



Survey Report
**Precise Differential
Levelling**
Tuvalu
May 2003



This project is sponsored by the Australian Agency for International Development (AusAID), managed by Australian Marine Science and Technology Ltd (AMSAT), and supported by NTF Australia at the Flinders University of South Australia.

**PACIFIC MULTI-COUNTRY SEA LEVEL
AND
CLIMATE MONITORING PROJECT**

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Quality Certification:

I authorise the issue of this document in accordance with the National Tidal Facility Australia Quality Assurance procedures.

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December 2003

FONGAFALE, FUNAFUTI, TUVALU

Bench Mark Locality Map



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South Pacific Sea Level and Climate Monitoring Project

Precise Differential Levelling Survey

TUVALU

May 2003

The eighth precise differential levelling survey of the three deep benchmarks installed during 1992 in Tuvalu has been successfully completed. The survey was carried out by Mr. Steven Turner, Geodetic Surveyor from the National Tidal Facility (NTF) Australia and Mr. Andrick Lal, Assistant Surveyor, from the South Pacific Applied Geoscience Commission (SOPAC).

For the first time a levelling connection was made to the Continuous Global Positioning System (CGPS) pillar and associated reference marks in the Tuvalu Weather Service Office compound. A closing connection was also made between the CGPS pillar and deep benchmark, BM 24, at the end of the airstrip.

An additional three new deep benchmarks were established as part of this survey.

Survey of Deep Bench Mark Array and SEAFRAME Station

Precise Differential Levelling was undertaken between six deep benchmarks, BM 22 - BM 27, the SEAFRAME station and the CGPS Pillar. Additional levelling was done to connect to the University of Hawaii tide gauge at the old wharf.

Precise level connections were made to the following marks:

- Six deep benchmarks BM 22 – BM27.
- SEAFRAME Sensor BenchMark, TUV 20.
- TUVABM, a mark on the Project's CGPS Pillar, and the associated reference marks, RM1, RM2 & RM3.
- University of Hawaii BenchMarks, UH 1 & UH 2.

- SW 1, SW 2 and Top of Tide Board on the University of Hawaii Tide Gauge.
- Local bench mark, TUV4

The 2001 Survey Report noted that many of the electric light poles were to be upgraded with the possibility that the concrete bases of these poles in which the holding marks are placed were likely to be disturbed. Since then this upgrading has occurred and many, though not all, holding marks have been destroyed. Replacement holding marks were established during this survey.

Twenty new and replacement holding marks were placed during this survey. Location Diagram Pages (LDP's) have been prepared for these new marks. These, together with BenchMark Records for the new deep benchmarks, have been sent to the Ministry of Natural Resources, Lands & Survey Division for inclusion in Departmental records.

Results of the Bench Mark Array Survey

All the data have now been reduced and copies of the results and adjustment are included in this report. BM 22 has been held fixed at a Reduced Level (RL) of 3.2254 metres in the adjustment. This is the RL determined for the mark in the 1993 adjustment. The datum for this RL is the University of Hawaii Tide Staff Zero.



Installation of deep benchmark, BM 27

There is good agreement between the results of all the surveys. Since the start of the levelling program BM 24 has been moving with relation to the TGBM. Initially this relative movement was downwards to the extent that the movement was outside of Project

Specifications. It is pleasing to note that this relative movement has reversed over the past two surveys and the benchmark is now back within Project Specifications.

Adopting BM 22 as the TGBM produces the following RL comparisons:

Mark No.	2003 RL	2001 RL	2000 RL	1998 RL	1996 RL	1995 RL	1994 RL	1993 RL
BM 22	3.2254	3.2254	3.2254	3.2254	3.2254	3.2254	3.2254	3.2254
BM 23	3.1391	3.1390	3.1386	3.1383	3.1387	3.1392	3.1394	3.1385
BM 24	3.7960	3.7952	3.7951	3.7953	3.7958	3.7972	3.7968	3.7982
TUV 20	4.4593	4.4599	4.4600	4.4615	4.4608	4.4609	4.4603	4.4599
UH 2	3.0134	3.0128	3.0132	3.0152	3.0142	3.0177	3.0185	3.0259

Mark No.	03RL – 01RL (mm)	03RL – 93RL (mm)
BM 22	FIXED	FIXED
BM 23	+0.15	+0.61
BM 24	+0.83	-2.20
TUV 20	-0.59	-0.60
UH 2	+0.54	-12.55

This survey further confirms the substantial movement of several of the University of Hawaii marks that was measured in the 1998 survey. The structure on which the tide gauge is mounted continues to move down relative to all survey marks. This movement is now in excess of 19mm. There are no obvious signs of this movement nor are there any indications to a possible cause.

The movement of the SEAFRAME Sensor Bench Mark, TUV 20, relative to the Tide Gauge Bench Mark, BM 22, is –0.59mm since the last survey in 2001 and –0.60mm since the first survey in 1992. This relative movement is well within Project Specifications. With the relative movement of the other deep benchmarks also being within Project specifications indications are that the benchmark array and SEAFRAME gauge are stable.



Levelling deep benchmark BM24 at the end of the airstrip

The latest listing of RL's for all marks using the University of Hawaii Tide Staff Zero (TSZ) as datum is to be found on pages 13 and 14 of this report. A similar listing using Chart Datum as defined by the Royal New Zealand Navy follows on pages 15 and 16.

A summary of the 2003 levelling accompanies this report.

Survey Support

The Director of the Tuvalu Meteorological Service, Ms. Hilia Vavae, provided invaluable support for this survey by assisting in the clearance of the survey equipment prior to the arrival of the survey team in country. Furthermore Ms. Vavae helped by arranging for a hire vehicle for the survey team. The assistance and hospitality given by the Tuvalu Meteorological Service was appreciated by the survey team.



Levelling along main road

Staff from the Lands and Survey Division provided valuable help to the survey team by obtaining permission for the placement of the three additional deep benchmarks. Their involvement in the installation of the marks was greatly appreciated by the survey team. Similarly the survey team also appreciated their hospitality.

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- **BM 22** is the adopted reference point for the coastal array.
RL = 3.2254 metres TSZ (University of Hawaii Tide Staff Zero)
- The height of **BM 22** was derived by:
 - **1993** Adopting the height of **UH 1**
RL = 3.0072 metres TSZ
 - **1994** Adopting the height of **BM 22** as derived in the 1993 survey
- Points **BM 22**, **BM 23** & **BM 24** are the Deep BenchMarks.
- **TUV 20** is the Sensor Bench mark
- **TUV 19** is the Project's plaque
- **BM SW**
RL= 1.217m TSZ Dec 90
- **UH 2**
RL= 3.0227m TSZ Dec 90
- **Tide Staff Zero**
RL= 0.000m TSZ Dec 90
- New points

BM 25 – BM 27

TUV 55

TUV 56

TUV 57

TUV 58

TUV 59

TUV 60

TUV 61

TUV 62

TUV 63

TUV 64

TUV 65

TUV 66 – TUV 74

Deep BenchMarks

replaces **TUV 31**

replaces **TUV 43**

replaces **TUV 45**

replaces **TUV 46**

replaces **TUV 33**

replaces **TUV 47**

replaces **TUV 50**

replaces **TUV 36**

replaces **TUV17**

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2003 REDUCED LEVELS

INSTRUMENT: Wild NA 3003 S/N 92897 **DATUM:** Tide Staff Zero
DATE: 13th – 20th May 2003 **PAGES:** 3051 - 3112

