EDM Height Traversing Levelling Survey Report

Tarawa, Kiribati, August 2013

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# Introduction

This report outlines the high precision level 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 15th – 22nd August 2013.

Personnel involved in the survey were Steve Yates, Project Officer, Geoscience Australia and Andrick Lal, Surveyor, Secretariat of the Pacific 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 2.2km from the SEAFRAME tide gauge sensor to the CGNSS Station. Previous levelling surveys have been conducted along the route using this technique in 2006, 2007, 2009, 2010 and 2012.

In addition, precise differential levelling surveys were performed along the deep bench mark array from 1992 to 2006 by the National Tidal Centre Australia (NTCA) and the survey in 2006 included a comparison between the precise differential levelling and EDM height traversing techniques. This report contains a comparison between the 2013 and 2012 EDM height traversing results as well as a combined comparison since the first levelling survey in 1992.

# The Survey

The EDM height traversing levelling survey was carried out between the SEAFRAME tide gauge sensor, CGNSS station and the deep driven bench mark array:

KIR1 – reference deep driven bench mark

KIR2 – deep driven bench mark

KIR3 – deep driven bench mark

KIR46 – deep driven bench mark

KIR47 – deep driven bench mark

KIR49 – deep driven bench mark

KIR12 – SEAFRAME sensor bench mark

KIR13 – SEAFRAME Project plaque bench mark

KIRIBM – reference bench mark for the GNSS pillar

Also included in the survey were temporary holding marks – KIR39, KIR44, KIR100, KIR101, KIR102, KIR104, KIR105 and KIR106.

The CGNSS Reference Point - KIRI and the three CGNSS Reference Marks – RM1, RM2 and RM3 were also levelled. All the deep bench marks were located and found in good order and undisturbed.

The EDM Height Traversing levelling technique was performed to the Class L2A specifications. After reduction an internal precision of 1mm √K or better was achieved, where K is distance in kilometres. This is well within the project specification of 2mm √K. A table of results and comparisons and the 2013 reduced levels are detailed later in this report.

## Bench Mark Locations – Tarawa



## 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.

## Equipment

* LEICA total station model TCA2003 and 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

## 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 (±1mm) 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.

## Kiribati 2013 Reduced Levels

Table 2.1 Tarawa, Kiribati – Reduced levels 2013 survey  
Date: 15 – 22 August 2013  
Datum: Tide Gauge Zero

| Point ID | Reduced Level 2013 | Type |
| --- | --- | --- |
| KIR1 | 3.5334 | Stainless Steel Rod in Ground |
| KIR102 | 4.0096 | Stainless Steel Pin in Concrete |
| KIR100 | 3.8317 | Stainless Steel Pin in Concrete |
| KIR39 | 4.0779 | Stainless Steel Pin in Concrete |
| KIR101 | 4.1426 | Stainless Steel Pin in Concrete |
| KIR49 | 4.0224 | Stainless Steel Rod in Ground |
| KIR12 | 4.2188 | Stainless Steel Pin in Concrete |
| KIR13 | 4.6316 | Stainless Steel Pin |
| KIR46 | 3.3801 | Stainless Steel Rod in Ground |
| KIR106 | 3.8032 | Stainless Steel Pin in Concrete |
| KIR104 | 3.6795 | Stainless Steel Pin in Concrete |
| KIR2 | 3.1836 | Stainless Steel Rod in Ground |
| KIR44 | 3.6198 | Stainless Steel Pin in Concrete |
| KIR47 | 3.2957 | Stainless Steel Rod in Ground |
| KIR105 | 3.8308 | Stainless Steel Rod in Ground |
| KIR3 | 3.5665 | Stainless Steel Rod in Ground |
| \*KIRI | 5.3576 | Pillar Plate (ARP) |
| KIRIBM | 4.4147 | Stainless Steel Pillar Pin |
| KIRIRM1 | 3.5391 | Stainless Steel Rod in Ground |
| KIRIRM2 | 3.5017 | Stainless Steel Rod in Ground |
| KIRIRM3 | 3.5169 | Stainless Steel Rod in Ground |

\*The RL of the Reference Point KIRI (ARP) is derived from adding the static height difference of 0.9429m (KIRIBM to KIRI) to the 2013 levelled RL of KIRIBM.

