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EDM Height Traversing Levelling Survey Report

Tarawa, Kiribati, April 2012

S. J. K. Yates, A. Lal

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GEOSCIENCE AUSTRALIA
RECORD 2014/17

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Australian Government
Geoscience Australia

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Parliamentary Secretary: The Hon Bob Baldwin MP

Secretary: Ms Glenys Beauchamp PSM

Geoscience Australia

Chief Executive Officer: Dr Chris Pigram

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1 Introduction

This report outlines the high precision levelling survey completed between the Sea Level Fine Resolution Acoustic Measuring Equipment (SEAFRAME) tide gauge and the Continuous Global Navigation Satellite System (CGNSS) station in Tarawa, Kiribati from 23 – 30 April 2012.

Personnel involved in the survey were Steve Yates, Surveyor, Geoscience Australia and Andrick Lal, Surveyor, Secretariat of the Pacific Islands Community (SPC).

The Electronic Distance Measurement (EDM) height traversing levelling technique was employed to observe differences in height between the deep bench mark arrays in Tarawa, which runs approximately 2.2 km from the tide gauge sensor to the CGNSS antenna. Previous levelling surveys using this technique have been conducted along the route in 2006, 2007, 2009 and 2010.

In addition, precise differential levelling surveys were performed along the deep bench mark (BM) array from 1992 to 2006 by the National Tidal Centre Australia (NTCA). This report contains a comparison between the 2012 and 2010 EDM height traversing results as well as a combined comparison since the first levelling survey in 1992.

2 The Survey

The EDM height traversing levelling survey was carried out between the SEAFRAME tide gauge sensor, continuous GNSS station and the deep driven bench marks:

KIR 12	- Project plaque at tide gauge
KIR 13	- SEAFRAME sensor benchmark
KIR 1	- Deep Driven BM
KIR 2	- Deep Driven BM
KIR 3	- Deep Driven BM
KIR 46	- Deep Driven BM
KIR 47	- Deep Driven BM
KIR 49	- Deep Driven BM

All the deep bench marks were located and found in good order and undisturbed. Also included in the survey were the permanent holding marks KIR39, KIR44, KIR100, KIR101, KIR102, KIR104, KIR105 and KIR106 which are stainless steel bolts drilled in concrete and glued in place.

The EDM height traversing levelling technique was performed to the Class L2A specifications (ICSM, Standards and Practices for Control Surveys). After reduction an internal precision of $1\text{mm}\sqrt{K}$ or better was achieved (zero order); well within the specifications of the project which is $2\sqrt{K}$ where K is the distance in kilometres. A table of results and comparisons and the 2012 reduced levels are detailed later in this report.

2.1 Bench Mark Locality Diagram



2.2 The Kiribati Datum

The adopted reference point for this survey is KIR1. Reduction of the data was calculated holding KIR 1 fixed at 3.5334 metres relative above the Tide Gauge Zero (TGZ) mark from the University of Hawaii tide gauge.

The original reference point for the 1992 survey was UT8 which had a height of 4.027 m above the Tide Gauge Zero (TGZ) mark from the University of Hawaii tide gauge, however, both the UT8 and the tide gauge no longer exist.

2.3 Equipment

- Leica total station model TM30 (Serial No: 361441)
- Leica precision prisms GPH1P (2).
- Leica rigid tripod.
- Stainless steel target poles supported by Leica telescopic bi-poles (2).
- Shortened stainless steel target pole for the SEAFRAME sensor BM connection.

- Leica cast iron change plates (2).
- Kestral 4000 pocket weather tracker

2.4 Method

The “Leap-Frog” EDM height traversing technique was employed for the Betio Island tide gauge levelling survey. This technique involves setting up a total station (TCA1800L) midway between two target/reflectors (on reflector rods with struts). The targets remain at a particular change point for the back-sight and fore-sight observations. The instrument measures slope distances ($\pm 1\text{mm}$) and vertical angle ($1''$) to derive height differences (between the instrument’s trunnion axis and the reflectors). In support of the slope distance observations, the ambient temperature, pressure and humidity are recorded (Kestral 4000 pocket weather tracker) and input into the instrument to apply the first velocity correction to the observed distances (Rüeger & Brunner, 1982). Four rounds of observations are taken to the back-sight and fore-sight targets from each instrument setup. All levelling runs 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. This technique can also be performed using a single set-up / single rod configuration which is particularly useful when levelling between bench marks which are close together e.g. between the CGNSS RMs.

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.

2.5 Survey Support

Assistance from Boata Iabeta, Acting Chief Surveyor in Romano Reo’s absence, and his staff; from the Ministry of Lands was appreciated, they provided great support throughout the survey, including assistance in obtaining customs clearances for the surveying equipment. This is a lengthy process and seems to becoming more time consuming throughout most countries in the Pacific.

The staff from the Kiribati Weather Office also provided great assistance during the 2012 visit.

2.6 Issues

No issues of any significance were encountered during the 2012 visit.

3 Comparisons

3.1 Comparisons between 2012 and 2010 EDM Surveys

Table 3.1 Tarawa, Kiribati 2012 EDM Height Traversing Levelling & Comparison 2012 - 2010. KIR1 - adopted fixed height of 3.5334 m

From	To	Levelled Ht. Diff.	RL 2012	Misclosure (mm)	Dist. (km)	1mm√k	RL 2010	Difference (mm) 2012 - 2010
KIR1			3.5334					
KIR102	KIR102	0.47631	4.0097	0.10	0.051	0.227	4.0098	-0.09
KIR100	KIR100	-0.17738	3.8323	-0.20	0.056	0.237	3.8325	-0.16
KIR39	KIR39	0.24661	4.0789	-0.16	0.196	0.443	4.0787	0.24
KIR101	KIR101	0.06483	4.1438	0.44	0.204	0.452	4.1435	0.28
KIR49	KIR49	-0.12041	4.0234	0.06	0.143	0.378	4.0229	0.47
KIR12	KIR12	0.19764	4.2210	0.27	0.179	0.423	4.2200	1.01
	KIR13	0.41256	4.6336	-0.11	0.011	0.105	4.6322	1.36
KIR102			4.0097				4.0098	-0.09
KIR46	KIR46	-0.62951	3.3802	0.42	0.160	0.400	3.3794	0.80
KIR106	KIR106	0.42358	3.8038	0.28	0.140	0.374	3.8032	0.59
KIR104	KIR104	-0.12327	3.6805	0.24	0.202	0.449	3.6747	5.82
	KIR2	-0.49652	3.1840	0.27	0.107	0.327	3.1828	1.19
KIR104			3.6805					
KIR44	KIR44	-0.05929	3.6212	-0.09	0.187	0.432	3.6204	0.83
KIR47	KIR47	-0.32439	3.2968	-0.27	0.091	0.302	3.2954	1.44
KIR105	KIR105	0.53270	3.8295	-0.26	0.166	0.407	3.8267	2.84
KIR3	KIR3	-0.26293	3.5666	0.19	0.211	0.459	3.5655	1.11
	KIRBM	0.84791	4.4145	0.06	0.023	0.152	4.4134	1.11
			Misclose for all bays levelled =	1.24	2.127	1.459		
KIRIBM			4.41450					
	RM1	-0.8757	3.53881	-0.03	0.023	0.152	3.5378	1.06
KIRIBM								
	RM2	-0.9129	3.50159	0.06	0.023	0.152	3.5006	1.03
KIRIBM								
	RM3	-0.8977	3.51685	0.02	0.300	0.548	3.5158	1.01

All levelling was performed within the project specifications of 2√k

3.2 Combined Comparisons 1992 to 2012

Table 3.2 Tarawa, Kiribati - Comparison of the RL's for Precise Differential Levelling (1992 - 2006) and EDM Height Traversing (2006 - 2012). Units are in metres.

