



**Australian Government**

**Geoscience Australia**

South Pacific Sea Level and Climate Monitoring  
Project (SPSLCMP)

**Survey Report**

EDM Height Traversing  
Levelling Survey

**KIRIBATI**

**February / March 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 # 69399



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## Introduction

This report outlines the level survey completed during the visit to Betio Island, the Republic of Kiribati in February / March 2009.

Personnel: Steve Yates – Surveyor - **GEOSCIENCE AUSTRALIA**

Andrick Lal – Surveyor - **SOPAC**

This is the third EDM Height Traversing levelling survey of the deep driven bench mark array in the Republic of Kiribati. These surveys follow the nine previous surveys from 1992 to 2004 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 6 deep driven BM's:

**KIR 1**

**KIR 2**

**KIR 3**

**KIR 46**

**KIR 47**

**KIR 49**

Included in the survey was the CGPS Station bench mark, **KIRIBM** and the three Reference Marks **RM1**, **RM2** and **RM3**, the Project Plaque point **KIR12** and SEAFRAME Sensor Bench Mark **KIR13** at the Tide Gauge, Holding Marks **KIR39**, **KIR44**, **KIR100**, **KIR101**, **KIR102**, **KIR106** (replacement for KIR103), **KIR104**, and **KIR105**.

When locating the Deep driven Bench Marks prior to the survey it was found that BM KIR49 (located outside the Police Marine Workshop) had been buried under an extension of the concrete driveway and not accessible. With the assistance of the Marine Police, a 300mm diameter hole was chiselled away to expose the BM below the concrete and a valve box with lid cemented in place. All other deep driven bench marks were located and found undisturbed and in good order.

A new permanent holding mark KIR106 was established to replace KIR103 which was



destroyed after the 2007 survey. KIR106 is a domed stainless steel bolt drilled in concrete and glued in place with quality epoxy resin.

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 for precision is  $2\text{mm} \sqrt{K}$

## Bench Mark Locality Map



## The Kiribati Datum

**KIR 1** is the adopted reference point for the coastal array.

Reduction of the data was calculated holding **KIR 1** fixed at 3.5334 metres Tide Gauge Zero (TGZ), University of Hawaii - the value NTC derived for KIR 1 by adopting the TGZ height (RL = 4.027) of bench mark UT 8 for the initial 1992 survey. The bench mark UT 8 has since been destroyed.

## Equipment

LEICA Total Station Model TCA2003 (S/N 440883).

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's 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, i.e. 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 Kiribati 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 new Director of the Kiribati Meteorological Service, Mr. Tareti Kireua and his staff Romano Reo and Boata Iabeta, from the Land Management Division provided valuable support during our visit. A special mention to Boata Iabeta, Field Surveyor, for collecting and providing secure storage for all our survey equipment prior to our arrival.

Due to work commitments in the Land Management Division, Boata Iabeta was unable to assistance the survey team on this visit.

Other personnel consulted during the visit:

Ms. Anne Quinane – Australian High Commissioner.

Ms. Meria Russell – AusAid Program Manager.

## Issues

Only one point worth mentioning – the condition of the security fence (especially the south west corner) around the Weather Office is a potential point of unauthorised access and should be inspected regularly.



## Description of Marks

### BETIO ISLAND, REPUBLIC OF KIRIBATI

**KIR 1** is the bench mark held fixed with an **RL = 3.53340 metres**

The height of **KIR 1** was derived by NTC by adopting the TGZ height for the 1992 levelling survey of the University of Hawaii's bench mark **UT 8**.

UT8 Reduced Level = 4.027 metres TGZ.

UT 8 is now destroyed.

Bench Marks:

**KIR 1, KIR 2, KIR 3, KIR 46, KIR 47, and KIR 49** are all Deep Driven BM's.

Point:

**KIR 13** is the SEAFRAME Sensor Bench Mark

**KIR 12** is the Project Plaque point

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

**RM1, RM2 and RM3** are the Reference Monitoring Marks for the CGPS Pillar.

**KIR39, KIR44, KIR100, KIR101, KIR102, KIR104, KIR105 and KIR106** are all permanent stainless steel bolt holding marks, drilled in concrete and glued in place.





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

### KIRIBATI 2009 - EDM Height Traversing Levelling Comparison 2007 - 2009 and Table of Results

KIR 1 - Adopted fixed height (TGZ) 3.53340

FROM	TO	Levelled Height Difference	Reduced Level 2009	Misclose (mm)	Distance (Km)	1mm√K	Reduced Level 2007	Difference (m) 2007 - 2009
KIR 1	KIR 102	0.47630	4.00970	0.189	0.051	0.226	4.02185	0.01215
KIR 102	KIR 100	-0.17707	3.83263	-0.034	0.056	0.237	3.83306	0.00043
KIR 100	KIR 39	0.24629	4.07892	0.164	0.197	0.444	4.07867	-0.00025
KIR 39	KIR 101	0.06455	4.14348	-0.277	0.203	0.451	4.14362	0.00015
KIR 101	KIR 49	-0.12062	4.02285	0.060	0.147	0.383	4.02296	0.00011
KIR 49	KIR 12	0.19706	4.21991	0.205	0.173	0.416	4.22020	0.00029
KIR 12	KIR 13	0.41213	4.63204	-0.025	0.012	0.110	4.63078	-0.00126
KIR 1	KIR 102	0.47630	4.00970	0.189	0.051	0.226	4.02185	0.01215
KIR 102	KIR 46	-0.63064	3.37906	-0.029	0.151	0.389	3.37949	0.00043
KIR 46	KIR 106	0.42377	3.80283	0.386	0.146	0.382	<i>New mark established in 2009</i>	
KIR 106	KIR 104	-0.12972	3.67311	0.186	0.202	0.449	3.67264	-0.00047
KIR 104	KIR 2	-0.48963	3.18348	-0.165	0.106	0.326	3.18303	-0.00045
KIR 104	KIR 44	-0.05153	3.62158	0.361	0.187	0.432	3.62292	0.00134
KIR 44	KIR 47	-0.32648	3.29509	-0.112	0.092	0.303	3.29410	-0.00099
KIR 47	KIR 105	0.52975	3.82484	0.383	0.166	0.407	3.82427	-0.00057
KIR 105	KIR 3	-0.26028	3.56456	-0.255	0.199	0.446	3.56405	-0.00051
KIR 3	KIRIBM	0.84793	4.41250	-0.077	0.023	0.152	4.41191	-0.00059

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





## Combined Comparisons 1992 to 2009

**KIRIBATI - Comparison of RL's for Precise Differential Levelling (1992 - 2006) and EDM Height Traversing (2006 - 2009)**

YEAR					MARK				
	KIR1	KIR2	KIR3	KIR12	KIR13	KIR46	KIR47	KIR49	KIR1BM
<b>1992</b>	3.5334	3.1835	3.5657	4.2176	4.6302				
<b>1994</b>	3.5334	3.1838	3.5655	4.2187	4.6319				
<b>1995</b>	3.5334	3.1845	3.5654	4.2195	4.6331				
<b>1996</b>	3.5334	3.1843	3.5654	4.2191	4.6321				
<b>1997</b>	3.5334	3.1843	3.5657	4.2196	4.6325				
<b>1999</b>	3.5334	3.1844	3.5644	4.2195	4.6324				
<b>2000</b>	3.5334	3.1847	3.5658	4.2195	4.6321				
<b>2002</b>	3.5334	3.1843	3.5648	4.2191	4.6321	3.3782	3.2948	4.0232	4.4124
<b>2004</b>	3.5334	3.1843	3.5653	4.2190	4.6324	3.3788	3.2952	4.0225	4.4130
<b>2006</b>	3.5334	3.1839	3.5662	4.2195	4.6328	3.3788	3.2956	4.0226	4.4139
<b>2006 EDM</b>	3.5334	3.1844	3.5646	4.2193	4.6326	3.3794	3.2953	4.0230	4.4124
<b>2007 EDM</b>	3.5334	3.1830	3.5641	4.2202	4.6308	3.3795	3.2941	4.0230	4.4119
<b>2009 EDM</b>	3.5334	3.1835	3.5646	4.2199	4.6320	3.3791	3.2951	4.0229	4.4125