## Survey Support

Assistance from Boata Iabeta, Acting Chief Surveyor in Romano Reo’s absence, and his survey staff namely, Tiure Toorua and Tentao Takaaio; 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 2013 visit.

## Issues

No issues of any significance were encountered during the 2013 visit.

# Comparisons

## Comparisons between 2013 and 2012 EDM Surveys

Table 3. Results of Tarawa, Kiribati 2013 EDM Height Traversing Comparison 2013 – 2012. KIR1 - adopted fixed height of 3.5334m

| From | To | Levelled Ht. Diff. | RL 2013 | Misclose (mm) | Dist. (km) | 1mm√k | RL 2012 | Difference (mm) 2013 - 2012 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| KIR1 |  |  | 3.5334 |  |  |  | 3.5334 |  |
| KIR102 | KIR102 | 0.4762 | 4.0096 | -0.083 | 0.051 | 0.227 | 4.0097 | -0.12 |
| KIR100 | KIR100 | -0.1779 | 3.8317 | 0.086 | 0.051 | 0.225 | 3.8323 | -0.65 |
| KIR39 | KIR39 | 0.2463 | 4.0779 | 0.398 | 0.196 | 0.442 | 4.0789 | -0.99 |
| KIR101 | KIR101 | 0.0647 | 4.1426 | -0.395 | 0.204 | 0.452 | 4.1438 | -1.21 |
| KIR49 | KIR49 | -0.1202 | 4.0224 | -0.367 | 0.146 | 0.382 | 4.0234 | -1.04 |
| KIR12 | KIR12 | 0.1965 | 4.2188 | -0.383 | 0.179 | 0.423 | 4.2210 | -2.16 |
|  | KIR13 | 0.4127 | 4.6316 | -0.008 | 0.011 | 0.105 | 4.6336 | -2.05 |
| KIR102 |  |  | 4.0096 |  |  |  |  |  |
| KIR46 | KIR46 | -0.6294 | 3.3801 | 0.370 | 0.150 | 0.387 | 3.3802 | -0.07 |
| KIR106 | KIR106 | 0.4230 | 3.8032 | -0.363 | 0.142 | 0.377 | 3.8038 | -0.64 |
| KIR104 | KIR104 | -0.1236 | 3.6795 | 0.010 | 0.202 | 0.450 | 3.6805 | -0.97 |
|  | KIR2 | -0.4960 | 3.1836 | -0.140 | 0.101 | 0.318 | 3.1840 | -0.43 |
| KIR104 |  |  | 3.6795 |  |  |  |  |  |
| KIR44 | KIR44 | -0.0597 | 3.6198 | -0.392 | 0.188 | 0.433 | 3.6212 | -1.39 |
| KIR47 | KIR47 | -0.3241 | 3.2957 | 0.220 | 0.092 | 0.303 | 3.2968 | -1.06 |
| KIR105 | KIR105 | 0.5350 | 3.8308 | 0.117 | 0.166 | 0.407 | 3.8295 | 1.27 |
| KIR3 | KIR3 | -0.2642 | 3.5665 | 0.257 | 0.216 | 0.464 | 3.5666 | -0.07 |
|  | KIRIBM | 0.8481 | 4.4147 | -0.108 | 0.070 | 0.265 | 4.4145 | 0.16 |
|  |  |  | Misclose for all bays levelled = | -0.783 | 2.166 | 1.472 |  |  |
| KIRIBM |  |  | 4.4147 |  |  |  |  |  |
|  | RM1 | -0.8756 | 3.5391 | -0.092 | 0.043 | 0.208 | 3.5388 | 0.28 |
| KIRIBM |  |  | 4.4147 |  |  |  |  |  |
|  | RM2 | -0.9130 | 3.5017 | 0.067 | 0.050 | 0.223 | 3.5016 | 0.08 |
| KIRIBM |  |  | 4.4147 |  |  |  |  |  |
|  | RM3 | -0.8978 | 3.5169 | -0.058 | 0.031 | 0.177 | 3.5169 | 0.03 |