Year	KIR1	KIR2	KIR3	KIR12	KIR13	KIR46	KIR47	KIR49	KIRIBM
1992.9	3.5334	3.1835	3.5657	4.2176	4.6302				
1994.2	3.5334	3.1838	3.5655	4.2187	4.6319	New point est. 2002	New point est. 2002	New point est. 2002	New point est. 2002
1995.2	3.5334	3.1845	3.5654	4.2195	4.6331	New point est. 2002	New point est. 2002	New point est. 2002	New point est. 2002
1996.7	3.5334	3.1843	3.5654	4.2191	4.6321	New point est. 2002	New point est. 2002	New point est. 2002	New point est. 2002
1997.9	3.5334	3.1843	3.5657	4.2196	4.6325	New point est. 2002	New point est. 2002	New point est. 2002	New point est. 2002
1999.5	3.5334	3.1844	3.5644	4.2195	4.6324	New point est. 2002	New point est. 2002	New point est. 2002	New point est. 2002
2000.7	3.5334	3.1847	3.5658	4.2195	4.6321	New point est. 2002	New point est. 2002	New point est. 2002	New point est. 2002
2002.4	3.5334	3.1843	3.5648	4.2191	4.6321	3.3782	3.2948	4.0232	4.4124
2004.4	3.5334	3.1843	3.5653	4.2190	4.6324	3.3788	3.2952	4.0225	4.4130
2006.2	3.5334	3.1839	3.5662	4.2195	4.6328	3.3788	3.2956	4.0226	4.4139
2006.2	3.5334	3.1844	3.5646	4.2193	4.6326	3.3794	3.2953	4.0230	4.4124
2007.9	3.5334	3.1830	3.5641	4.2202	4.6308	3.3795	3.2941	4.0230	4.4119
2009.2	3.5334	3.1835	3.5646	4.2199	4.6320	3.3791	3.2951	4.0229	4.4125
2010.7	3.5334	3.1828	3.5655	4.2200	4.6322	3.3794	3.2954	4.0229	4.4134
2012.2	3.5334	3.1840	3.5666	4.2210	4.6336	3.3802	3.2968	4.0234	4.4145

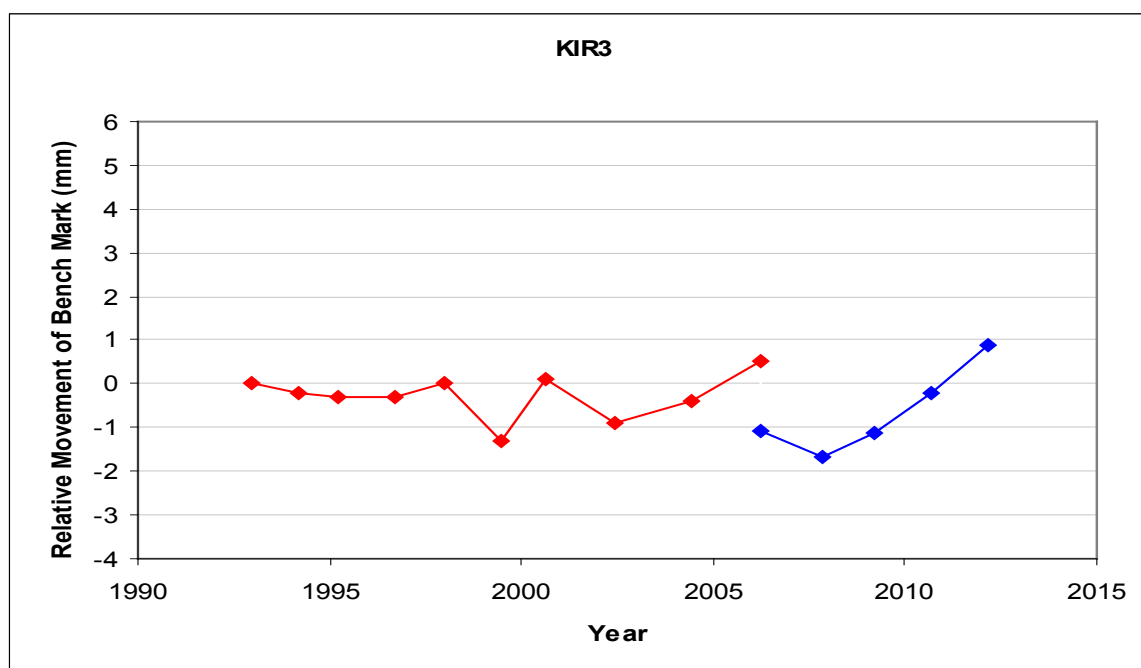
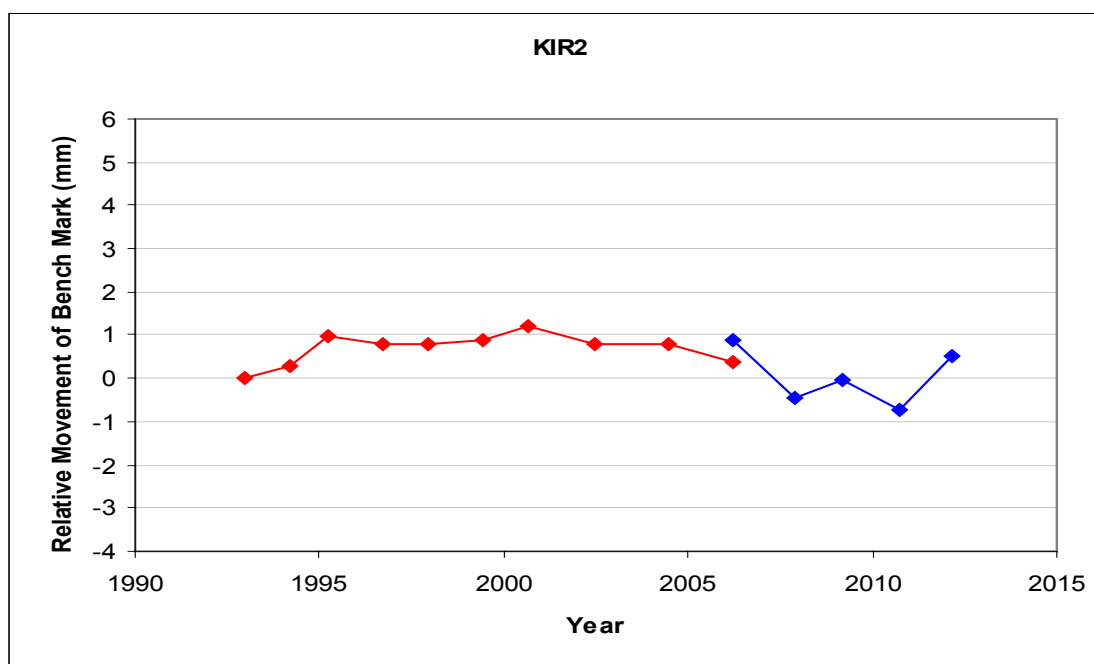
**The RL of the Reference Point KIRI (ARP) is derived from adding the static height difference of 0.9443 m (KIRIBM to KIRI) to the levelled RL of KIRIBM.*