## 2009 Reduced Levels

### KIRIBATI - 2009 REDUCED LEVELS

Date: February / March 2009

Datum: TGZ (University of Hawaii, Tide Gauge Zero)

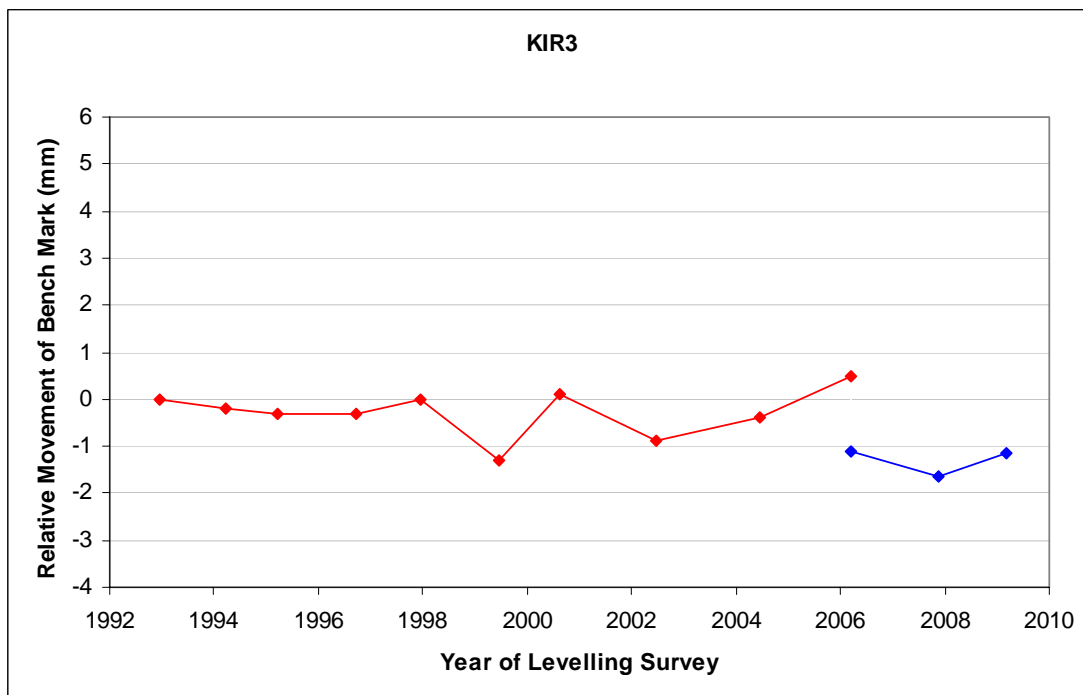
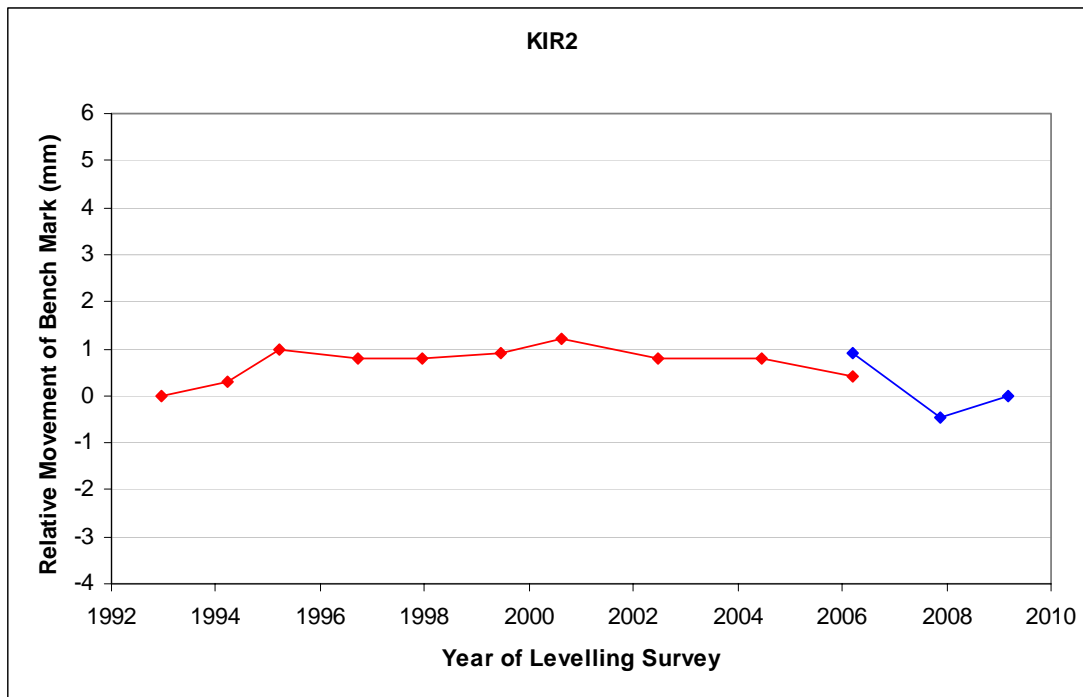
POINT #	2009 Levelled Diff Ht.	2009 RL	
<b><u>KIR 1 (fixed)</u></b>	<b>0.00000</b>	<b>3.53340</b>	<b>(fixed)</b>
KIR 102	0.47630	4.00970	
KIR 100	-0.17707	3.83263	
KIR 39	0.24629	4.07892	
KIR 101	0.06455	4.14348	
<b>KIR 49</b>	<b>-0.12062</b>	<b>4.02285</b>	
KIR 12	0.19706	4.21991	
<b>KIR 13</b>	<b>0.41213</b>	<b>4.63204</b>	
 <b><u>KIR 1 (fixed)</u></b>	 <b>0.00000</b>	 <b>3.53340</b>	 <b>(fixed)</b>
KIR 102	0.47630	4.00970	
<b>KIR 46</b>	<b>-0.63064</b>	<b>3.37906</b>	
KIR 106	0.42377	3.80283	
KIR 104	-0.12972	3.67311	
<b>KIR 2</b>	<b>-0.48963</b>	<b>3.18348</b>	
 KIR 104		3.67311	
KIR 44	-0.05153	3.62158	
<b>KIR 47</b>	<b>-0.32648</b>	<b>3.29509</b>	
KIR 105	0.52975	3.82484	
<b>KIR 3</b>	<b>-0.26028</b>	<b>3.56456</b>	
<b>KIRIBM</b>	<b>0.84793</b>	<b>4.41250</b>	
<b>KIRI</b>	<b>0.94433</b>	<b>5.35683</b>	
 KIRIBM		4.41250	
<b>KIRI RM1</b>	<b>-0.87571</b>	<b>3.53679</b>	
<b>KIRI RM2</b>	<b>-0.03728</b>	<b>3.49951</b>	
<b>KIRI RM3</b>	<b>0.01526</b>	<b>3.51477</b>	