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

## Combined Comparisons

Examination of the level survey results do not show any significant changes in reduced levels from the 2012 survey. All indications are that no immediate or significant displacement of any of the deep driven bench marks has occurred.

Table 3. Tarawa, Kiribati – Deep Bench Mark final RL's for Precise Differential Levelling (1992 - 2005) and EDM Height Traversing (2005 - 2013).

| Year | KIR1 | KIR2 | KIR3 | KIR12 | KIR13 | KIR46 | KIR47 | KIR49 | KIRIBM |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1992.96 | 3.5334 | 3.1835 | 3.5657 | 4.2176 | 4.6302 |  |  |  |  |
| 1994.21 | 3.5334 | 3.1838 | 3.5655 | 4.2187 | 4.6319 |  |  |  |  |
| 1995.21 | 3.5334 | 3.1845 | 3.5654 | 4.2195 | 4.6331 |  |  |  |  |
| 1996.71 | 3.5334 | 3.1843 | 3.5654 | 4.2191 | 4.6321 |  |  |  |  |
| 1997.96 | 3.5334 | 3.1843 | 3.5657 | 4.2196 | 4.6325 |  |  |  |  |
| 1999.46 | 3.5334 | 3.1844 | 3.5644 | 4.2195 | 4.6324 |  |  |  |  |
| 2000.63 | 3.5334 | 3.1847 | 3.5658 | 4.2195 | 4.6321 |  |  |  |  |
| 2002.46 | 3.5334 | 3.1843 | 3.5648 | 4.2191 | 4.6321 | 3.3782 | 3.2948 | 4.0232 | 4.4124 |
| 2004.46 | 3.5334 | 3.1843 | 3.5653 | 4.2190 | 4.6324 | 3.3788 | 3.2952 | 4.0225 | 4.4130 |
| 2006.21 | 3.5334 | 3.1839 | 3.5662 | 4.2195 | 4.6328 | 3.3788 | 3.2956 | 4.0226 | 4.4139 |

| Year | KIR1 | KIR2 | KIR3 | KIR12 | KIR13 | KIR46 | KIR47 | KIR49 | KIRIBM |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2006.21 | 3.5334 | 3.1844 | 3.5646 | 4.2193 | 4.6326 | 3.3794 | 3.2953 | 4.0230 | 4.4124 |
| 2007.88 | 3.5334 | 3.1830 | 3.5641 | 4.2202 | 4.6308 | 3.3795 | 3.2941 | 4.0230 | 4.4119 |
| 2009.17 | 3.5334 | 3.1835 | 3.5646 | 4.2199 | 4.6320 | 3.3791 | 3.2951 | 4.0229 | 4.4125 |
| 2010.71 | 3.5334 | 3.1828 | 3.5655 | 4.2200 | 4.6322 | 3.3794 | 3.2954 | 4.0229 | 4.4134 |
| 2012.16 | 3.5334 | 3.1840 | 3.5666 | 4.2210 | 4.6336 | 3.3802 | 3.2968 | 4.0234 | 4.4145 |
| 2013.62 | 3.5334 | 3.1836 | 3.5665 | 4.2188 | 4.6316 | 3.3801 | 3.2957 | 4.0224 | 4.4147 |