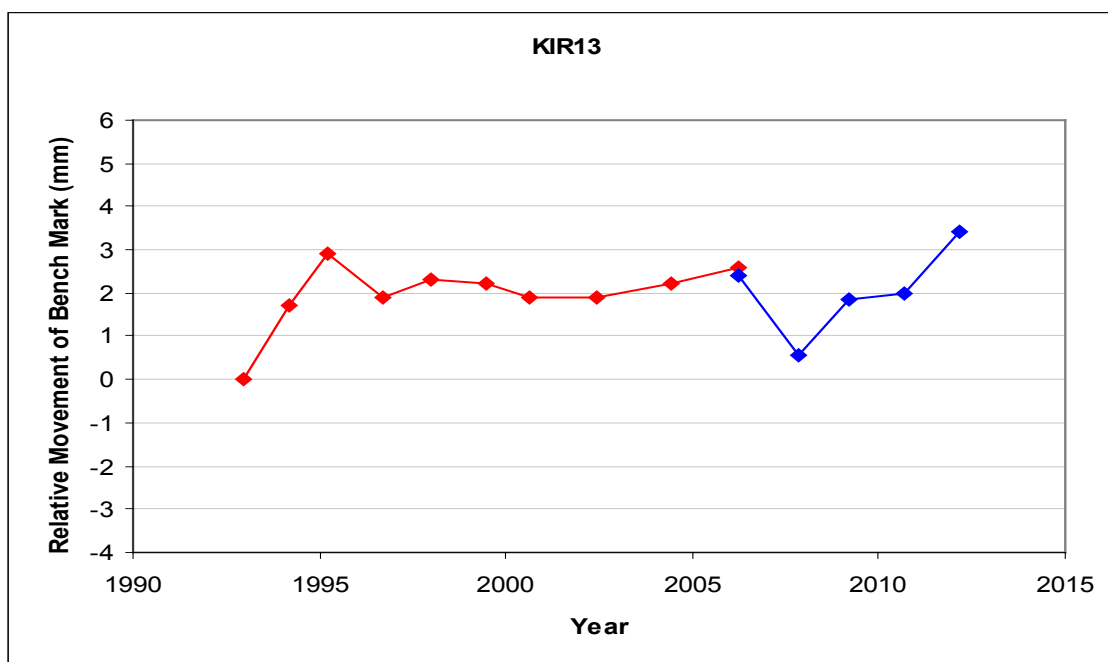
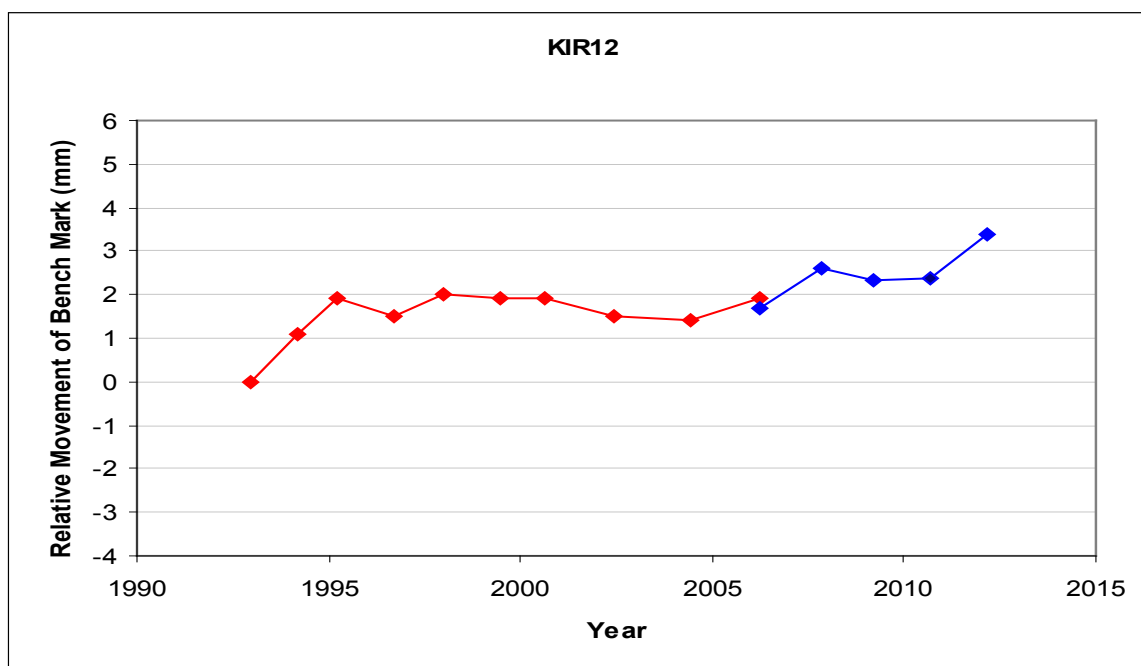
The 2012 Reduced Level for KIRI is 5.3588 m.

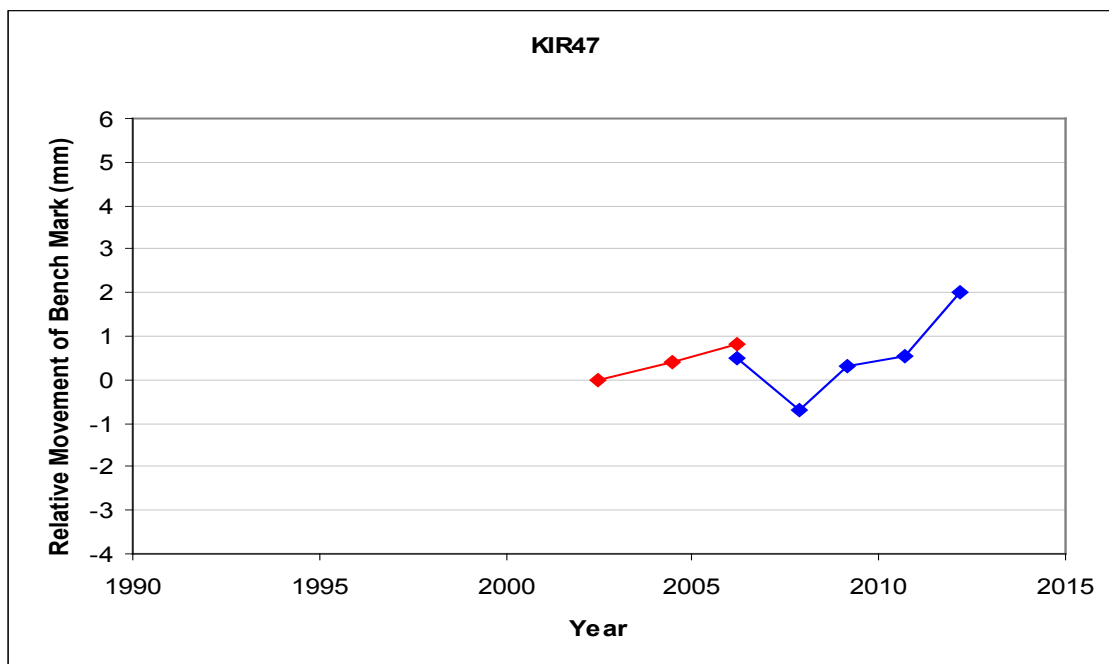
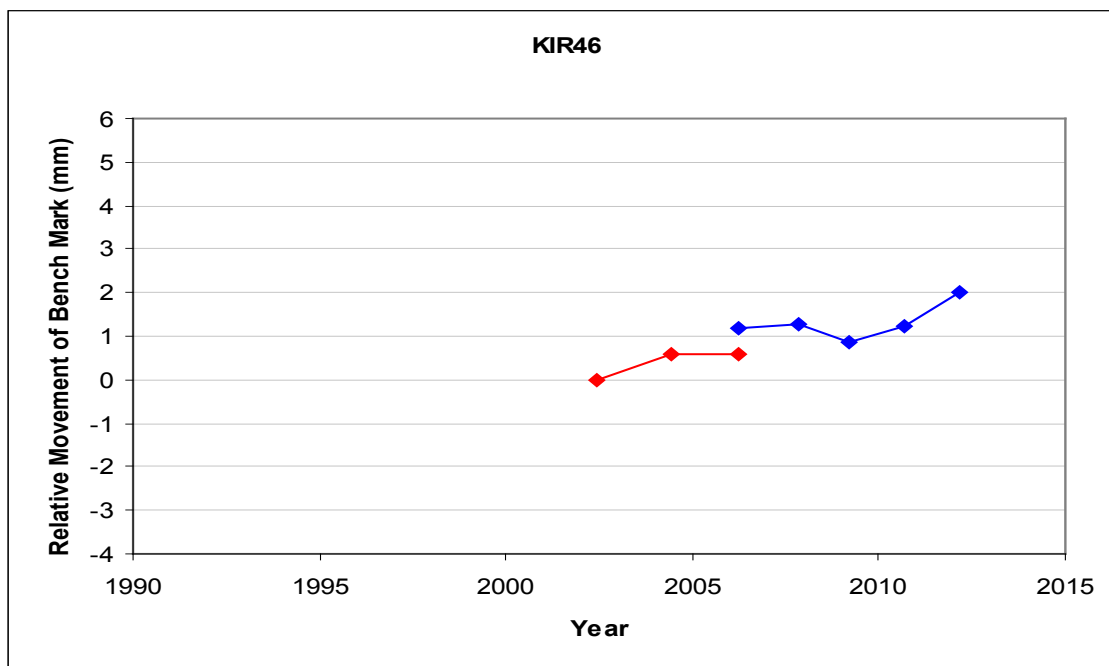
3.3 Time Series of Bench Mark Movement relative to Fixed Deep Bench Mark KIR1