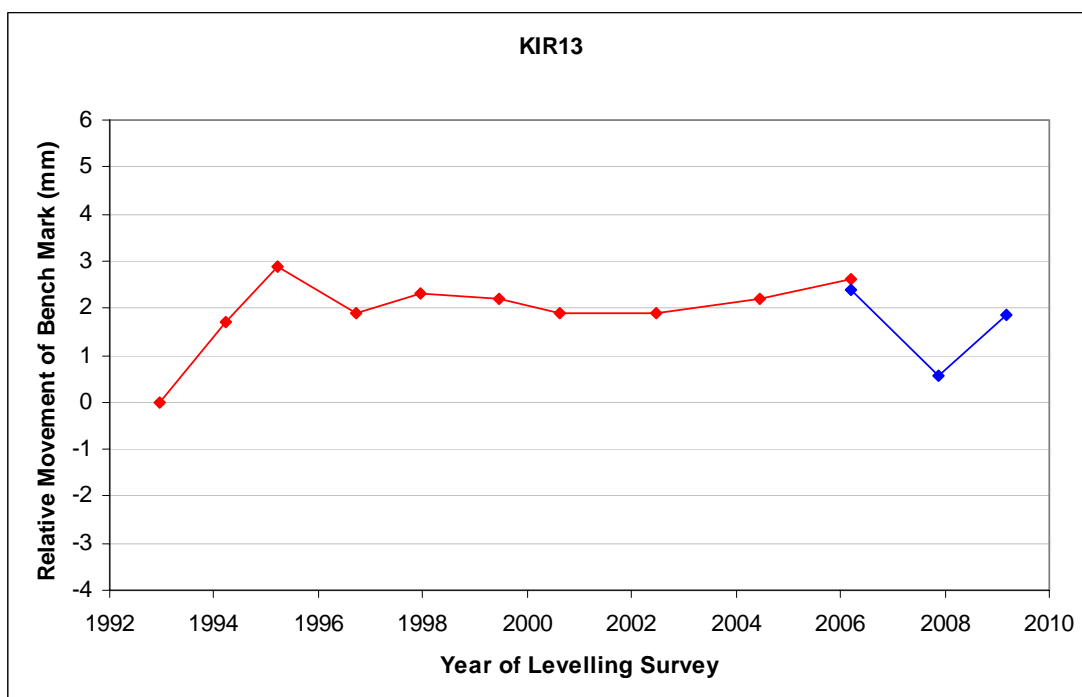
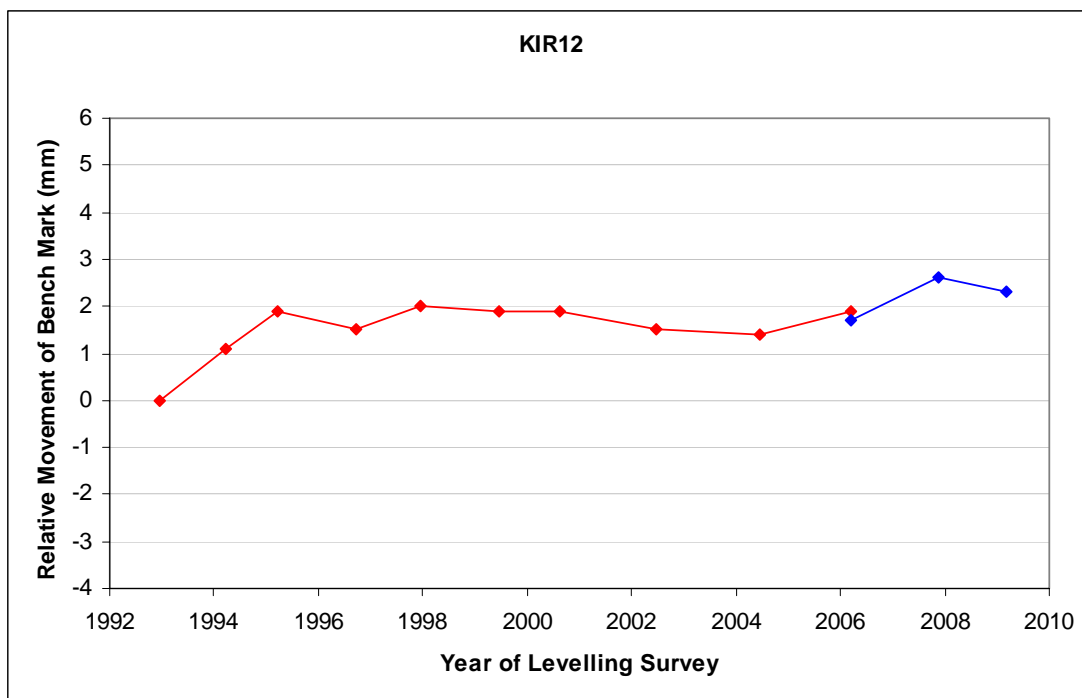


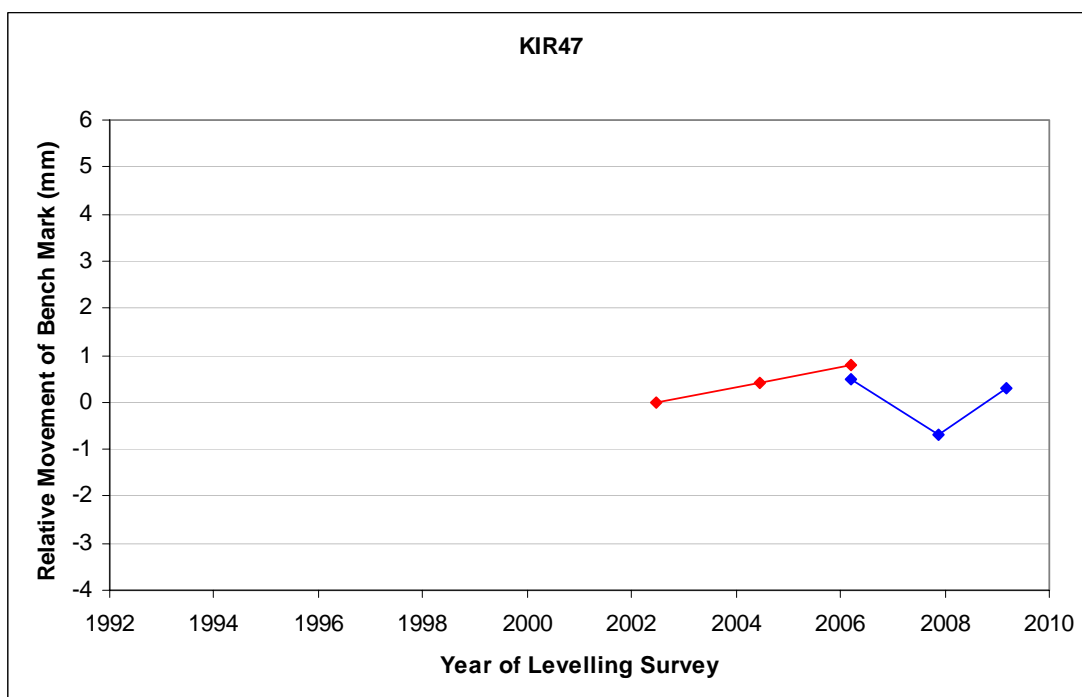
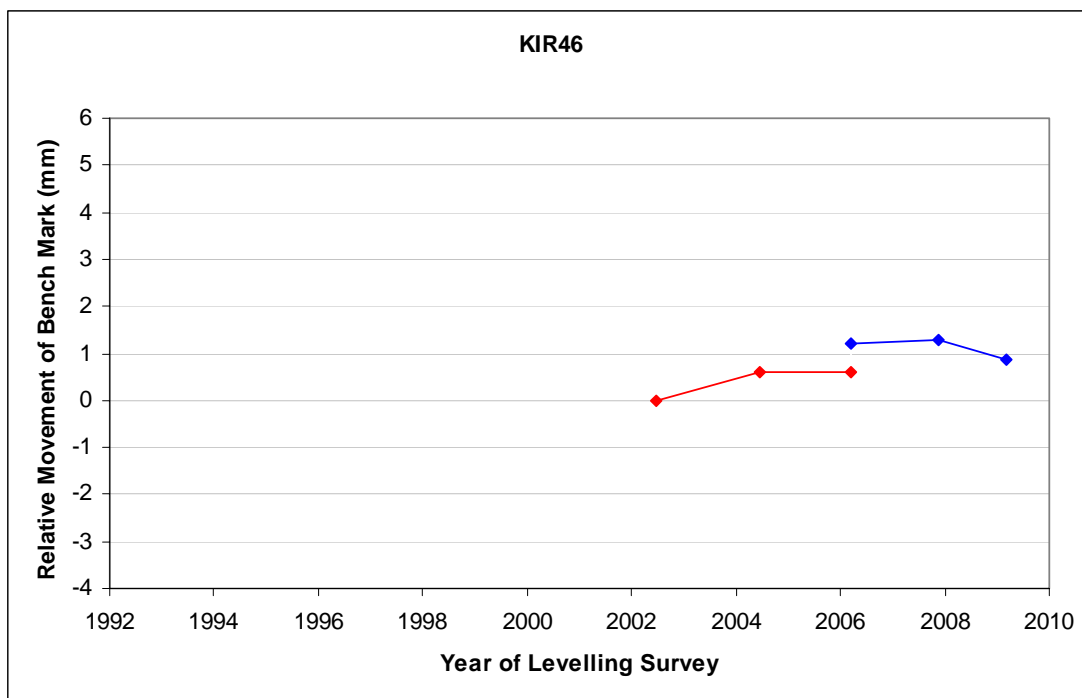
## Time Series of Bench Mark movement relative to the Fixed Deep driven Bench Mark – KIR 1