POINT #	2003 DIFF	2003 RL	
BM 22		3.2254000	Adopted Height
TUV 55	+0.4193400	3.6447400	
TUV 56	+0.2728850	3.9176250	
TUV 42	-0.1528400	3.7647850	
TUV 41	-0.0781000	3.6866850	
TUV 40	+0.0446925	3.7313775	
TUV 19	-0.2462950	3.4850825	
TUV 20	+0.9742150	4.4592975	
BM 22		3.2254000	Adopted Height
TUV 44	+0.1008425	3.3262425	
TUV 57	-0.5961675	2.7300750	
BM 23	+0.4090475	3.1391225	
TUV 6	+0.2339325	3.3730550	
TUV 58	+0.0036350	3.3766900	
TUV 46	-0.1868650	3.1861900	
TUV 59	+0.2370300	3.4232200	
TUV 60	-0.5015150	2.9217050	
TUV 61	-0.0436375	2.8780675	
TUV 48	+0.1835650	3.0616325	
TUV 49	+0.1862825	3.2479150	
TUV 74	-0.6639874	2.5839711	
BM 24	+1.2120325	3.7960036	
TUVA4	+0.1758500	3.9718536	

POINT # (cont.)	2003 DIFF (cont.)	2003 RL (cont.)
TUV 48		3.0616325
TUV 62	-0.1537574	2.9078751
TUV 51	+1.2713086	4.1791837
TUV 52	-0.2471353	3.9320484
TUV 35	-0.1775075	3.7545409
TUV 52		3.9320484
BM 25	-0.3951250	3.5369234
TUV 52		3.9320484
TUV 14	-0.0961167	3.8359317
TUV 63	-0.0009925	3.8349392
TUV 14		3.8359317
TUV 53	-0.2215657	3.6143660
TUV 24	-0.0038375	3.6105285
TUV 53		3.6143660
TUV 54	+0.1833525	3.7978750
TUV 16	-0.0020850	3.7956018
TUV 54		3.7978750
TUV 64	+0.0250856	3.8227724
TUV 65	-0.2158560	3.6069164
BM 26	-0.4969959	3.1099205
TUV 66	+0.1600507	3.2699712
TUV 38	+0.3245850	3.5945562
TUV 67	+0.0010775	3.5956337
TUV 38		3.5945562
TUV 39	-0.1791775	3.4153787
TUV 68	-0.0032125	3.4121662
TUV 39		3.4153787
UH 2	-0.4020150	3.0133637
UH 1	-0.0194675	2.9938962
UH 2		3.0133637
SW 2	-1.8650042	1.1483595
SW 1	+0.0845417	1.2329012
BM@	+0.6310275	1.8639287

POINT # (cont.)	2003 DIFF (cont.)	2003 RL (cont.)
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TUV 66		3.2699712
BM 27	-1.0534502	2.2165210
RM 3	-0.2849550	1.9315660
TUVABM	+0.8097975	2.7413635
RM 1	-0.6544050	2.0869585
TUVABM		2.7413635
RM 2	-0.5827550	2.1586085
BM 27		2.2165210
TUV 69	+0.0005881	2.2171091
TUV 70	+0.2835202	2.5006293
TUV 71	-0.2582689	2.2423604
TUV 72	-0.1105609	2.1317995
TUV 73	+0.1681907	2.2999902
TUV 74	+0.2839809	2.5839711

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TABLE OF REDUCED LEVELS:

INSTRUMENT: Wild NA 3003 S/N 92897 **DATUM:** Tide Staff Zero
DATE: 13th – 20th May 2003 **PAGES:** 3051 - 3112

POINT #	2003 RL	2001 RL	1993 RL (see note below)
BM 22	3.2254000	3.2254000	3.2254000
TUV 55	3.6447400	New Point (2003)	
TUV 56	3.9176250	New Point (2003)	
TUV 42	3.7647850	3.7677175	New Point (2001)
TUV 41	3.6866850	3.6875775	New Point (2001)
TUV 40	3.7313775	3.7313750	New Point (2001)
TUV 19	3.4850825	3.4848200	3.4812950
TUV 20	4.4592975	4.45988375	4.4598950
TUV 44	3.3262425	3.3266800	New Point (2001)
TUV 57	2.7300750	New Point (2003)	
BM 23	3.1391225	3.1389700	3.1385175
TUV 6	3.3730550	3.3731900	3.3740600
TUV 58	3.3766900	New Point (2003)	
TUV 46	3.1861900	3.1873525	New Point (2001)
TUV 59	3.4232200	New Point (2003)	
TUV 60	2.9217050	New Point (2003)	
TUV 61	2.8780675	New Point (2003)	
TUV 48	3.0616325	3.0625725	New Point (2001)
TUV 49	3.2479585	3.2478775	New Point (2001)
BM 24	3.7960036	3.7951750	3.7982000
TUVA4	3.9718536	3.9708625	New Point (2001)

POINT #	2003 RL	2001 RL	1993 RL (see note below)
TUV 62	2.9078950	New Point (2003)	
TUV 51	4.1791837	4.1836025	New Point (2001)
TUV 52	3.9320484	3.9320175	New Point (2001)
TUV 35	3.7545409	3.7533400	3.7540825
BM 25	3.5369234	New Point (2003)	
TUV 14	3.8359317	3.8356600	3.8406775
TUV 63	3.8349392	New Point (2003)	
TUV 53	3.6143660	3.6154800	New Point (2001)
TUV 24	3.6105285	3.6124825	3.6184300
TUV 54	3.7976868	3.7981125	New Point (2001)
TUV 16	3.7956018	3.7960150	3.8030825
TUV 64	3.8229950	New Point (2003)	
TUV 65	3.6071775	New Point (2003)	
BM 26	3.1102150	New Point (2003)	
TUV 66	3.2699715	New Point (2003)	
TUV 38	3.5945562	3.5939175	3.5938825
TUV 39	3.4153787	3.4146975	3.4144350
TUV 68	3.4121662	New Point (2003)	
UH 2	3.0133637	3.0128250	3.0259150
UH 1	2.9938962	2.9942175	3.0071625
SW1	1.2329012	1.2345825	1.2523625
SW2	1.1483595	1.1502350	1.1678225
BM@	1.8639287	1.8664425	1.8840675
BM 27	2.2165210	New Point (2003)	
RM 3	1.9315660	New Point (2003)	
TUVABM	2.7416925	New Point (2003)	
RM 1	2.0869585	New Point (2003)	
RM 2	2.1586085	New Point (2003)	
TUV 69	2.2171091	New Point (2003)	
TUV 70	2.5006293	New Point (2003)	
TUV 71	2.2423604	New Point (2003)	
TUV 72	2.1317995	New Point (2003)	
TUV 73	2.2999902	New Point (2003)	
TUV 74	2.5839711	New Point (2003)	

NOTE: The RL listed under 1993RL is the first RL determined for that point. The RL may not have first been determined in 1993 but is listed in that column for simplicity.