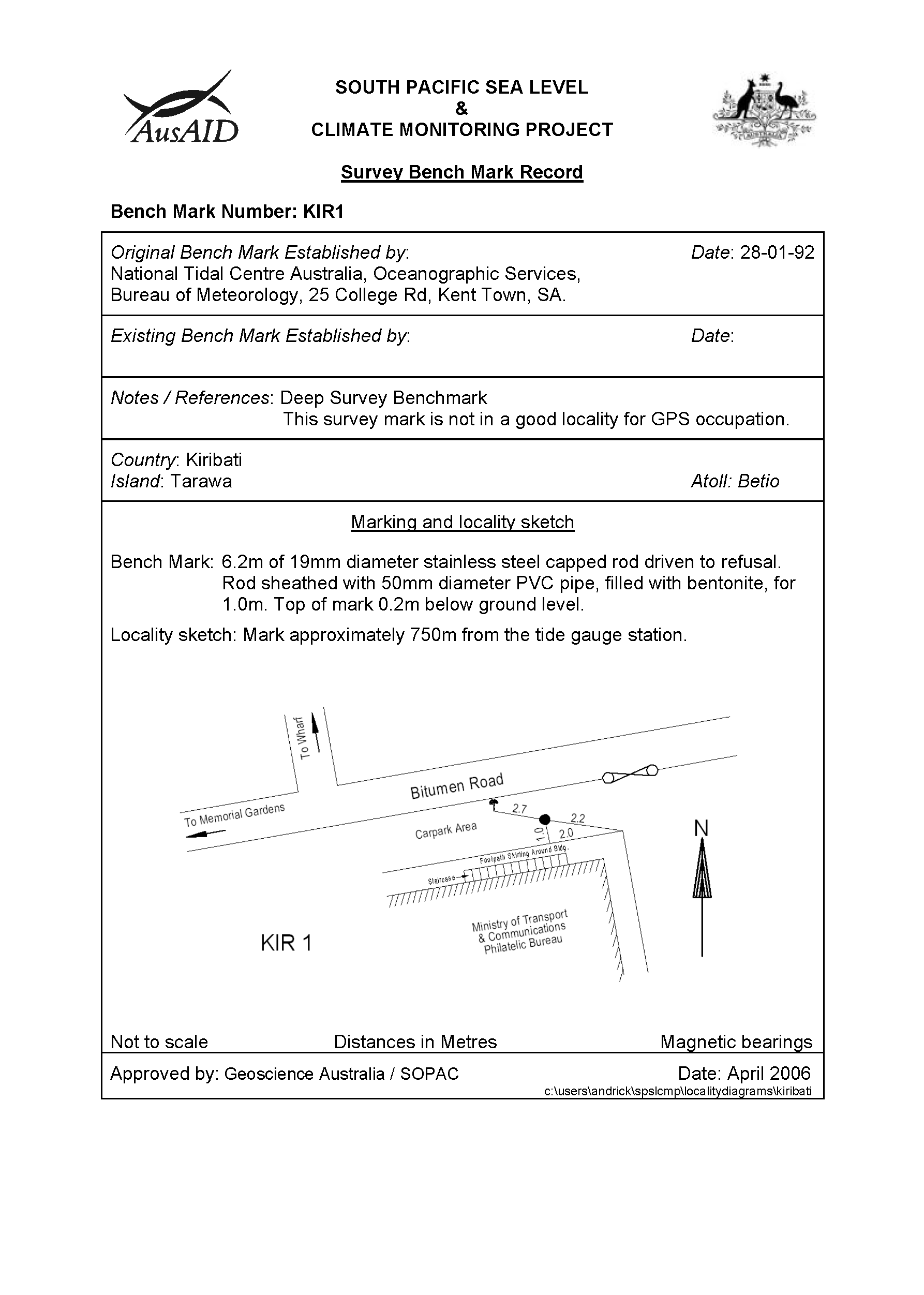
The 2013 RL of KIRI is 5.3576m

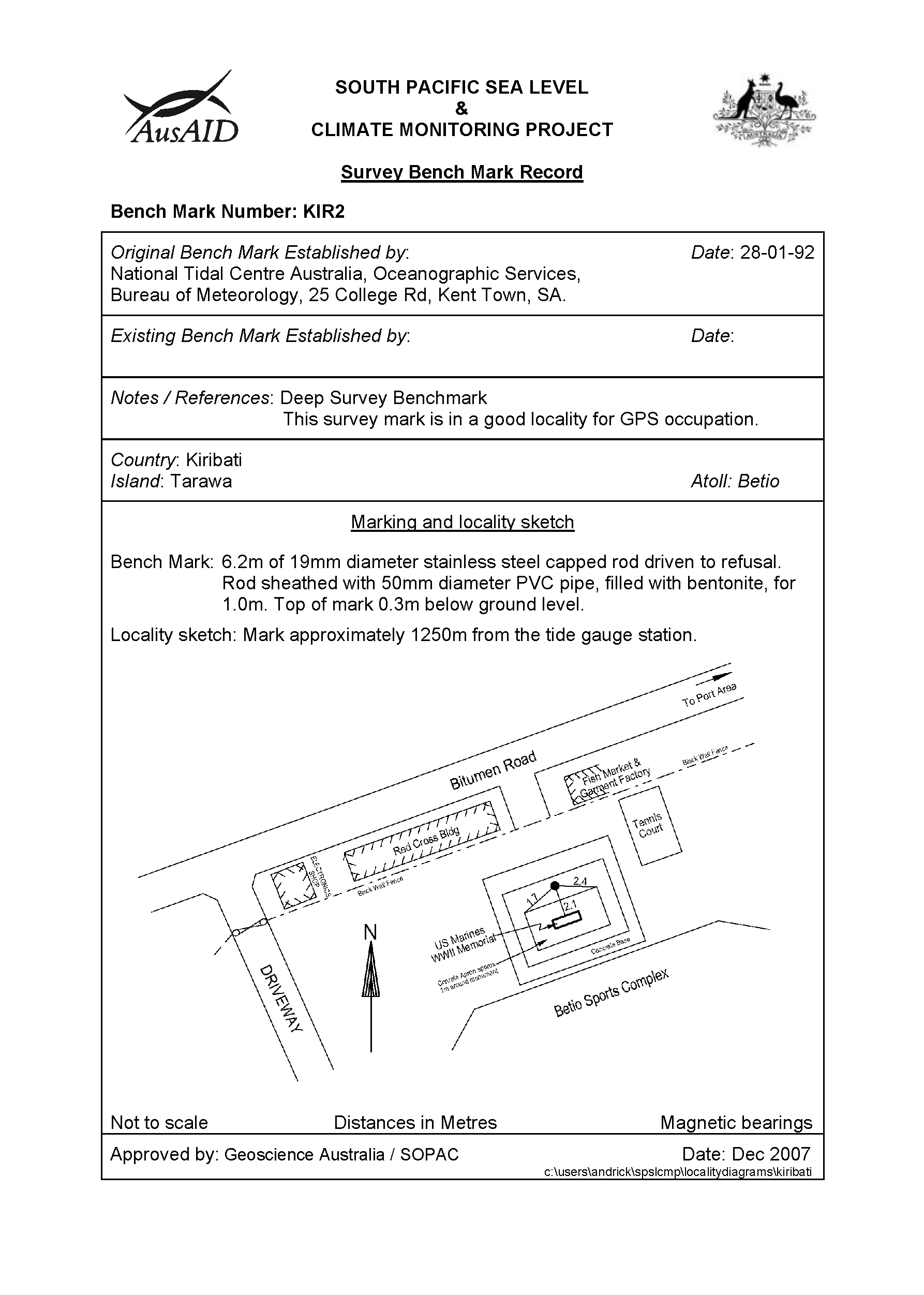
\*The RL of the Reference Point KIRI (ARP) is derived from adding the static height difference of 0.9429m (KIRIBM to KIRI) to the 2013 levelled RL of KIRIBM.