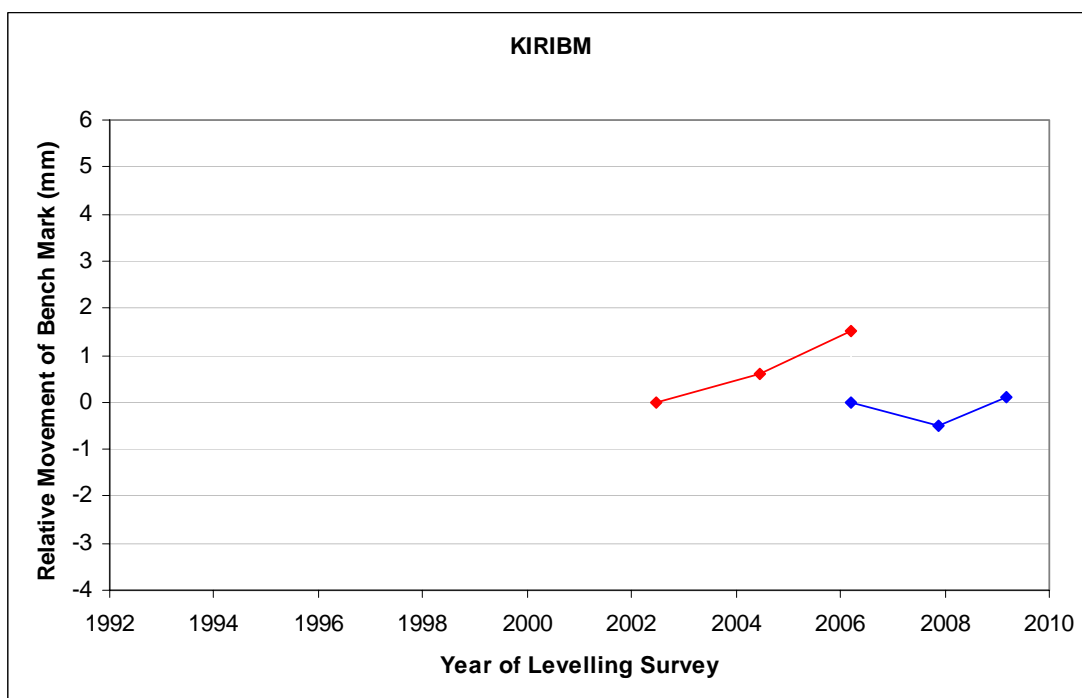
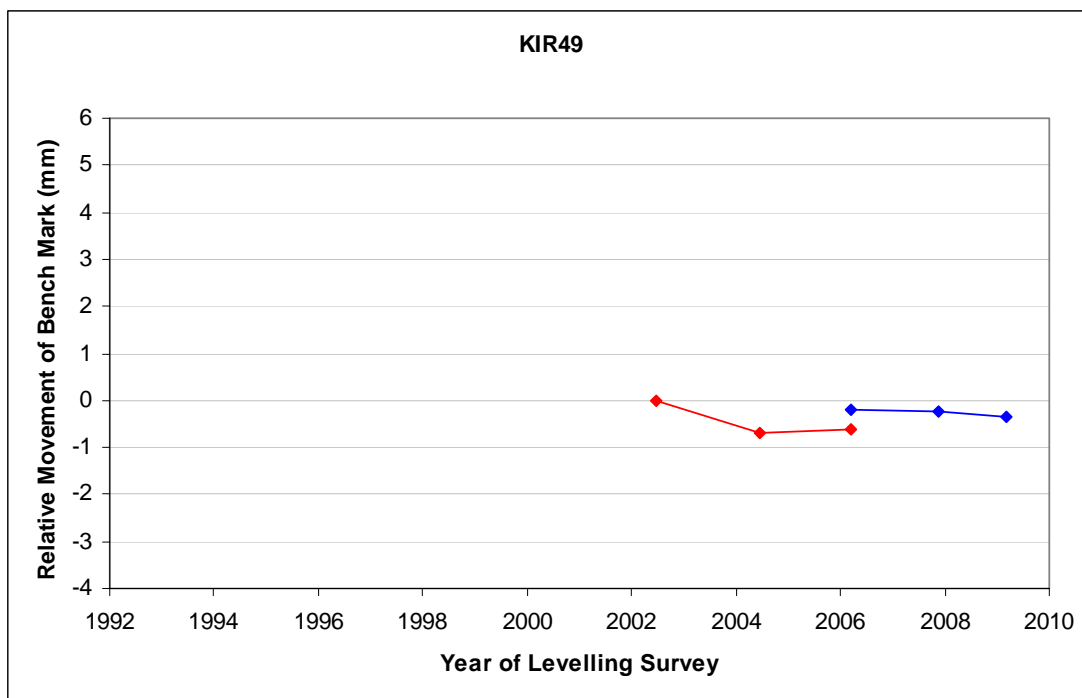
Precise Differential Levelling - 1992 to 2004 (2006) ◆ — ◆

EDM Height Traversing - commenced 2006 ◆ — ◆









# Deep driven BM and TBM's Locality Diagrams



## SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT



### Survey Bench Mark Record

**Bench Mark Number: KIR1**

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

*Date:* 28-01-92

*Existing Bench Mark Established by:*

*Date:*

*Notes / References:* Deep Survey Benchmark  
This survey mark is not in a good locality for GPS occupation.