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COMPARISON OF RL DIFFERENCES:

INSTRUMENT: Wild NA 3003 S/N 92897 **DATUM:** Tide Staff Zero
DATE: 13th – 20th May 2003 **PAGES:** 3051 - 3112

POINT #	03RL – 01RL (mm) Adopted Height	03RL – 93RL (mm)
BM 22		
TUV 42	-2.93	New Point (2001)
TUV 41	-0.89	New Point (2001)
TUV 40	0.00	New Point (2001)
TUV 19	+0.26	+3.79
TUV 20	-0.59	-0.60
TUV 44	-0.44	New Point (2001)
BM 23	+0.15	+0.61
TUV 6	-0.14	-1.01
TUV 46	-1.16	New Point (2001)
TUV 48	-0.94	New Point (2001)
TUV 49	+0.08	New Point (2001)
BM 24	+0.83	-2.20
TUVA4	+0.99	New Point (2001)
TUV 51	-4.42	New Point (2001)
TUV 52	+0.03	New Point (2001)
TUV 35	+1.20	+0.46
TUV 14	+0.27	-4.75
TUV 53	-1.11	New Point (2001)
TUV 24	-1.95	-7.90
TUV 54	-0.43	New Point (2001)
TUV 16	-0.41	-7.48
TUV 38	+0.64	+0.67
TUV 39	+0.68	+0.94
UH 2	+0.54	-12.55
UH 1	-0.32	-13.27
SW1	-1.68	-19.46
SW2	-1.88	-19.46
BM@	-2.51	-20.14

SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT

REDUCED LEVELS - FONGAFALE, FUNAFUTI, TUVALU

INSTRUMENT: Wild NA 3003 S/N 92897 **DATUM:** Tide Staff Zero
DATE: 13th – 20th May 2003 **PAGES:** 3051 - 3112

Table of University of Hawaii Benchmarks

POINT NUMBER	2003 RL	2001 RL	1993 RL	
T S ZERO	0.0000000	0.0000000	0.0000000	
BM @	1.8897600	1.8897600	1.8897600	Scale
UH 2	3.0391950	3.0361425	3.0242075	
SW 1	1.2587325	1.2579000	1.2580550	
SW 2	1.1741908	1.1735525	1.1735150	
UH 1	3.0197275	3.0175350	3.0054550	

Comparison of RL's

POINT #	03RL - 01RL (mm)	03RL - 93RL (mm)
UH 2	+3.05	+14.99
SW 1	+0.83	+0.68
SW 2	+0.64	+0.68
UH 1	+2.19	+14.27

SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT

REDUCED LEVELS - FONGFALE, FUNAFUTI, TUVALU

INSTRUMENT: Wild NA 3003 S/N 92897

DATE OF LEVELLING: 13th – 20th May 2003

SURVEY TYPE: First Order

DATUM FOR LEVELLING: Tide Staff Zero

BENCH MARK ADOPTED: BM 22 (3.2254 metres)

SURVEY MARK	2003 RL	TYPE OF MARK
BM 22	3.2254	Deep Bench Mark
TUV 55	3.6447	Stainless Steel Bolt in Concrete
TUV 56	3.9176	Stainless Steel Bolt in Concrete
TUV 42	3.7648	Stainless Steel Bolt in Concrete
TUV 41	3.6869	Stainless Steel Bolt in Concrete
TUV 40	3.7314	Stainless Steel Bolt in Concrete
TUV 19	3.4851	Project Plaque
TUV 20	4.4593	SEAFRAME Sensor Bench Mark
TUV 44	3.3262	Stainless Steel Bolt in Concrete
TUV 57	2.7301	Stainless Steel Bolt in Concrete
BM 23	3.1391	Deep Bench Mark
TUV 6	3.3731	Masonry Nail in Concrete
TUV 58	3.3767	Stainless Steel Bolt in Concrete
TUV 46	3.1862	Stainless Steel Bolt in Concrete
TUV 59	3.4232	Stainless Steel Bolt in Concrete
TUV 60	2.9217	Stainless Steel Bolt in Concrete
TUV 61	2.8781	Stainless Steel Bolt in Concrete
TUV 48	3.0616	Stainless Steel Bolt in Concrete
TUV 49	3.2479	Stainless Steel Bolt in Concrete
TUV 74	2.5840	Stainless Steel Bolt in Concrete
BM 24	3.7960	Deep Bench Mark
TUVA4	3.9719	Bench Mark

SURVEY MARK (cont.)	2003 RL (cont.)	TYPE OF MARK (cont.)
TUV 62	3.0616	Stainless Steel Bolt in Concrete
TUV 51	4.1792	Stainless Steel Bolt in Concrete
TUV 52	3.9320	Stainless Steel Bolt in Concrete
TUV14	3.8359	Masonry Nail in Concrete
TUV 53	3.6144	Stainless Steel Bolt in Concrete
TUV 54	3.7977	Stainless Steel Bolt in Concrete
TUV 16	3.7956	Masonry Nail in Concrete
TUV 64	3.8228	Stainless Steel Bolt in Concrete
TUV 65	3.6069	Stainless Steel Bolt in Concrete
BM 26	3.1099	Deep Bench Mark
TUV 66	3.2700	Stainless Steel Bolt in Concrete
TUV 38	3.5946	Masonry Nail in Concrete
TUV 67	3.5956	Stainless Steel Bolt in Concrete
TUV 39	3.4154	Masonry Nail in Concrete
TUV 68	3.4122	Stainless Steel Bolt in Concrete
UH 2	3.0134	Bench Mark
UH 1	2.9939	Bench Mark
SW 2	1.1484	Tide Gauge Switch
SW 1	1.2329	Tide Gauge Switch
BM @	1.8639	Top of Tide Board
BM 27	2.2165	Deep Bench Mark
RM 3	1.9316	Reference Mark
TUVABM	2.7414	CGPS Bench Mark
RM 1	2.0870	Reference Mark
RM 2	2.1586	Reference Mark
TUV 69	2.2175	Stainless Steel Bolt in Concrete
TUV 70	2.5010	Stainless Steel Bolt in Concrete
TUV 71	2.2428	Stainless Steel Bolt in Concrete
TUV 72	2.1323	Stainless Steel Bolt in Concrete
TUV 73	2.3005	Stainless Steel Bolt in Concrete