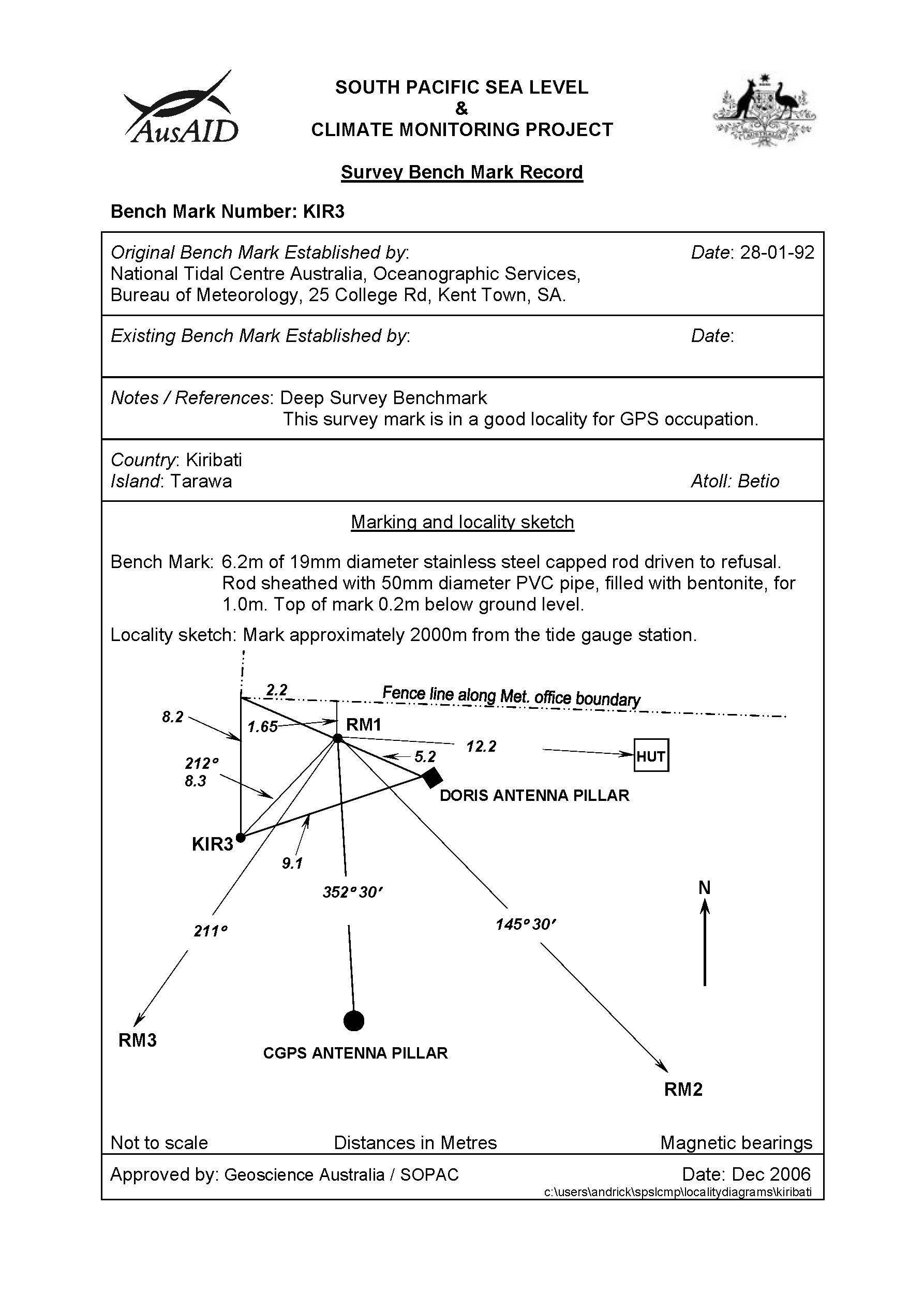
## Time Series of Bench Mark movement relative to Fixed Deep Bench Mark KIR1