*Country:* Kiribati

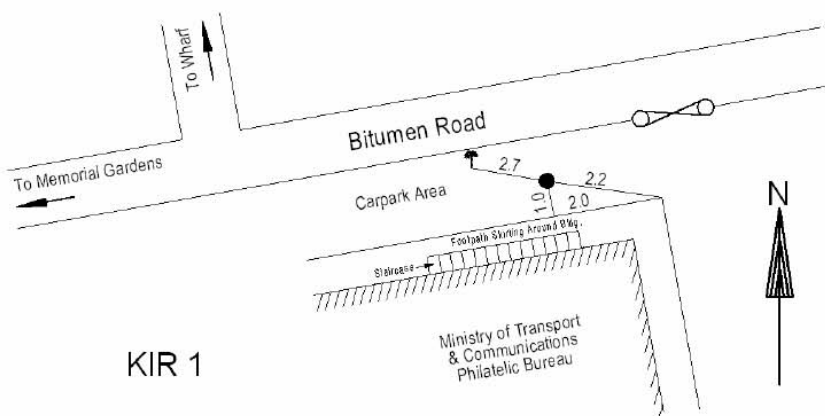
*Island:* Tarawa

*Atoll:* Betio

### Marking and locality sketch

**Bench Mark:** 6.2m of 19mm diameter stainless steel capped rod driven to refusal.  
Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for  
1.0m. Top of mark 0.2m below ground level.

**Locality sketch:** Mark approximately 750m from the tide gauge station.



Not to scale

Distances in Metres

Magnetic bearings

Approved by: Geoscience Australia / SOPAC

Date: April 2006

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



**Survey Bench Mark Record**

**Bench Mark Number: KIR2**

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

*Date:* 28-01-92

*Existing Bench Mark Established by:*

*Date:*

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

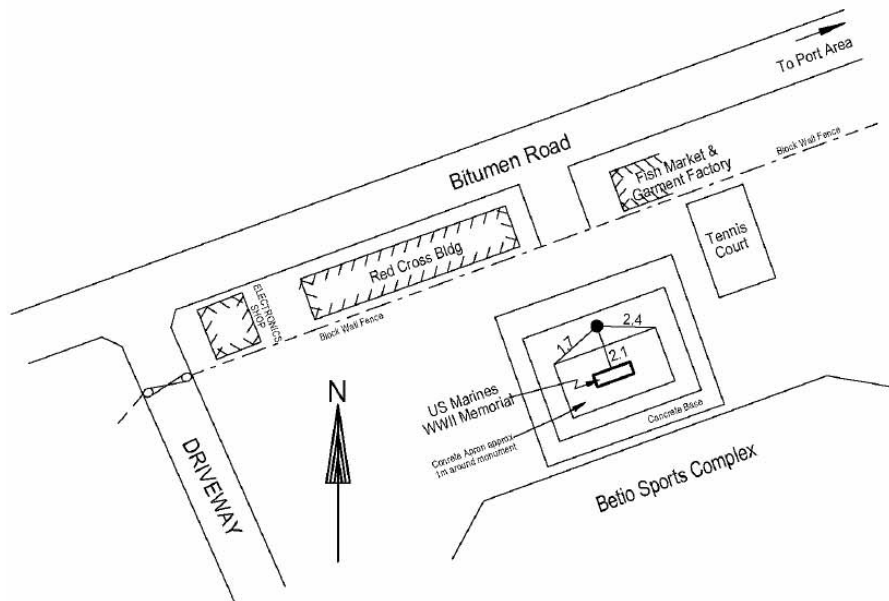
*Country:* Kiribati  
*Island:* Tarawa

*Atoll:* Betio

**Marking and locality sketch**

Bench Mark: 6.2m of 19mm diameter stainless steel capped rod driven to refusal.  
Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for  
1.0m. Top of mark 0.3m below ground level.

Locality sketch: Mark approximately 1250m from the tide gauge station.



Not to scale

Distances in Metres

Magnetic bearings

Approved by: Geoscience Australia / SOPAC

Date: Dec 2007

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



**Survey Bench Mark Record**

**Bench Mark Number: KIR3**

<i>Original Bench Mark Established by:</i> National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA.	<i>Date:</i> 28-01-92
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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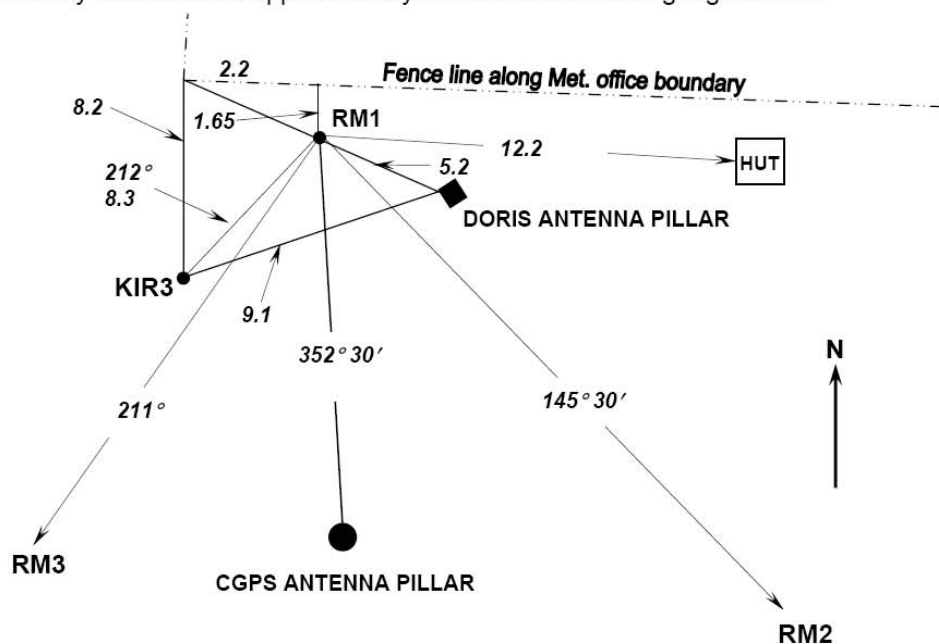
*Notes / References:* Deep Survey Benchmark  
 This survey mark is in a good locality for GPS occupation.

<i>Country:</i> Kiribati <i>Island:</i> Tarawa	<i>Atoll:</i> Betio
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**Marking and locality sketch**

Bench Mark: 6.2m of 19mm diameter stainless steel capped rod driven to refusal.  
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.0m. Top of mark 0.2m below ground level.

Locality sketch: Mark approximately 2000m from the tide gauge station.



Not to scale                      Distances in Metres                      Magnetic bearings

Approved by: Geoscience Australia / SOPAC	Date: Dec 2006 <small>c:\users\andrick\spslcmp\localitydiagrams\kiribati</small>
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SOUTH PACIFIC SEA LEVEL  
&  
CLIMATE MONITORING PROJECT



Survey Bench Mark Record

**Bench Mark Number: KIR46**

Original Bench Mark Established by: National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA. Date: 07-06-02

Existing Bench Mark Established by: Date:

Notes / References: Deep Survey Benchmark  
This survey mark is not in a good locality for GPS occupation.