SOUTH PACIFIC SEA LEVEL

AND CLIMATE MONITORING PROJECT

REDUCED LEVELS - FONGAFALE, FUNAFUTI, TUVALU

INSTRUMENT: Wild NA 3003 S/N 92897

DATE OF LEVELLING: 13th – 20th May 2003

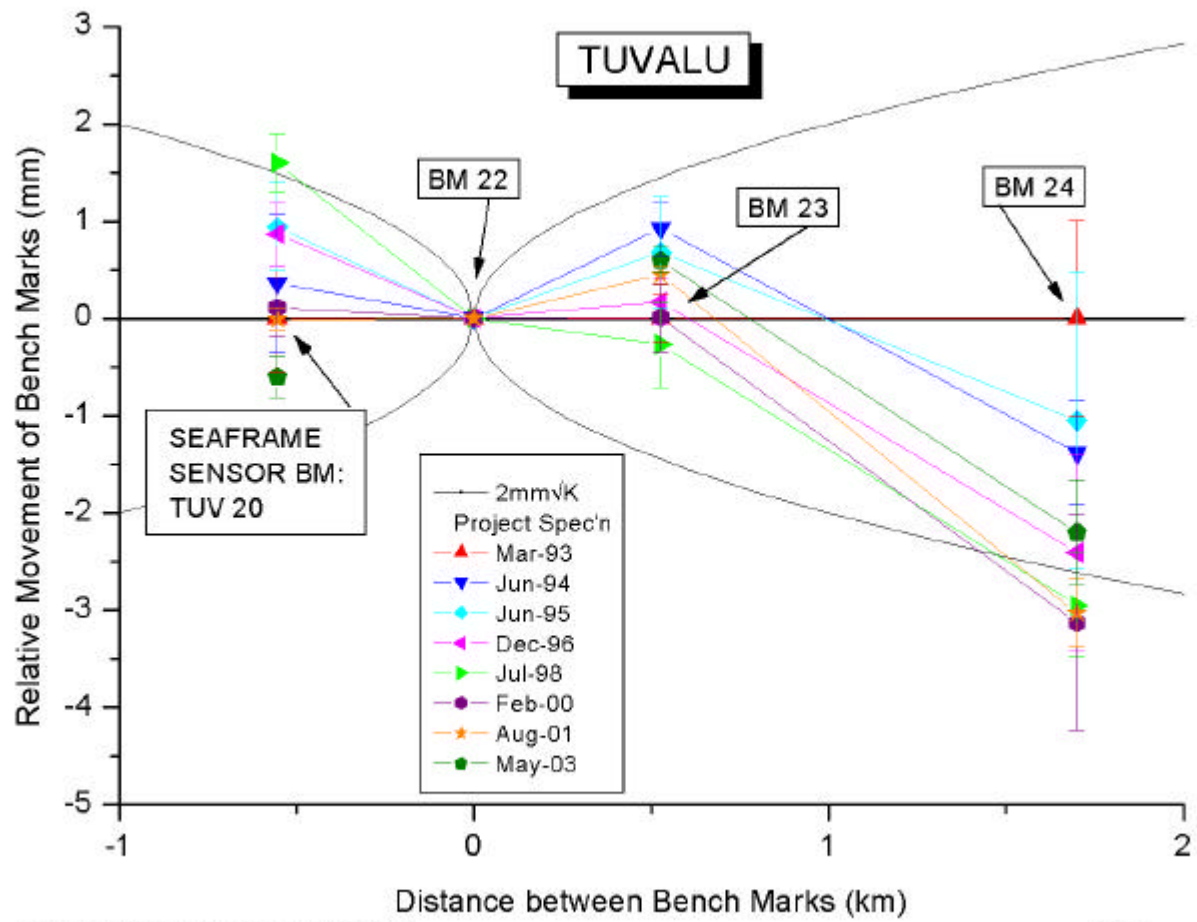
SURVEY TYPE: First Order

DATUM FOR LEVELLING: Chart Datum (Royal New Zealand Navy)

BENCH MARK ADOPTED: 1993 RNZN BM 2 (RL = 4.3190 m MSL)
1994 BM 22 (RL = 4.0123 m MSL)

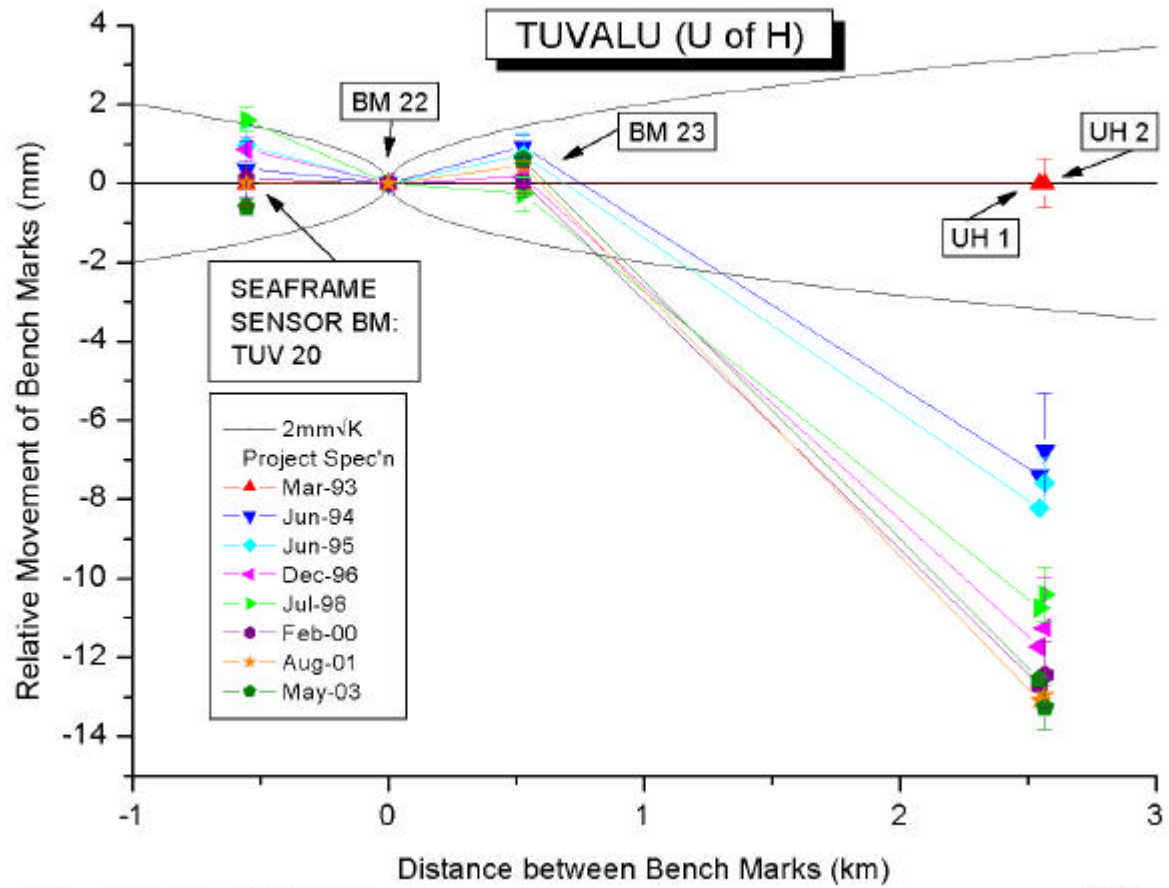
SURVEY MARK	2003 RL	TYPE OF MARK
BM 22	4.0123	Deep Bench Mark
TUV 55	4.4316	Stainless Steel Bolt in Concrete
TUV 56	4.7045	Stainless Steel Bolt in Concrete
TUV 42	4.5517	Stainless Steel Bolt in Concrete
TUV 41	4.4738	Stainless Steel Bolt in Concrete
TUV 40	4.5183	Stainless Steel Bolt in Concrete
TUV 19	4.2720	Project Plaque
TUV 20	5.2462	SEAFRAME Sensor Bench Mark
TUV 44	4.1131	Stainless Steel Bolt in Concrete
TUV 57	3.5170	Stainless Steel Bolt in Concrete
BM 23	3.9260	Deep Bench Mark
TUV 6	4.1600	Masonry Nail in Concrete
TUV 58	4.1636	Stainless Steel Bolt in Concrete
TUV 46	3.9731	Stainless Steel Bolt in Concrete
TUV 59	4.2101	Stainless Steel Bolt in Concrete
TUV 60	3.7086	Stainless Steel Bolt in Concrete
TUV 61	3.6650	Stainless Steel Bolt in Concrete
TUV 48	3.8485	Stainless Steel Bolt in Concrete
TUV 49	4.0348	Stainless Steel Bolt in Concrete
TUV 74	3.3709	Stainless Steel Bolt in Concrete
BM 24	4.5829	Deep Bench Mark
TUVA4	4.7588	Bench Mark
SURVEY MARK (cont.)	2003 RL (cont.)	TYPE OF MARK (cont.)
TUV 62	3.8485	Stainless Steel Bolt in Concrete
TUV 51	4.9661	Stainless Steel Bolt in Concrete
TUV 52	4.7189	Stainless Steel Bolt in Concrete