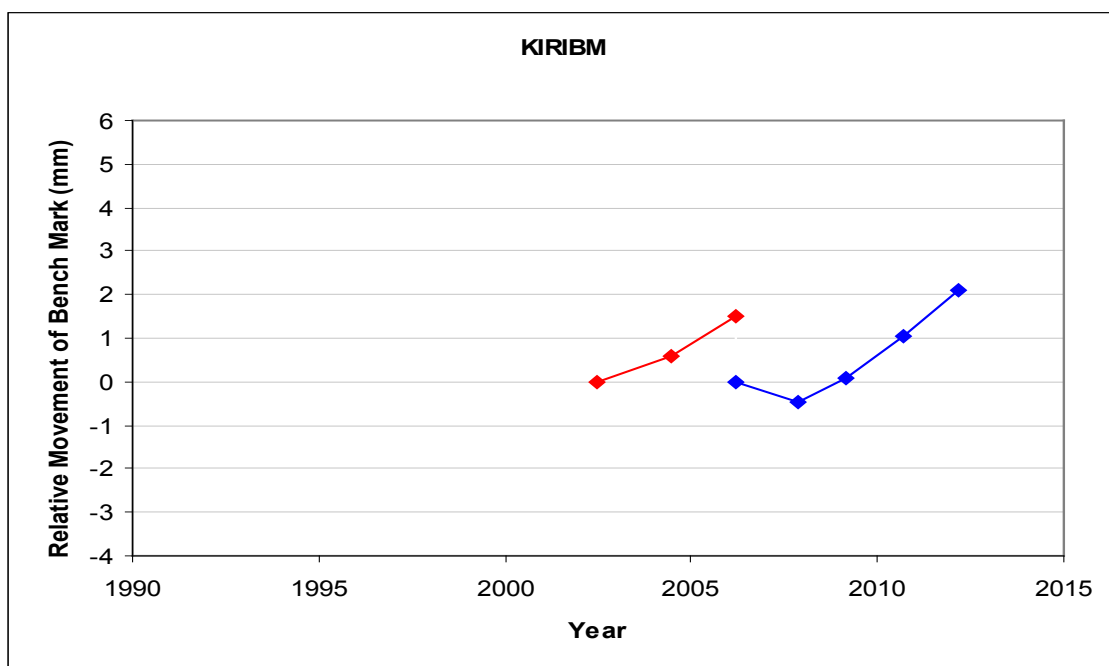
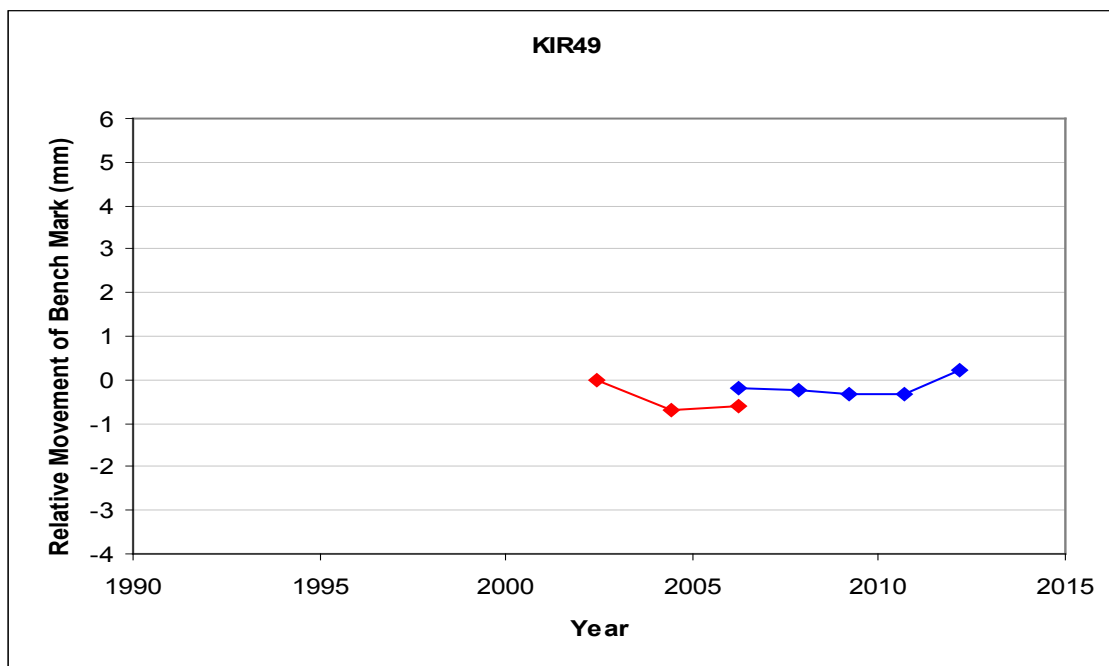
The purpose of this survey is twofold: firstly, to provide accurate changes in land height to be used in computations of absolute sea level rise and secondly to provide accurate assessments of relative sea level changes due to localised deformation.

Precise Differential Levelling: 1992 - 2006 ◆ — ◆
EDM Height Traversing: 2006 onwards ◆ — ◆









4 Deep Bench Mark 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.

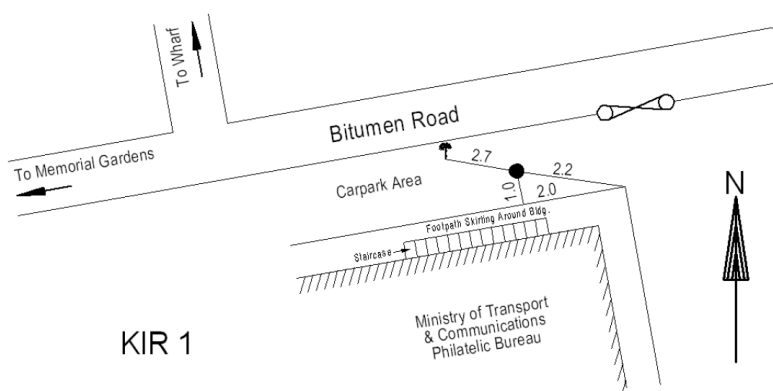
Country: Kiribati
Island: Tarawa

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

c:\users\landrick\spslcmp\localitydiagrams\kiribati



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



Survey Bench Mark Record

Bench Mark Number: KIR2

<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
--	-----------------------

<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
--	--------------

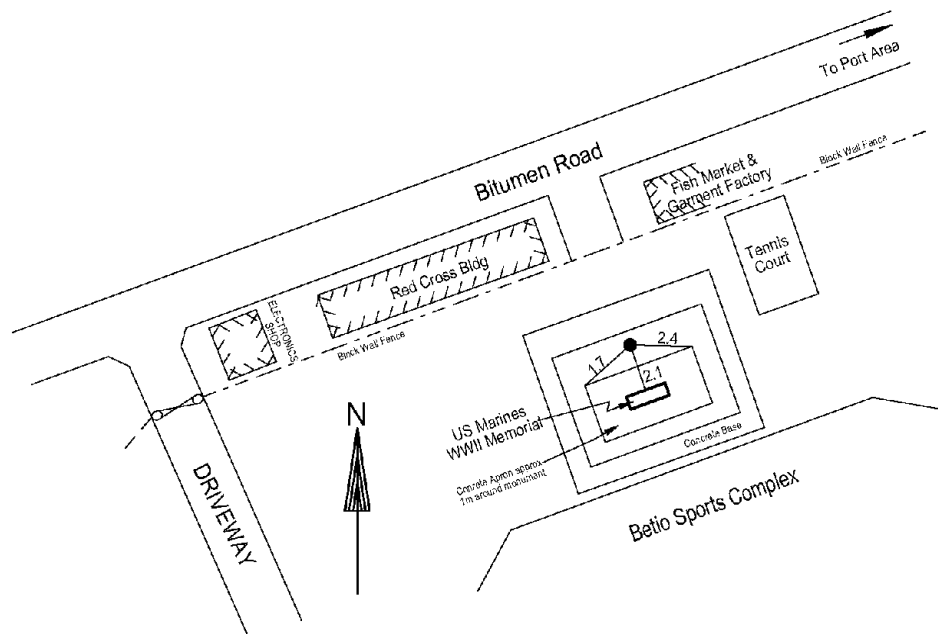
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
--