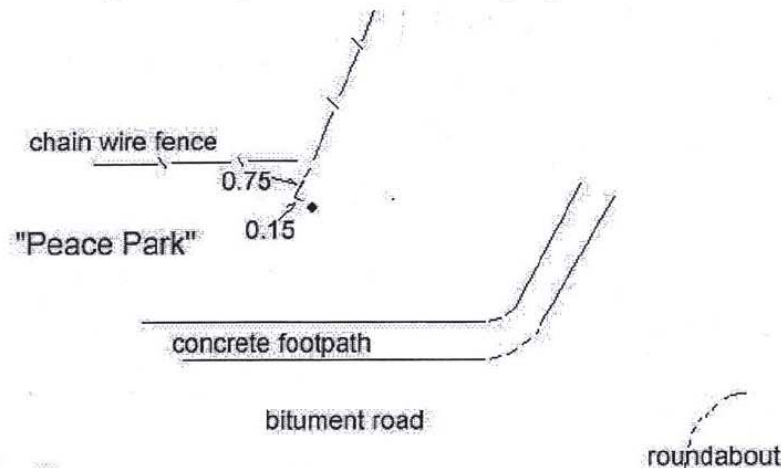
Country: Kiribati  
Island: Tarawa

City: Betio

Marking and locality sketch

Bench Mark: 7.0m 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 1000m from the tide gauge station.



Not to scale

Distances in Metres

Magnetic bearings

Approved by: Geoscience Australia / SOPAC

Date: April 2006

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



**Survey Bench Mark Record**

**Bench Mark Number: KIR47**

<i>Original Bench Mark Established by:</i> National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA.	<i>Date:</i> 07-06-02
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
--	--------------

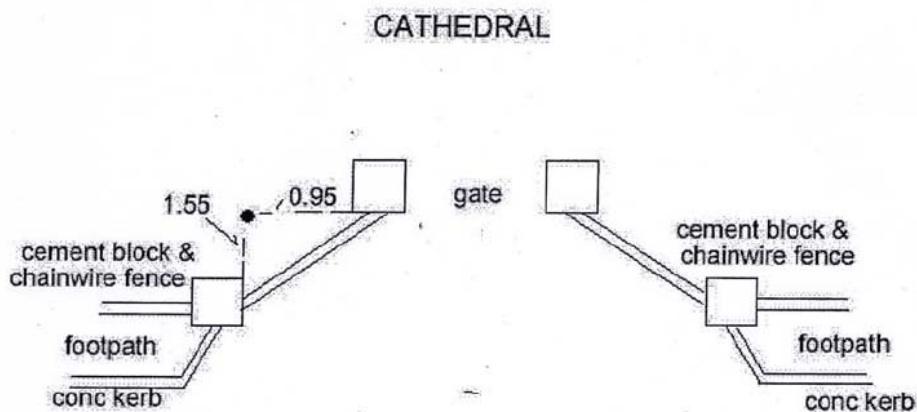
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is not in a good locality for GPS occupation.
--

<i>Country:</i> Kiribati <i>Island:</i> Tarawa	<i>Atoll:</i> Betio
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**Marking and locality sketch**

Bench Mark: 7.9m 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 1700m from the tide gauge station.



Not to scale	Distances in Metres	Magnetic bearings
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Approved by: Geoscience Australia / SOPAC

Date: April 2006

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

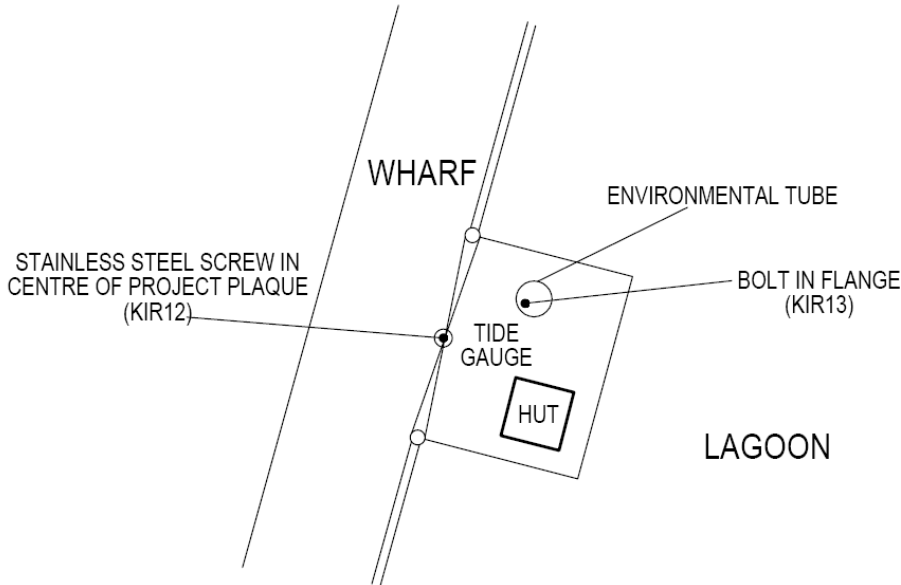
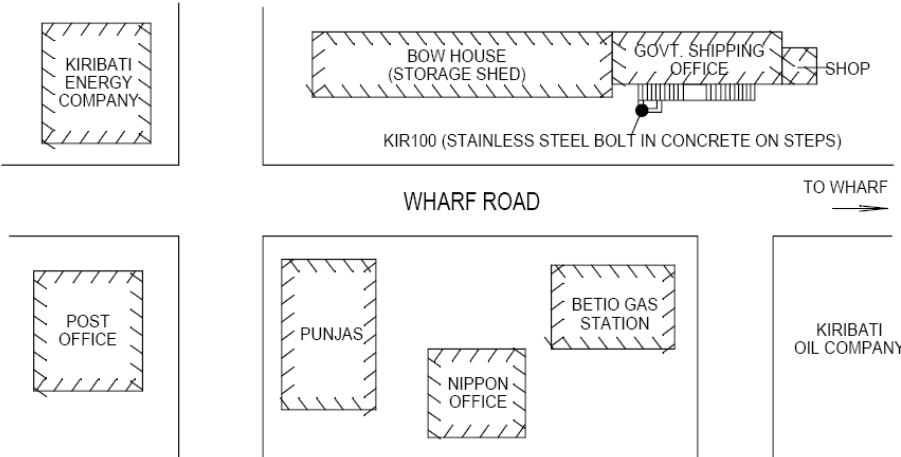


**Survey Bench Mark Record**

**Bench Mark Number: KIR49**

<i>Original Bench Mark Established by:</i> National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA.	<i>Date:</i> 07-06-02
<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is not in a good locality for GPS occupation.	
<i>Country:</i> Kiribati <i>Island:</i> Tarawa	<i>Atoll:</i> Betio
<p style="text-align: center;"><u>Marking and locality sketch</u></p> <p>Bench Mark: 2.5m 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.</p> <p>Locality sketch: Mark approximately 200m from the tide gauge station.</p> <div style="text-align: center;"> </div> <p>Not to scale                      Distances in Metres                      Magnetic bearings</p>	
Approved by: Geoscience Australia / SOPAC	
Date: April 2006 <small>c:\users\landrick\spslcmp\localitydiagrams\kiribati</small>	



COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 805 POINT NO. KIR12 & 13
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07
		
COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 806 POINT NO. KIR100
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07
		