TUV14	4.6228	Masonry Nail in Concrete
TUV 53	4.4013	Stainless Steel Bolt in Concrete
TUV 54	4.5846	Stainless Steel Bolt in Concrete
TUV 16	4.5825	Masonry Nail in Concrete
TUV 64	4.6097	Stainless Steel Bolt in Concrete
TUV 65	4.3938	Stainless Steel Bolt in Concrete
BM 26	3.8968	Deep Bench Mark
TUV 66	4.0569	Stainless Steel Bolt in Concrete
TUV 38	4.3815	Masonry Nail in Concrete
TUV 67	4.3825	Stainless Steel Bolt in Concrete
TUV 39	4.2023	Masonry Nail in Concrete
TUV 68	4.1991	Stainless Steel Bolt in Concrete
UH 2	3.8003	Bench Mark
UH 1	3.7808	Bench Mark
SW 2	1.9353	Tide Gauge Switch
SW 1	2.0198	Tide Gauge Switch
BM @	2.6508	Top of Tide Board
BM 27	3.0034	Deep Bench Mark
RM 3	2.7185	Reference Mark
TUVABM	3.5283	CGPS Bench Mark
RM 1	2.8739	Reference Mark
RM 2	2.9455	Reference Mark
TUV 69	3.0044	Stainless Steel Bolt in Concrete
TUV 70	3.2879	Stainless Steel Bolt in Concrete
TUV 71	3.0297	Stainless Steel Bolt in Concrete
TUV 72	2.9192	Stainless Steel Bolt in Concrete
TUV 73	3.0874	Stainless Steel Bolt in Concrete