<i>Country:</i> Kiribati <i>Island:</i> Tarawa	<i>Atoll:</i> Betio
---	---------------------

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
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Approved by: Geoscience Australia / SOPAC	Date: Dec 2007 c:\users\landrick\spslcmpl\localitydiagrams\kiribati
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**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: KIR3

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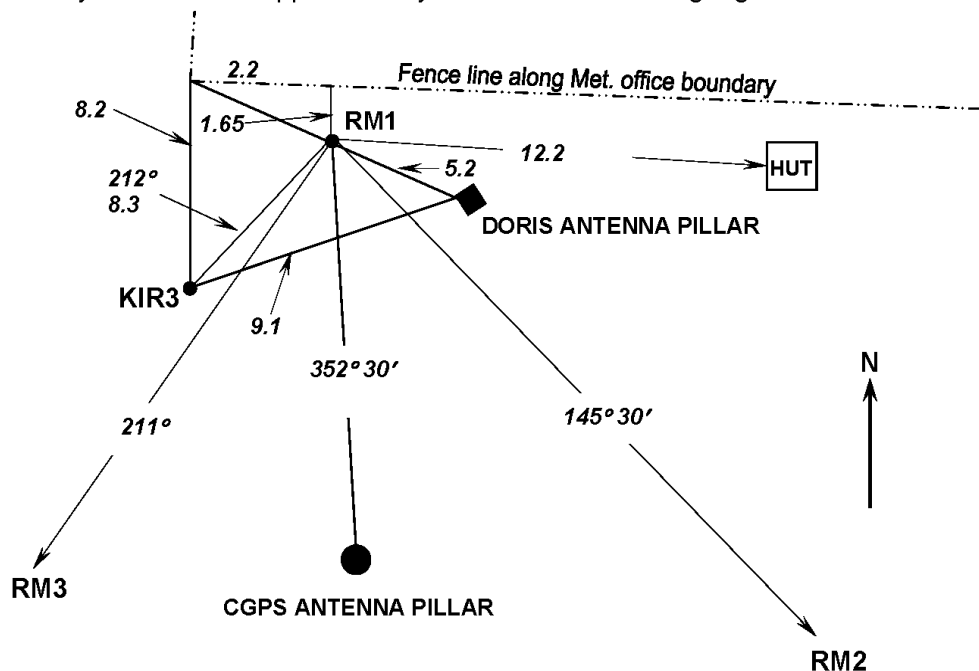
Notes / References: Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.

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 0.2m below ground level.

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



Not to scale	Distances in Metres	Magnetic bearings
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Approved by: Geoscience Australia / SOPAC	Date: Dec 2006
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**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: KIR46

<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>City:</i> Betio
<u>Marking and locality sketch</u> 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 c:\users\andrick\spslcmp\localitydiagrams\kiribati	



**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
<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
<u>Marking and locality sketch</u> 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. The diagram is a locality sketch showing the bench mark location. At the top center is the word 'CATHEDRAL'. Below it, a horizontal line represents a road or path. On the left side of this line, there is a 'conc kerb' and a 'footpath'. A 'cement block & chainwire fence' runs along the footpath. A point on the fence is marked with a dot and labeled '1.55'. To the right of this point, the path continues towards a 'gate'. The distance from the '1.55' point to the 'gate' is labeled '0.95'. On the right side of the gate, there is another 'conc kerb' and 'footpath', with another 'cement block & chainwire fence' running along it.	
Not to scale	Distances in Metres
Magnetic bearings	
Approved by: Geoscience Australia / SOPAC	
Date: April 2006 c:\users\landrick\spslcmpl\localitydiagrams\kiribati	



**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
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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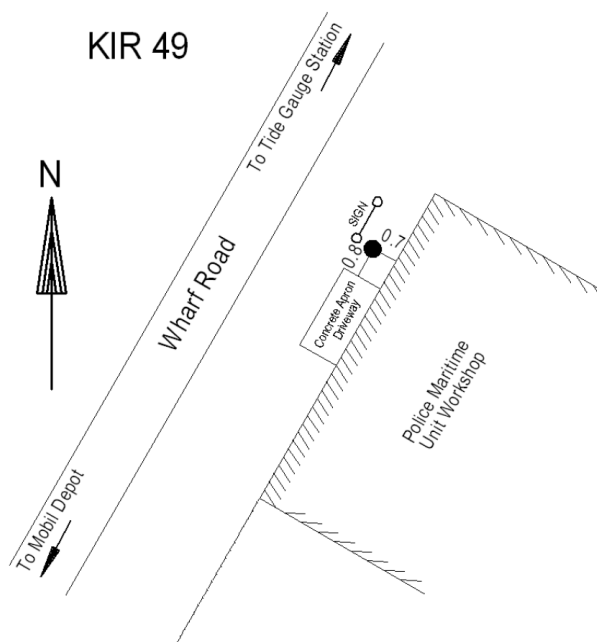
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is not in a good locality for GPS occupation.
--

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

Bench Mark: 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.

Locality sketch: Mark approximately 200m 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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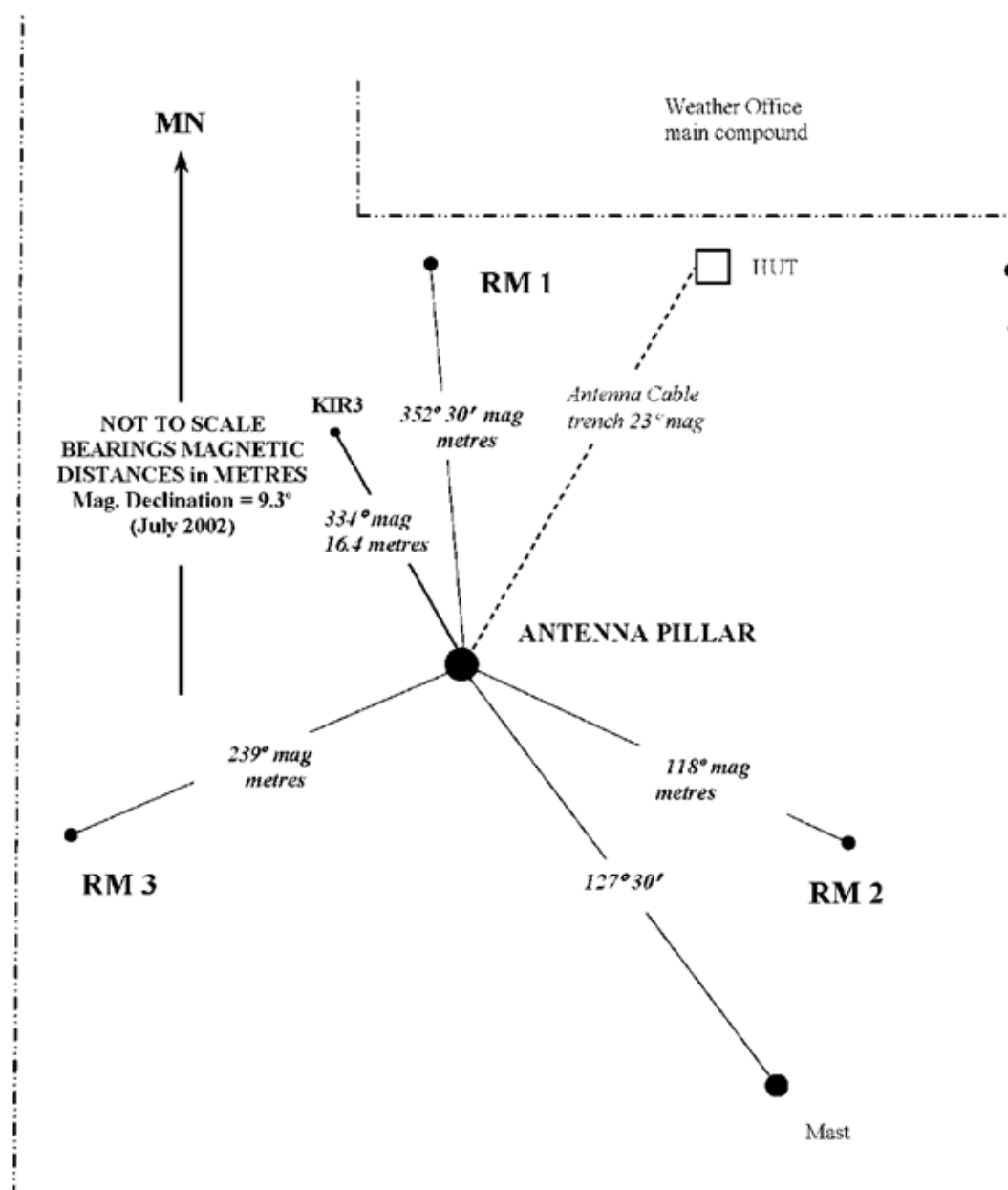
c:\users\landrick\spslcmpllocalitydiagrams\kiribati