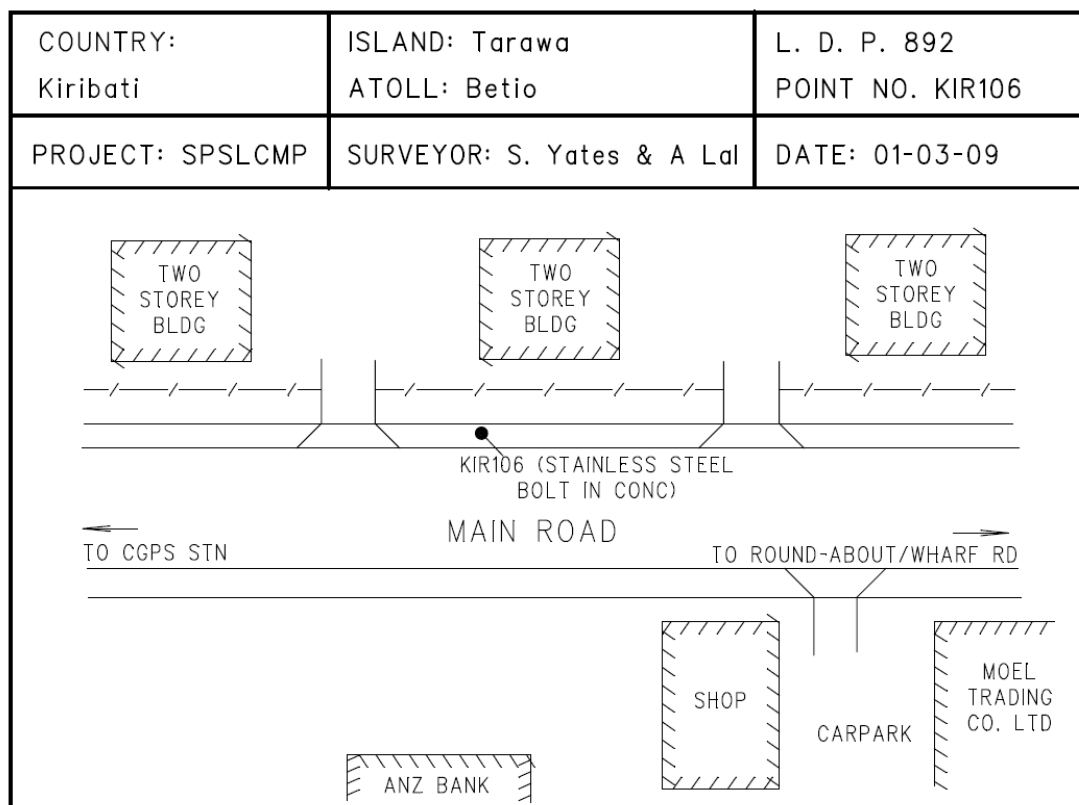
COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 807 POINT NO. KIR101
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07

COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 808 POINT NO. KIR102
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07



COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 809 POINT NO. KIR104
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07
COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 810 POINT NO. KIR105
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07

COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 811 POINT NO. KIR39
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07
<p>The diagram shows a plan view of the BP DEPOT area. A road labeled 'WHARF ROAD' runs diagonally from the top left towards the bottom right. To the right of this road is a 'TO TIDE GAUGE' line with an arrow pointing towards the top right. Further right is a 'PUMPING VALVE' represented by a small square with a dot in the center. A 'FUEL PIPE' runs from the pumping valve towards the bottom right. Below the pumping valve is a point labeled 'KIR39 (STAINLESS STEEL BOLT IN CONC.)'. The entire area is labeled 'BP DEPOT'.</p>		
COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 812 POINT NO. KIR44
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07
<p>The diagram shows a plan view of the BETIO CIRCULAR ROAD area. A horizontal line represents the 'BETIO CIRCULAR ROAD'. Above the road, on the left, is a 'NEW ELECTRICITY DISTRIBUTION BOX' with a point labeled 'KIR44 (STAINLESS STEEL BOLT IN CONC.)' below it. To the right of this is an 'ELECTRICITY DISTRIBUTION BOX T31112'. Below the road, on the left, is an arrow pointing left labeled 'TO CGPS STN.'. On the right, an arrow points right labeled 'TO WHARF'.</p>		