C:\Program Files\OriginLab\Origin 7\Tuvalu_bm22bm24-2003

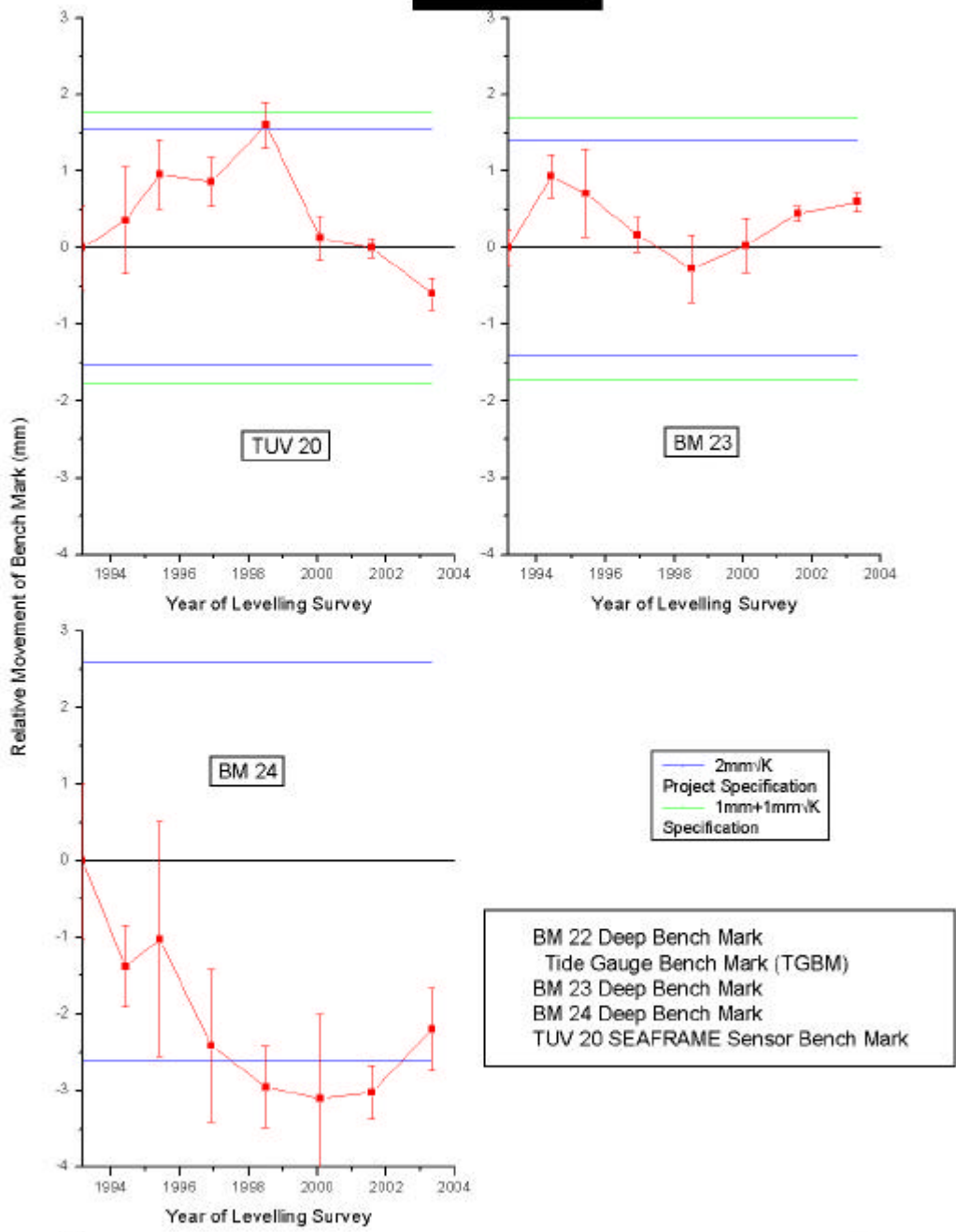
28/11/03



C:\Program Files\OriginLab\Origin 7\TUVALU_UoH-2003

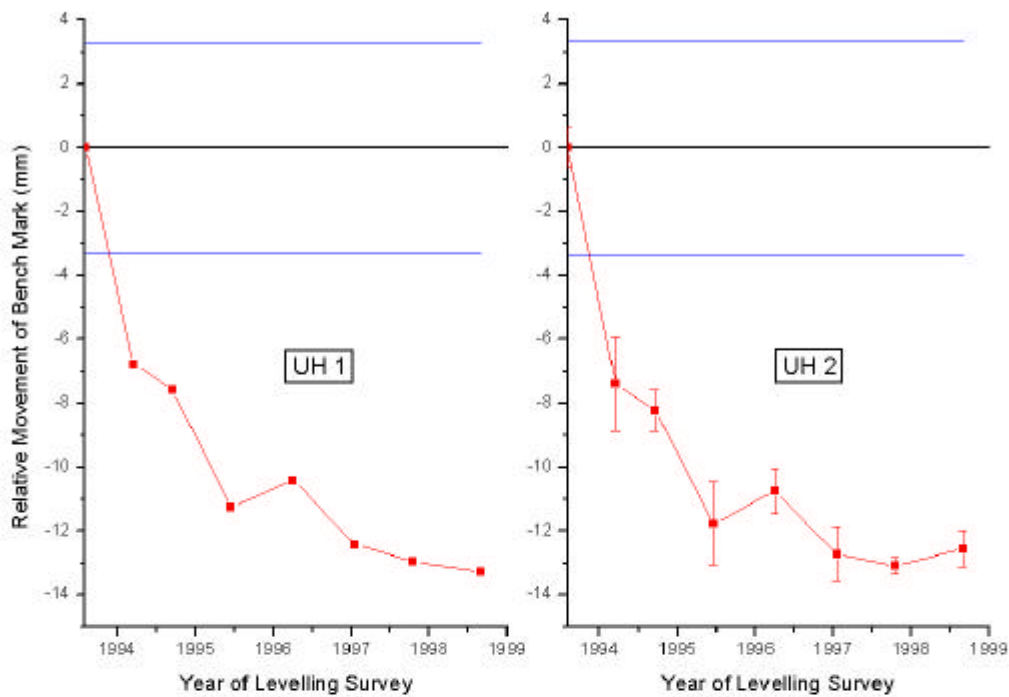
28/11/03

TUVALU



Time series of Bench Mark movement relative to the Tide Gauge Bench Mark, BM 22, since March 1993

TUVALU



— 2mm/K
Project Specification

BM 22, Deep Bench Mark
Tide Gauge Bench Mark (TGBM)
UH 1 University of Hawaii Bench Mark
UH 2 University of Hawaii Bench Mark

Time Series of Bench Mark movement relative to the Tide Gauge Bench Mark, BM 22, since March 1993

SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT

```

=====
° Date: ° 25-03-93 ° 27-06-94 ° 28-06-95 ° 11-12-96 °
=====
° Point no. ° 1. Meas. ° 2. Measurement ° 3. Measurement ° 4. Measurement °
° Height TSZ ° Height TSZ ° D 2-1 ° Height TSZ ° D 3-2 ° D 3-1 ° Height TSZ ° D 4-3 ° D 4-1 °
° m ° m ° mm ° m ° mm ° mm ° m ° mm ° mm °
=====
° SW1 ° ° 1.25236 ° ° 1.25189 ° -0.47 ° -0.47 ° ° 1.24938 ° -2.51 ° -2.98 °
° SW2 ° ° 1.16782 ° ° 1.16677 ° -1.05 ° -1.05 ° ° 1.16431 ° -2.46 ° -3.51 °
° TSZ ° ° -0.00569 ° ° -0.00608 ° -0.39 ° -0.39 ° ° -0.00873 ° -2.65 ° -3.04 °
° UH1 ° 3.00716 ° 3.00039 ° -6.77 ° 2.99958 ° -0.81 ° -7.58 ° 2.99591 ° -3.67 ° -11.25 °
° UH2 ° 3.02592 ° 3.01852 ° -7.40 ° 3.01770 ° -0.82 ° -8.22 ° 3.01418 ° -3.52 ° -11.74 °
° BM22 ° 3.22540 ° 3.22540 ° 0.00 ° 3.22540 ° 0.00 ° 0.00 ° 3.22540 ° 0.00 ° 0.00 °
° BM23 ° 3.13852 ° 3.13945 ° 0.93 ° 3.13923 ° -0.22 ° 0.71 ° 3.13869 ° -0.54 ° 0.17 °
° BM24 ° 3.79820 ° 3.79682 ° -1.38 ° 3.79718 ° 0.36 ° -1.02 ° 3.79579 ° -1.39 ° -2.41 °
° TUV6 ° 3.37406 ° 3.37448 ° 0.42 ° 3.37421 ° -0.27 ° 0.15 ° 3.37311 ° -1.10 ° -0.95 °
° TUV14 ° 3.84068 ° 3.83898 ° -1.70 ° 3.83918 ° 0.20 ° -1.50 ° 3.83608 ° -3.10 ° -4.60 °
° TUV16 ° 3.80308 ° 3.79953 ° -3.55 ° 3.79957 ° 0.04 ° -3.51 ° 3.79620 ° -3.37 ° -6.88 °
° TUV19 ° 3.48130 ° 3.48259 ° 1.29 ° 3.48328 ° 0.69 ° 1.98 ° 3.48335 ° 0.07 ° 2.05 °
° TUV20 ° 4.45990 ° 4.46026 ° 0.36 ° 4.46086 ° 0.60 ° 0.96 ° 4.46076 ° -0.10 ° 0.86 °
° TUV24 ° ° 3.61843 ° ° 3.61638 ° -2.05 ° -2.05 ° ° 3.61332 ° -3.06 ° -5.11 °
=====

```

Difference from 1st measurement always refers to 1st measurement of respective point (D=last-initial measurement),
 Difference from measurement n-1 always refers to penultimate measurement (D=last-penultimate measurement)

SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT

```

=====
° Date: ° 31-07-98 ° 03-03-00 ° 29-08-01 °
=====
° Point no. ° 5. Measurement ° 6. Measurement ° 7. Measurement °
° Height TSZ ° D 5-4 ° D 5-1 ° Height TSZ ° D 6-5 ° D 6-1 ° Height TSZ ° D 7-6 ° D 7-1 °
° m ° mm ° mm ° m ° mm ° mm ° m ° mm ° mm °
=====
° SW1 ° 1.23789 ° -11.49 ° -14.47 ° 1.23526 ° -2.63 ° -17.10 ° 1.23460 ° -0.66 ° -17.76 °
° SW2 ° 1.15349 ° -10.82 ° -14.33 ° 1.15048 ° -3.01 ° -17.34 ° 1.15024 ° -0.24 ° -17.58 °
° TSZ ° -0.02035 ° -11.62 ° -14.66 ° ° ° ° ° ° °
° UH1 ° 2.99675 ° 0.84 ° -10.41 ° 2.99474 ° -2.01 ° -12.42 ° 2.99423 ° -0.51 ° -12.93 °
° UH2 ° 3.01517 ° 0.99 ° -10.75 ° 3.01321 ° -1.96 ° -12.71 ° 3.01284 ° -0.37 ° -13.08 °
° BM22 ° 3.22540 ° 0.00 ° 0.00 ° 3.22540 ° 0.00 ° 0.00 ° 3.22540 ° 0.00 ° 0.00 °
° BM23 ° 3.13825 ° -0.44 ° -0.27 ° 3.13855 ° 0.30 ° 0.03 ° 3.13897 ° 0.42 ° 0.45 °
° BM24 ° 3.79525 ° -0.54 ° -2.95 ° 3.79509 ° -0.16 ° -3.11 ° 3.79518 ° 0.09 ° -3.02 °
° TUV6 ° 3.37261 ° -0.50 ° -1.45 ° 3.37288 ° 0.27 ° -1.18 ° 3.37320 ° 0.32 ° -0.86 °
° TUV14 ° 3.83804 ° 1.96 ° -2.64 ° 3.83644 ° -1.60 ° -4.24 ° 3.83569 ° -0.75 ° -4.99 °
° TUV16 ° 3.79806 ° 1.86 ° -5.02 ° 3.79655 ° -1.51 ° -6.53 ° 3.79604 ° -0.51 ° -7.04 °
° TUV19 ° 3.48482 ° 1.47 ° 3.52 ° 3.48423 ° -0.59 ° 2.93 ° 3.48482 ° 0.59 ° 3.52 °
° TUV20 ° 4.46150 ° 0.74 ° 1.60 ° 4.46003 ° -1.47 ° 0.13 ° 4.45990 ° -0.13 ° 0.00 °
° TUV24 ° 3.61566 ° 2.34 ° -2.77 ° 3.61311 ° -2.55 ° -5.32 ° 3.61251 ° -0.60 ° -5.92 °
=====