5 Reference Mark Locality Diagrams

KIRIBATI CGPS Station, Betio Is. – Reference Marks

REFERENCE MARKS

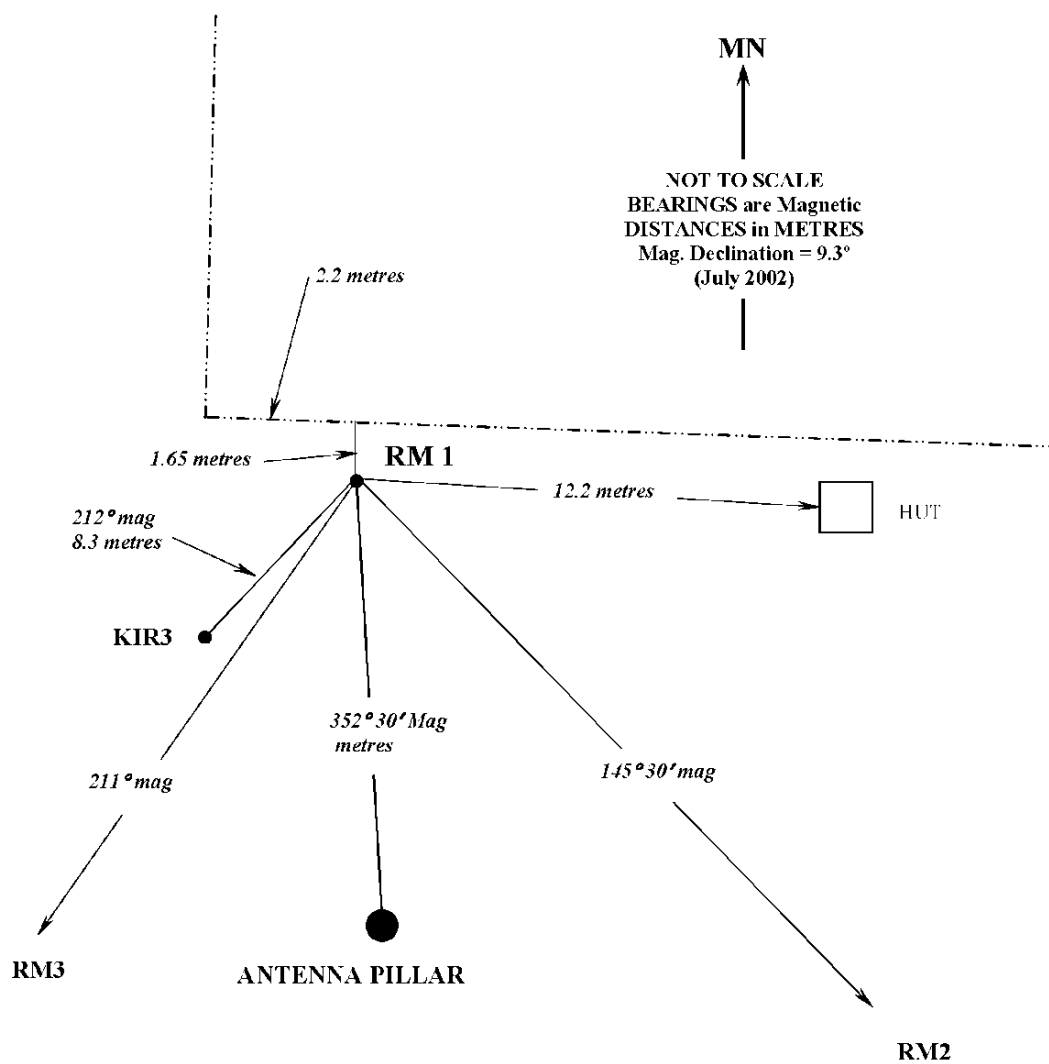
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



KIRIBATI CGPS Station, Betio Is. – RM 1

REFERENCE MARKS

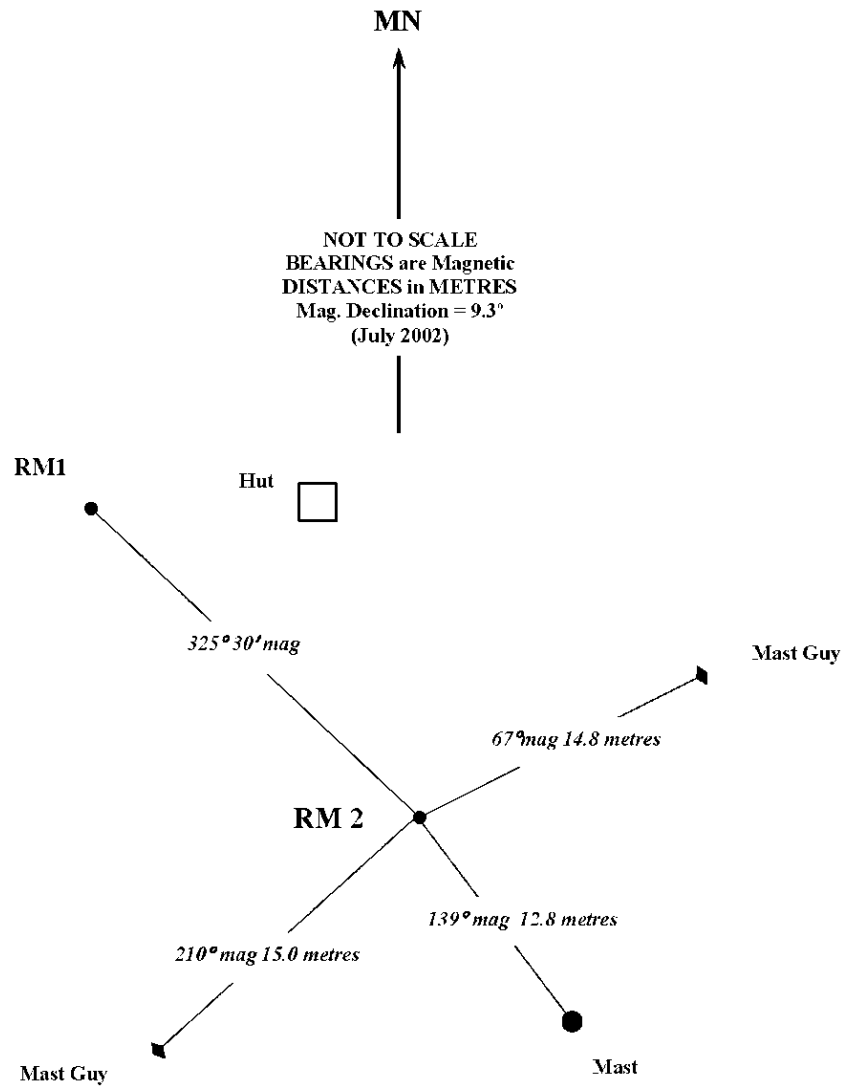
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