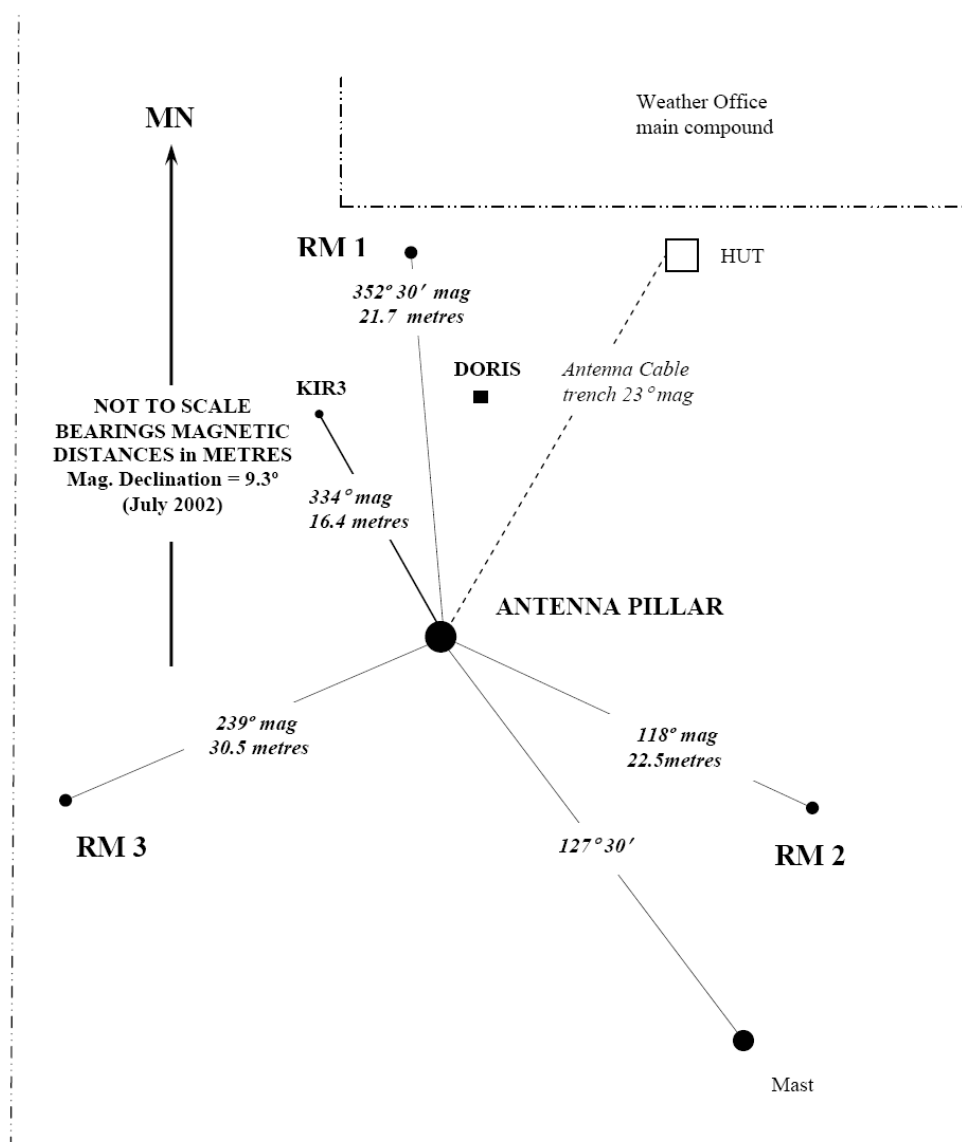


# KIRIBM and KIRI Reference Mark Locality Diagrams

## KIRIBATI CGPS Station, Betio Is. – Reference Marks

### REFERENCE MARKS

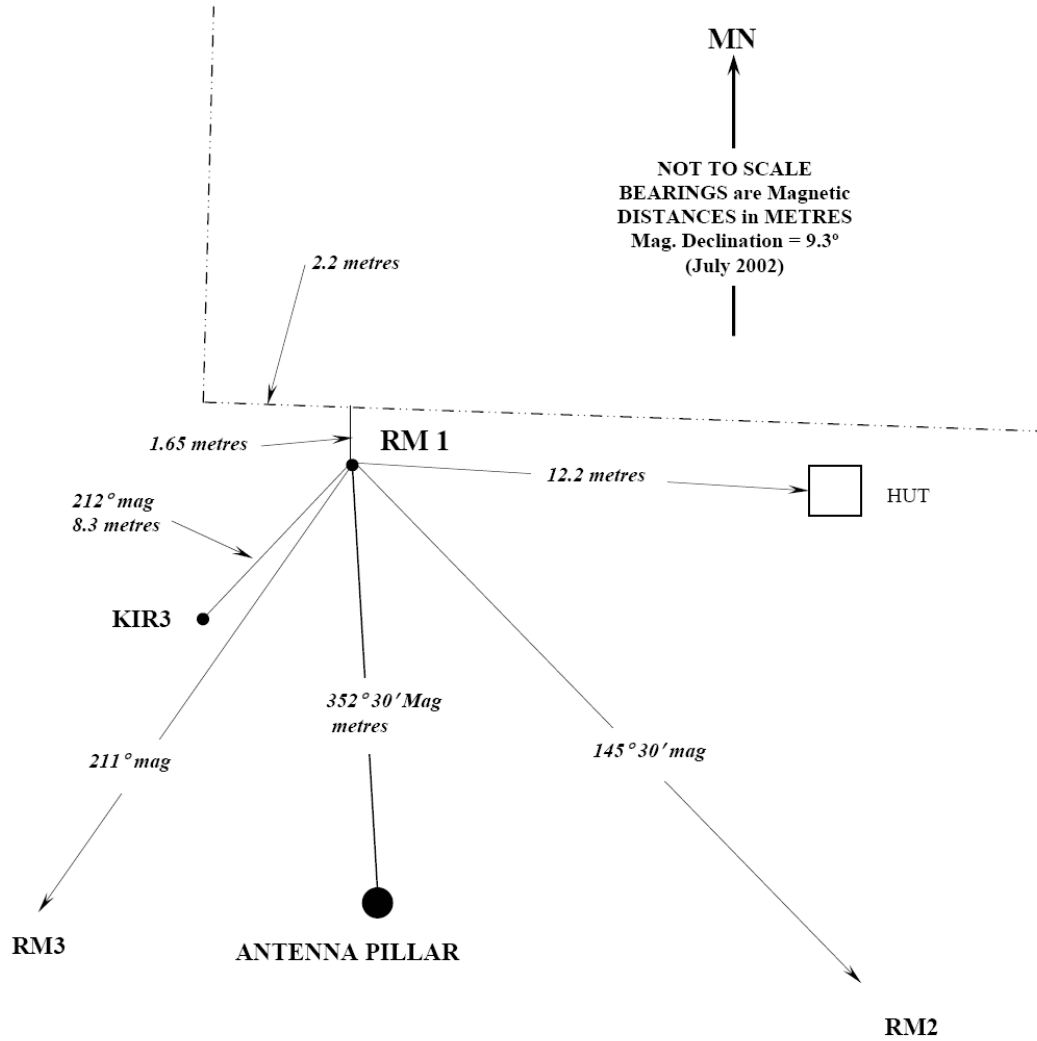
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



## KIRIBATI CGPS Station, Betio Is. – RM 1

### REFERENCE MARKS

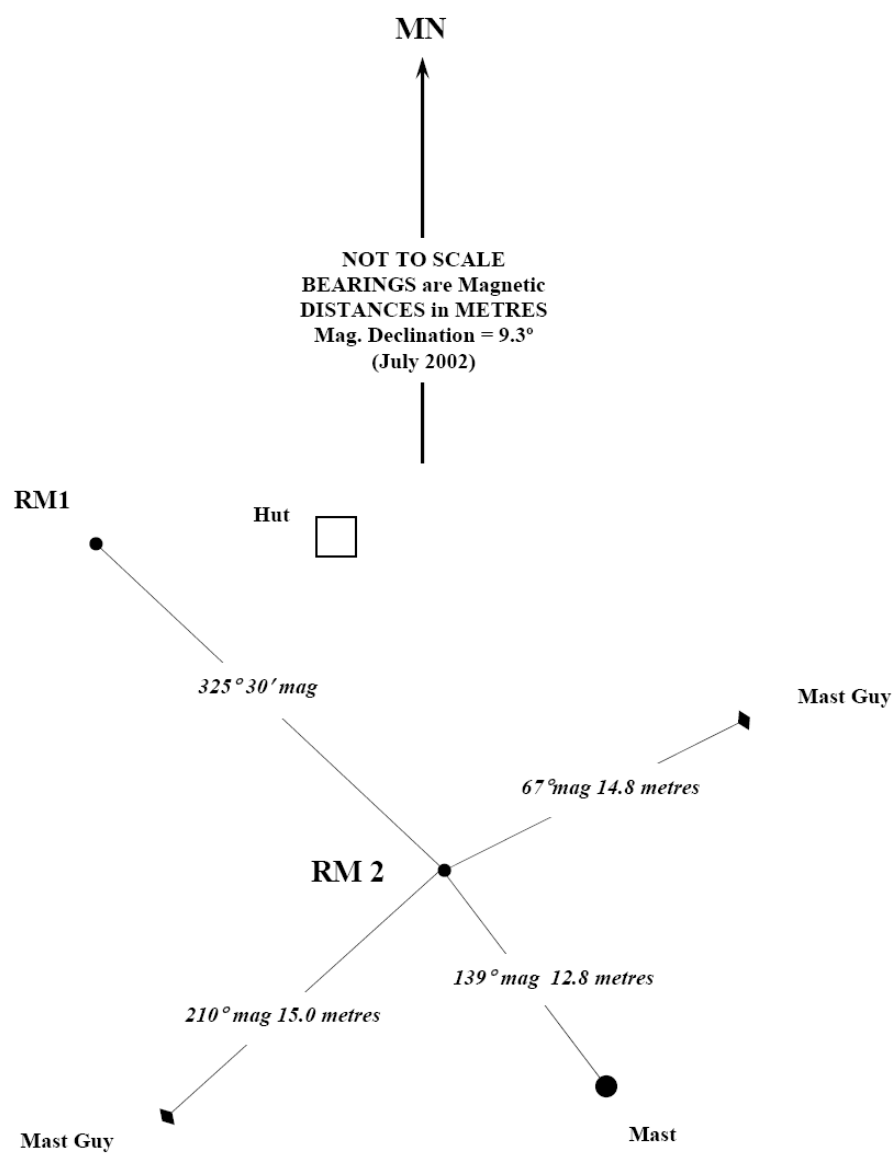
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



## KIRIBATI CGPS Station, Betio Is. – RM 2

### REFERENCE MARKS

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



## KIRIBATI CGPS Station, Betio Is. – RM 3

### REFERENCE MARKS

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

