 POINT NO. TUV 101
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 18-01-07



COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 777 POINT NO. TUV 48
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 29-03-07

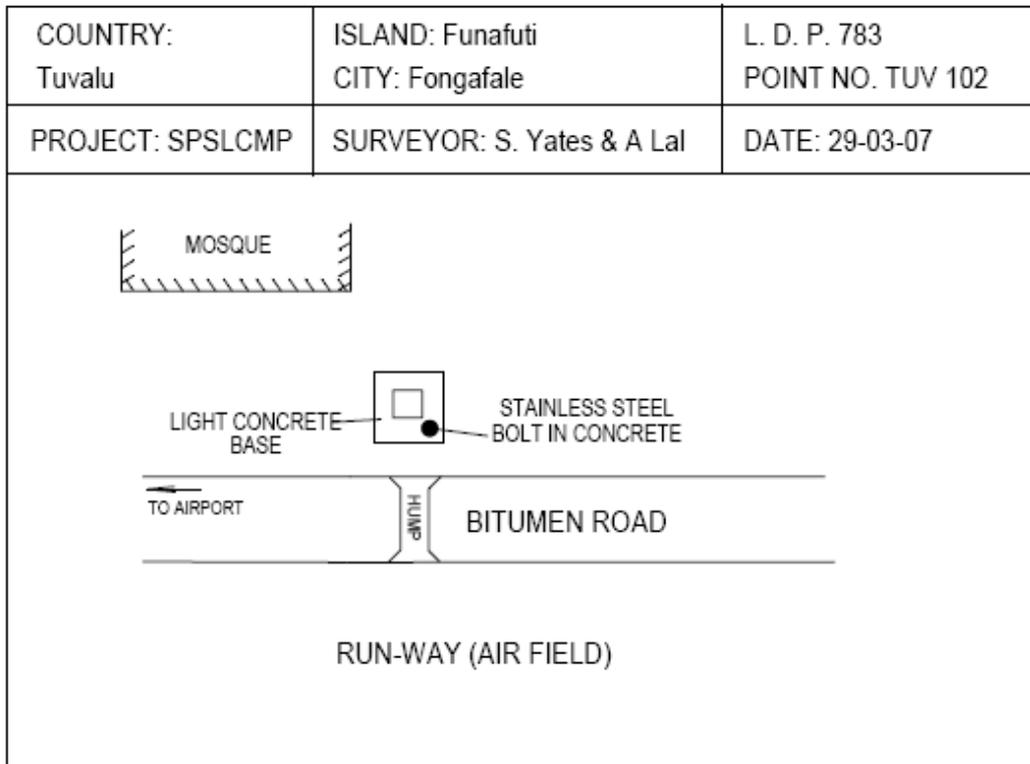


COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 778 POINT NO. TUV 61
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 18-01-07



COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 779 POINT NO. TUV 73
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 29-03-07
<p style="text-align: center;">MATAG GALI BAR</p> <p style="text-align: center;">LIGHT CONCRETE BASE      STAINLESS STEEL BOLT IN CONCRETE</p> <p style="text-align: center;">TO AIRPORT      BITUMEN ROAD</p> <p style="text-align: center;">HUMP</p> <p style="text-align: center;">RUN-WAY (AIR FIELD)</p>		
COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 780 POINT NO. TUV 74
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 18-01-07
<p style="text-align: center;">STAINLESS STEEL BOLT IN CONCRETE</p> <p style="text-align: center;">LIGHT CONCRETE BASE</p> <p style="text-align: center;">TEUTUA ROAD</p> <p style="text-align: center;">To BM27 37° Mag Bearings</p> <p style="text-align: center;">RUN-WAY (AIR FIELD)</p>		