```

Difference from 1st measurement always refers to 1st measurement of respective point (D=last-initial measurement),
 Difference from measurement n-1 always refers to penultimate measurement (D=last-penultimate measurement)

SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT

```

=====
° Date: ° 31-07-98 ° 03-03-00 ° 29-08-01 °
=====
° Point no. ° 5. Measurement ° 6. Measurement ° 7. Measurement °
° Height TSZ ° D 5-4 ° D 5-1 ° Height TSZ ° D 6-5 ° D 6-1 ° Height TSZ ° D 7-6 ° D 7-1 °
° m ° mm ° mm ° m ° mm ° mm ° m ° mm ° mm °
=====
° TUV35 ° 3.75408 ° ° ° 3.75314 ° -0.94 ° -0.94 ° 3.75335 ° 0.21 ° -0.73 °
° TUV38 ° ° ° ° 3.59391 ° ° ° ° 3.59394 ° 0.03 ° 0.03 °
° TUV39 ° ° ° ° 3.41446 ° ° ° ° 3.41472 ° 0.26 ° 0.26 °
° TUV40 ° ° ° ° ° ° ° ° 3.73137 ° ° ° °
° TUV41 ° ° ° ° ° ° ° ° 3.68756 ° ° ° °
° TUV42 ° ° ° ° ° ° ° ° 3.76772 ° ° ° °
° TUV44 ° ° ° ° ° ° ° ° 3.32668 ° ° ° °
° TUV46 ° ° ° ° ° ° ° ° 3.18736 ° ° ° °
° TUV48 ° ° ° ° ° ° ° ° 3.06258 ° ° ° °
° TUV49 ° ° ° ° ° ° ° ° 3.24788 ° ° ° °
° TUV51 ° ° ° ° ° ° ° ° 4.18361 ° ° ° °
° TUV52 ° ° ° ° ° ° ° ° 3.93203 ° ° ° °
° TUV53 ° ° ° ° ° ° ° ° 3.61551 ° ° ° °
° TUV54 ° ° ° ° ° ° ° ° 3.79814 ° ° ° °
° TUV4A ° ° ° ° ° ° ° ° 3.97087 ° ° ° °
=====

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Difference from 1st measurement always refers to 1st measurement of respective point (D=last-initial measurement),
 Difference from measurement n-1 always refers to penultimate measurement (D=last-penultimate measurement)

SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT

```

=====
° Date: ° 20-05-03 ° °
=====
° Point no. ° 8. Measurement ° 9. Measurement ° 10. Measurement °
° Height TSZ ° D 8-7 ° D 8-1 ° Height TSZ ° D 9-8 ° D 9-1 ° Height TSZ ° D 10-9 ° D 10-1 °
° m ° mm ° mm ° m ° mm ° mm ° m ° mm ° mm °
=====
° RM1 ° 2.08692 ° ° ° ° ° ° ° ° ° ° °
° RM2 ° 2.15857 ° ° ° ° ° ° ° ° ° ° °
° RM3 ° 1.93153 ° ° ° ° ° ° ° ° ° ° °
° SW1 ° 1.23286 ° -1.74 ° -19.50 ° ° ° ° ° ° ° ° °
° SW2 ° 1.14834 ° -1.90 ° -19.48 ° ° ° ° ° ° ° ° °
° TSZ ° -0.02583 ° -20.14 ° -5.48 ° ° ° ° ° ° ° ° °
° UH1 ° 2.99386 ° -0.37 ° -13.30 ° ° ° ° ° ° ° ° °
° UH2 ° 3.01333 ° 0.49 ° -12.59 ° ° ° ° ° ° ° ° °
° BM22 ° 3.22540 ° 0.00 ° 0.00 ° ° ° ° ° ° ° ° °
° BM23 ° 3.13912 ° 0.15 ° 0.60 ° ° ° ° ° ° ° ° °
° BM24 ° 3.79594 ° 0.76 ° -2.26 ° ° ° ° ° ° ° ° °
° BM25 ° 3.53692 ° ° ° ° ° ° ° ° ° ° °
° BM26 ° 3.10989 ° ° ° ° ° ° ° ° ° ° °
° BM27 ° 2.21648 ° ° ° ° ° ° ° ° ° ° °
° TUV6 ° 3.37306 ° -0.14 ° -1.00 ° ° ° ° ° ° ° ° °
° TUV14 ° 3.83593 ° 0.24 ° -4.75 ° ° ° ° ° ° ° ° °
° TUV16 ° 3.79558 ° -0.46 ° -7.50 ° ° ° ° ° ° ° ° °
° TUV19 ° 3.48507 ° 0.25 ° 3.77 ° ° ° ° ° ° ° ° °
° TUV20 ° 4.45929 ° -0.61 ° -0.61 ° ° ° ° ° ° ° ° °
° TUV24 ° 3.61051 ° -2.00 ° -7.92 ° ° ° ° ° ° ° ° °
=====

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°	TUV35	°	3.75454	°	3	1.19	°	3	0.46	°	3	3	°	3	3	°
°	TUV38	°	3.59453	°	3	0.59	°	3	0.62	°	3	3	°	3	3	°

=====
Difference from 1st measurement always refers to 1st measurement of respective point (D=last-initial measurement),
Difference from measurement n-1 always refers to penultimate measurement (D=last-penultimate measurement)

National Tidal Facility, The Flinders University of South Australia

DELTA - Levelling, Version 1.1

10-27-03

Page:

5

Job: TUV03

SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT

=====
° Date: ° 20-05-03 ° °

=====
° Point no. ° 8. Measurement ° 9. Measurement ° 10. Measurement °
° Height TSZ ° D 8-7 ° D 8-1 ° Height TSZ ° D 9-8 ° D 9-1 ° Height TSZ ° D 10-9 ° D 10-1 °
° m ° mm ° mm ° m ° mm ° mm ° m ° mm ° mm °