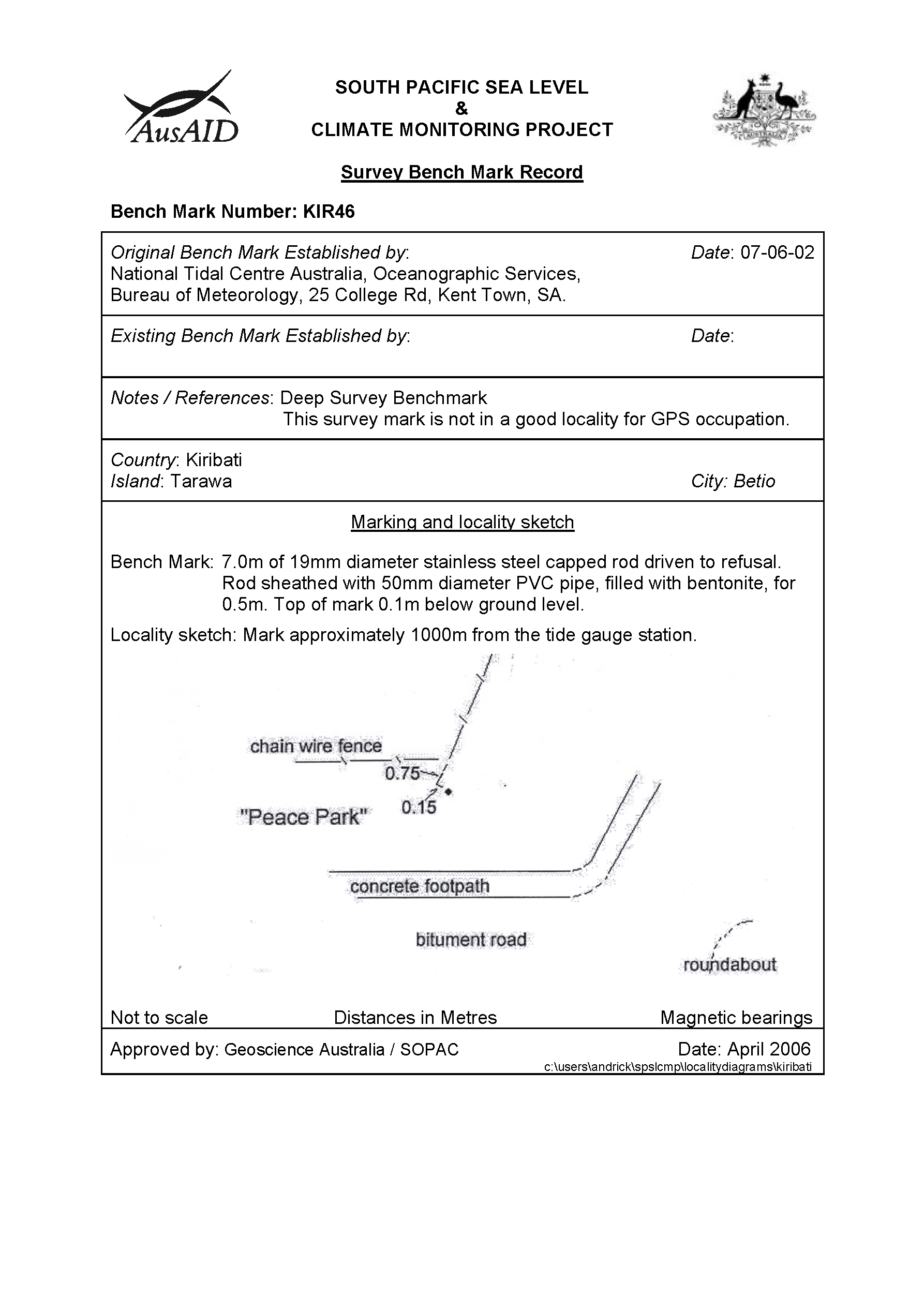
Precise Differential Levelling: 1992 - 2005   
EDM Height Traversing: 2005 onwards