KIRIBATI CGPS Station, Betio Is. – RM 2

REFERENCE MARKS

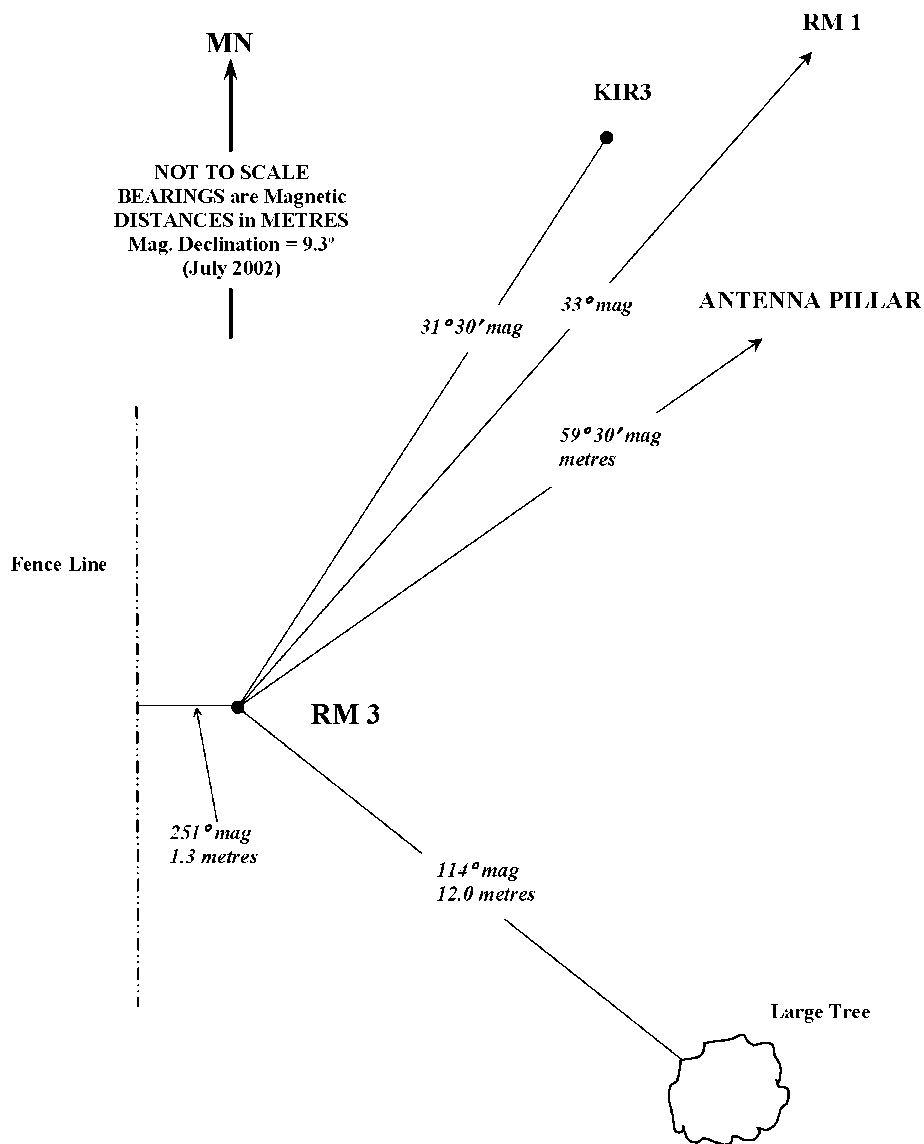
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



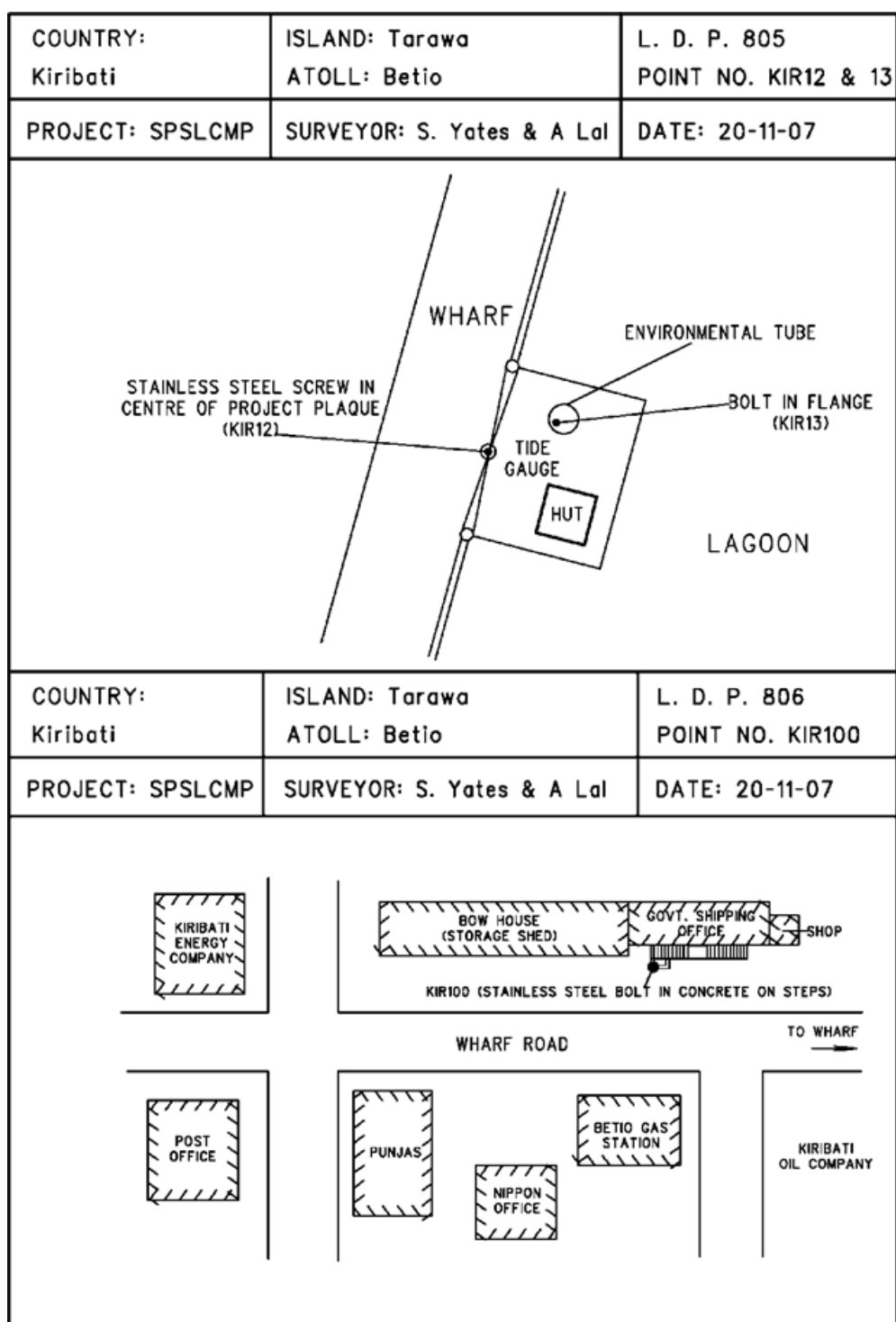
KIRIBATI CGPS Station, Betio Is. – RM 3

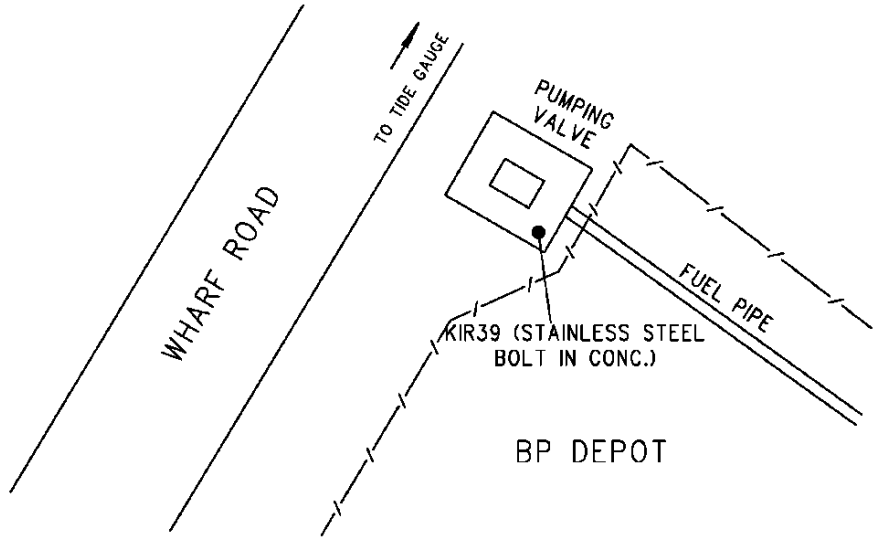
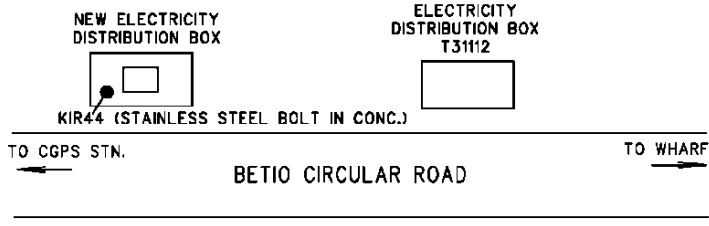
REFERENCE MARKS

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.