°	TUV39	°	3.41535	°	3	0.63	°	3	0.89	°	3	3	°	3	3	°
°	TUV40	°	3.73137	°	3	0.00	°	3	0.00	°	3	3	°	3	3	°
°	TUV41	°	3.68668	°	3	-0.88	°	3	-0.88	°	3	3	°	3	3	°
°	TUV42	°	3.76478	°	3	-2.94	°	3	-2.94	°	3	3	°	3	3	°
°	TUV44	°	3.32624	°	3	-0.44	°	3	-0.44	°	3	3	°	3	3	°
°	TUV46	°	3.18619	°	3	-1.17	°	3	-1.17	°	3	3	°	3	3	°
°	TUV48	°	3.06163	°	3	-0.95	°	3	-0.95	°	3	3	°	3	3	°
°	TUV49	°	3.24792	°	3	0.04	°	3	0.04	°	3	3	°	3	3	°
°	TUV51	°	4.17920	°	3	-4.41	°	3	-4.41	°	3	3	°	3	3	°
°	TUV52	°	3.93205	°	3	0.02	°	3	0.02	°	3	3	°	3	3	°
°	TUV53	°	3.61435	°	3	-1.16	°	3	-1.16	°	3	3	°	3	3	°
°	TUV54	°	3.79767	°	3	-0.47	°	3	-0.47	°	3	3	°	3	3	°
°	TUV55	°	3.64474	°	3		°	3		°	3	3	°	3	3	°
°	TUV56	°	3.91763	°	3		°	3		°	3	3	°	3	3	°
°	TUV57	°	2.73007	°	3		°	3		°	3	3	°	3	3	°
°	TUV58	°	3.37670	°	3		°	3		°	3	3	°	3	3	°

o	TUV59	o	3.42322	3	3	o	3	3	o	3	3	o
o	TUV60	o	2.92170	3	3	o	3	3	o	3	3	o
o	TUV61	o	2.87806	3	3	o	3	3	o	3	3	o
o	TUV62	o	2.90789	3	3	o	3	3	o	3	3	o
o	TUV63	o	3.83493	3	3	o	3	3	o	3	3	o
o	TUV64	o	3.82276	3	3	o	3	3	o	3	3	o

=====

Difference from 1st measurement always refers to 1st measurement of respective point (D=last-initial measurement),
Difference from measurement n-1 always refers to penultimate measurement (D=last-penultimate measurement)

SOUTH PACIFIC SEA LEVEL AND CLIMATE MONITORING PROJECT

```

=====
° Date: ° 20-05-03 ° °
=====
° Point no. ° 8. Measurement ° 9. Measurement ° 10. Measurement °
° Height TSZ ° D 8-7 ° D 8-1 ° Height TSZ ° D 9-8 ° D 9-1 ° Height TSZ ° D 10-9 ° D 10-1 °
° m ° mm ° mm ° m ° mm ° mm ° m ° mm ° mm °
=====
° TUV65 ° 3.60689 ° ° ° ° ° ° ° ° ° ° °
° TUV66 ° 3.26994 ° ° ° ° ° ° ° ° ° ° °
° TUV67 ° 3.59561 ° ° ° ° ° ° ° ° ° ° °
° TUV68 ° 3.41213 ° ° ° ° ° ° ° ° ° ° °
° TUV69 ° 2.21707 ° ° ° ° ° ° ° ° ° ° °
° TUV70 ° 2.50059 ° ° ° ° ° ° ° ° ° ° °
° TUV71 ° 2.24231 ° ° ° ° ° ° ° ° ° ° °
° TUV72 ° 2.13175 ° ° ° ° ° ° ° ° ° ° °
° TUV73 ° 2.29993 ° ° ° ° ° ° ° ° ° ° °
° TUV74 ° 2.58391 ° ° ° ° ° ° ° ° ° ° °
° TUVA4 ° 3.97180 ° 0.93 ° 0.93 ° ° ° ° ° ° ° ° °
° TUVABM ° 2.74133 ° ° ° ° ° ° ° ° ° ° °
=====
  
```

Difference from 1st measurement always refers to 1st measurement of respective point (D=last-initial measurement),
 Difference from measurement n-1 always refers to penultimate measurement (D=last-penultimate measurement)

TUVALU

PRECISION OF 2003 SURVEY:

INSTRUMENT: Wild NA 3003 S/N 92897

DATUM: Tide Staff Zero

DATE: 13th – 20th May 2003

PAGES: 3051 - 3112

POINT #	FORWARD LEVELLING	BACK LEVELLING	DIFF (mm)	DIST (km)	PRECISION (mm/K)
TUV 20 BM 22	-1.2338025	-1.2339925	0.190	0.610	0.24/K
TUV 20 BM 24	-0.6628125	-0.6639075	1.095	2.327	0.72/K
TUV 20 UH 2	-1.4451325	-1.4461175	0.985	3.435	0.53/K
TUV 20 TUVABM	-1.7173125	-1.7181050	0.585	3.388	0.32/K
TUVABM UH 2	+0.2718950	+0.2720650	0.170	0.543	0.23/K
BM 22 TUVABM	-0.4835100	-0.4839050	0.395	2.778	0.24/K
BM 22 BM 24	+0.5709900	+0.5700850	0.905	1.717	0.69/K
BM 22 UH 2	-0.2113300	-0.2121250	0.795	2.825	0.47/K
BM 24 TUVABM	-1.0549900	-1.0553600	0.370	1.211	0.34/K

**INDIVIDUALS CONSULTED DURING THE
GEODETIC SURVEY VISIT**

MINISTRY OF NATURAL RESOURCES

Lands & Survey Division

Mr. Fa'atasi Malologa, Surveyor
Mr. Vakafa Lupe, Survey Assistant
Mr. Manuella Falaile, Survey Assistant
Mr. Savaliga Malau, Survey Assistant

TUVALU METEOROLOGICAL SERVICE

Ms. Hilia Vavae, Director

GEODETIC SURVEY VISIT ITINERARY

Depart Adelaide	0820	QF740	Sunday 11 May 2003
Arrive Sydney	1040		Sunday 11 May 2003
Depart Sydney	1235	QF391	Sunday 11 May 2003
Arrive Nadi	1830		Sunday 11 May 2003
Depart Nadi	0645	PC502	Monday 12 May 2003
Arrive Suva	0715		Monday 12 May 2003
Depart Suva	0830	PC601	Monday 12 May 2003
Arrive Funafuti	1045		Monday 12 May 2003
Depart Funafuti	1130	PC602	Thursday 22 May 2003
Arrive Suva	1345		Thursday 22 May 2003
Depart Nadi	1015	FJ211	Saturday 31 May 2003
Arrive Tonga	1235		Saturday 31 May 2003
Depart Tonga	0820	PH749	Saturday 07 June 2003
Arrive Auckland	1000		Saturday 07 June 2003
Depart Auckland	1300	QF190	Saturday 07 June 2003
Arrive Sydney	1430		Saturday 07 June 2003
Depart Sydney	1650	QF765	Saturday 07 June 2003
Arrive Adelaide	1825		Saturday 07 June 2003