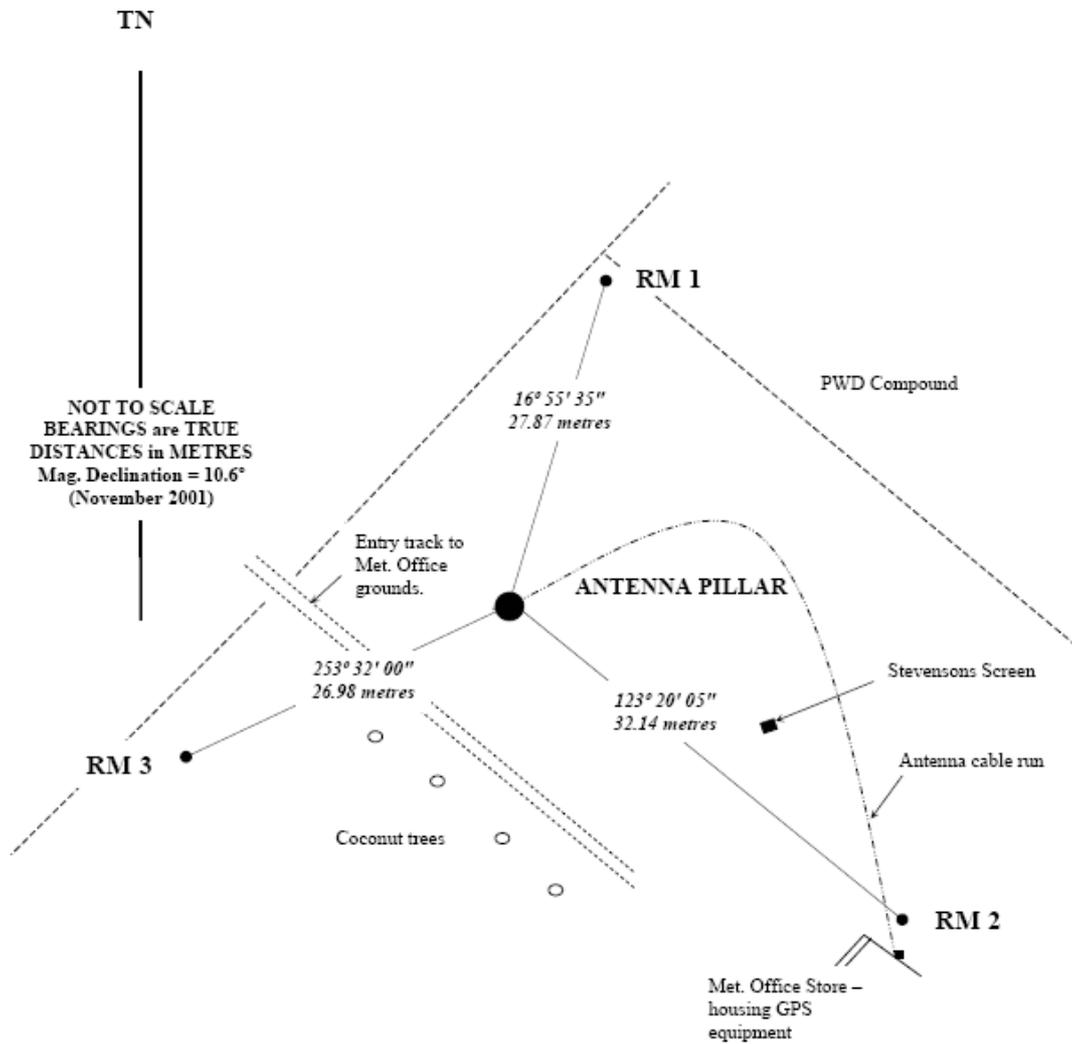


# TUVABM and TUVA Reference Mark Locality Diagrams

## TUVALU CGPS Station, Funafuti – Reference Marks

### REFERENCE MARKS

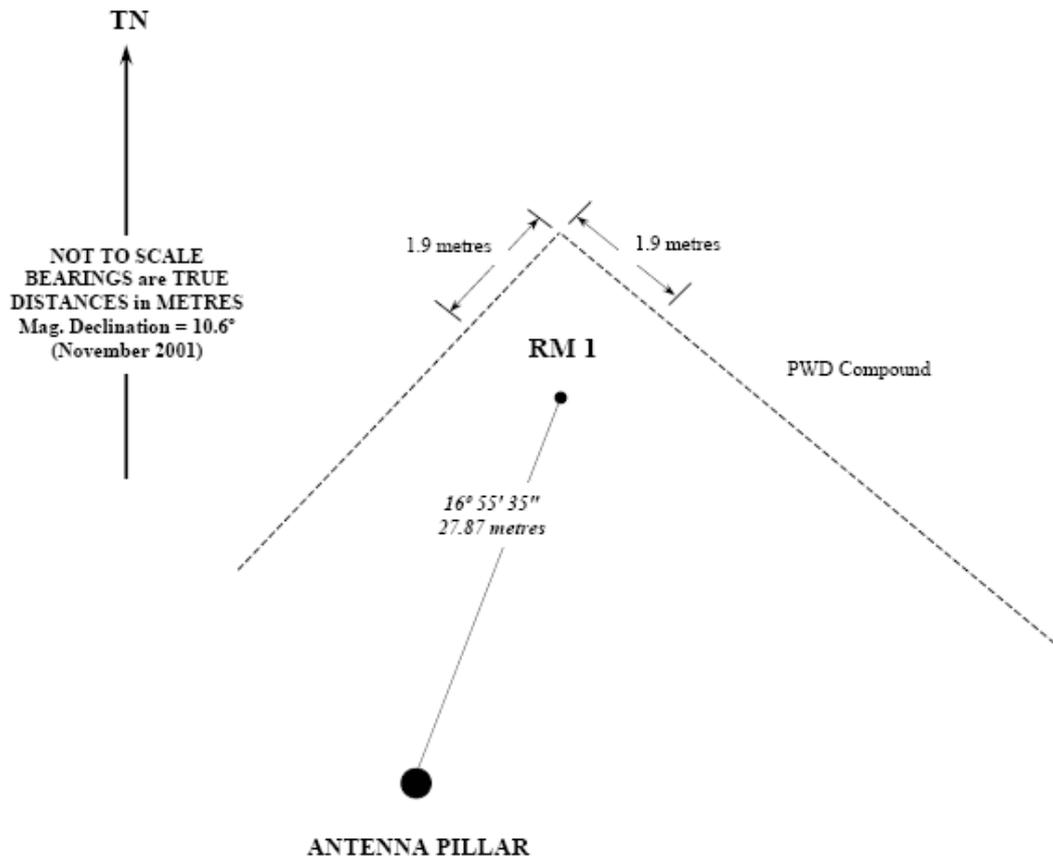
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



## TUVALU CGPS Station, Funafuti – 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.



## TUVALU CGPS Station, Funafuti – 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.