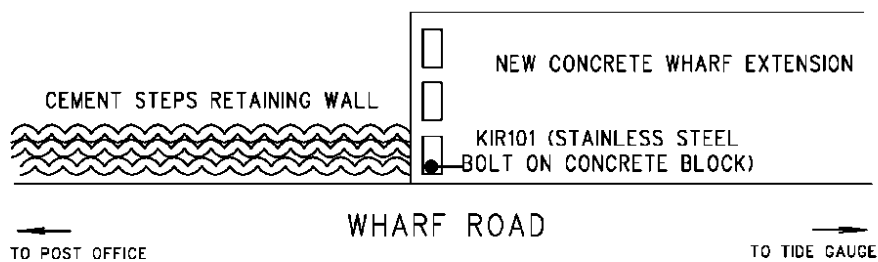


6 Permanent Holding Mark Locality Diagrams

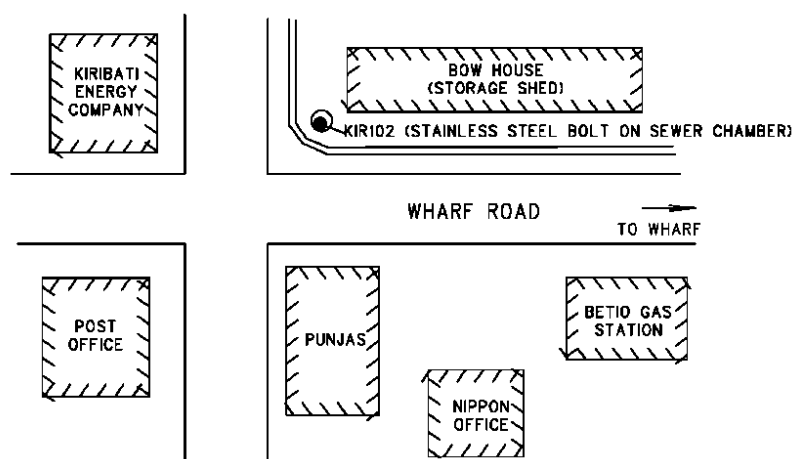


COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 811 POINT NO. KIR39
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07
 The diagram shows a plan view of a coastal area. On the left, a line is labeled 'WHARF ROAD'. To its right, a line points 'TO TIDE GAUGE'. Further right is a rectangular structure labeled 'BP DEPOT'. Inside the depot is a 'PUMPING VALVE'. A dashed line labeled 'FUEL PIPE' runs from the depot towards the right. A point labeled 'KIR39 (STAINLESS STEEL BOLT IN CONC.)' is marked on a dashed line extending from the depot towards the bottom left.		
COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 812 POINT NO. KIR44
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07
 The diagram shows a plan view of a road labeled 'BETIO CIRCULAR ROAD'. On the left side of the road, a point labeled 'KIR44 (STAINLESS STEEL BOLT IN CONC.)' is marked next to a 'NEW ELECTRICITY DISTRIBUTION BOX'. On the right side of the road, there is an 'ELECTRICITY DISTRIBUTION BOX T3112'. Arrows at the ends of the road indicate directions: 'TO CGPS STN.' on the left and 'TO WHARF' on the right.		

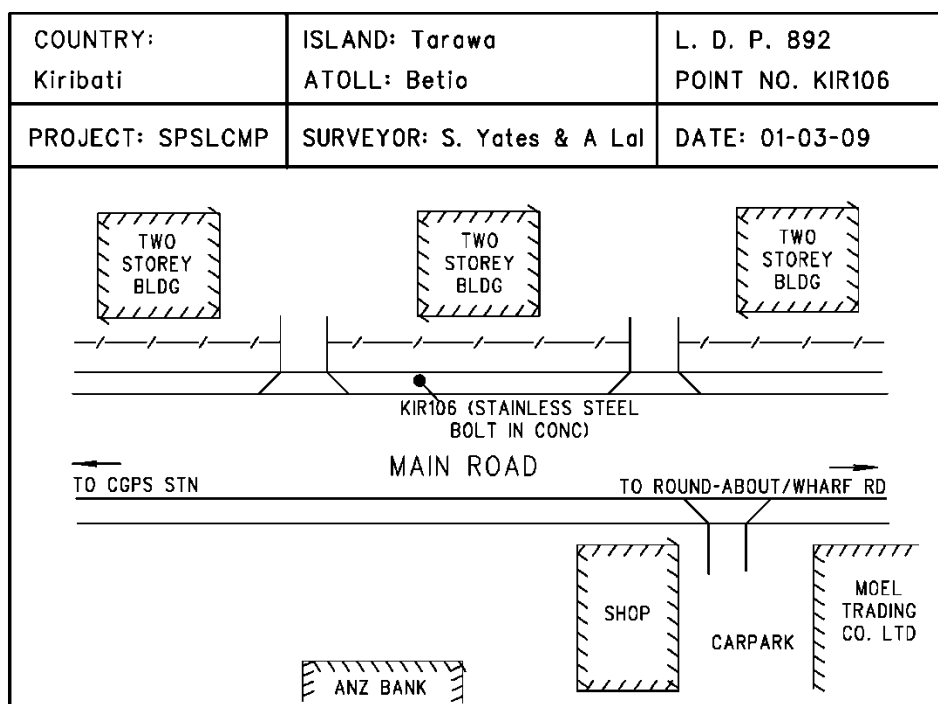
COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 807 POINT NO. KIR101
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07



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
The diagram for KIR104 shows a horizontal line representing a 'BITUMEN ROAD'. Above the road, from left to right, are a 'SEWER CHAMBER' (circle), 'KIR104 (STAINLESS STEEL BOLT ON ROAD KERB)' (a dot on the road line), and an 'ELECT. DISTRIBUTION BOX' (rectangle). Below the road, from left to right, are a dashed line pointing 'TO BETIO SPORTS COMPLEX', a rectangle for 'ELECTRONICS SHOP', a larger rectangle for 'RED CROSS BLDG.', and another dashed line pointing 'TO ROUND-ABOUT' with a 'FISH MARKET' rectangle nearby.		
COUNTRY: Kiribati	ISLAND: Tarawa ATOLL: Betio	L. D. P. 810 POINT NO. KIR105
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 20-11-07
The diagram for KIR105 shows a horizontal line representing 'BETIO CIRCULAR ROAD'. Above the road, from left to right, are a 'LIGHT POLE' (square with an 'X'), 'KIR105 (STAINLESS STEEL BOLT ON ROAD KERB)' (a dot on the road line), and an 'ELECT. DISTRIBUTION BOX' (rectangle). Below the road, a vertical line represents a 'DIRT ROAD'. To the left of the dirt road is an arrow pointing 'TO WHARF'. To the right of the dirt road is an arrow pointing 'TO MET. OFFICE'.		



7 References

- Rüeger, J.M. & Brunner, F.K. 1982, 'EDM Height Traversing versus Geodetic Levelling', The Canadian Surveyor, vol. 36, no. 1, pp. 69-87.
- Inter-Government Committee on Surveying and Mapping (ICSM) 2002, Standards and Practices for Control Surveys, SP1, Ver. 1.5, May 2002.