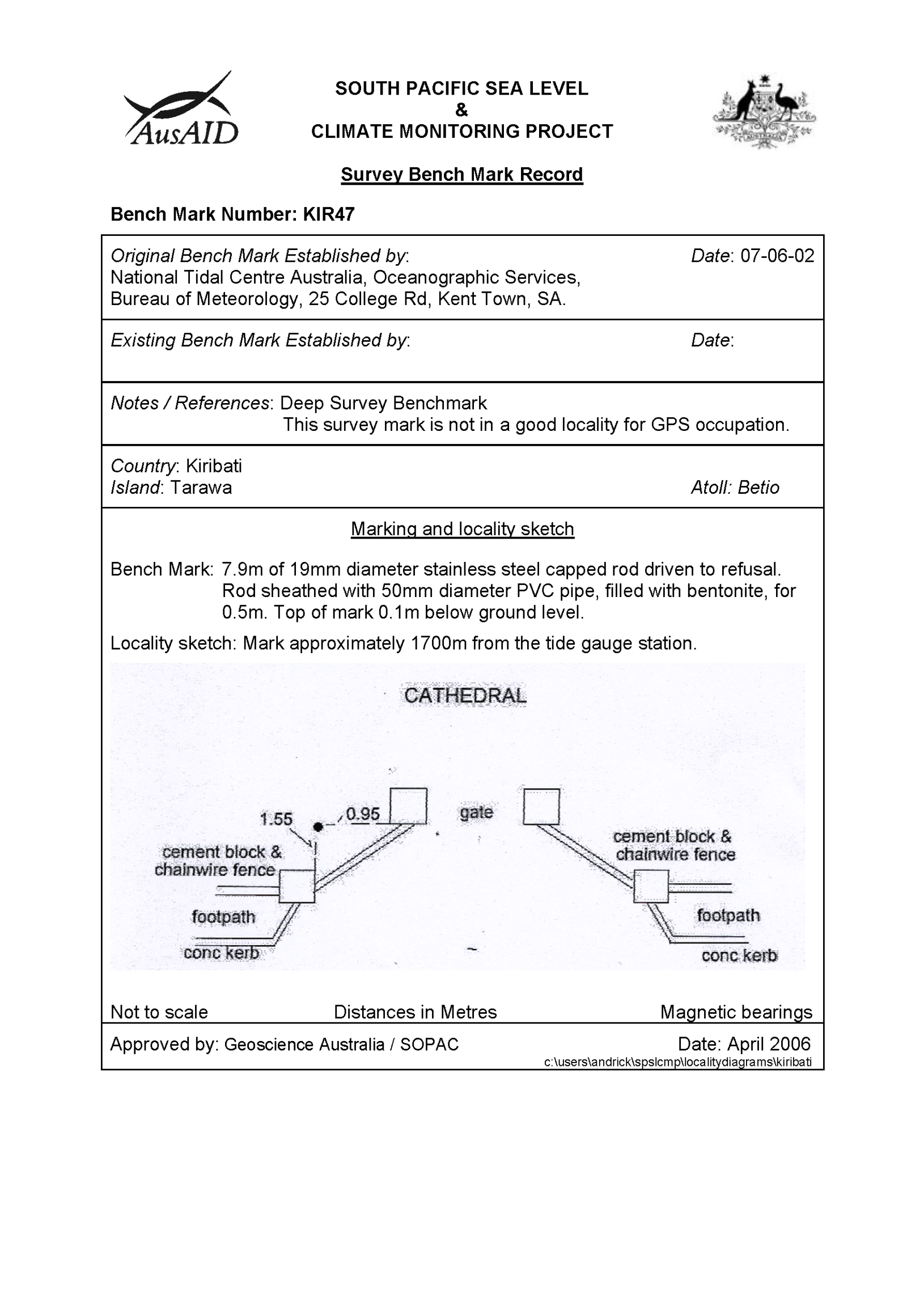
# Deep Bench Mark Locality Diagrams

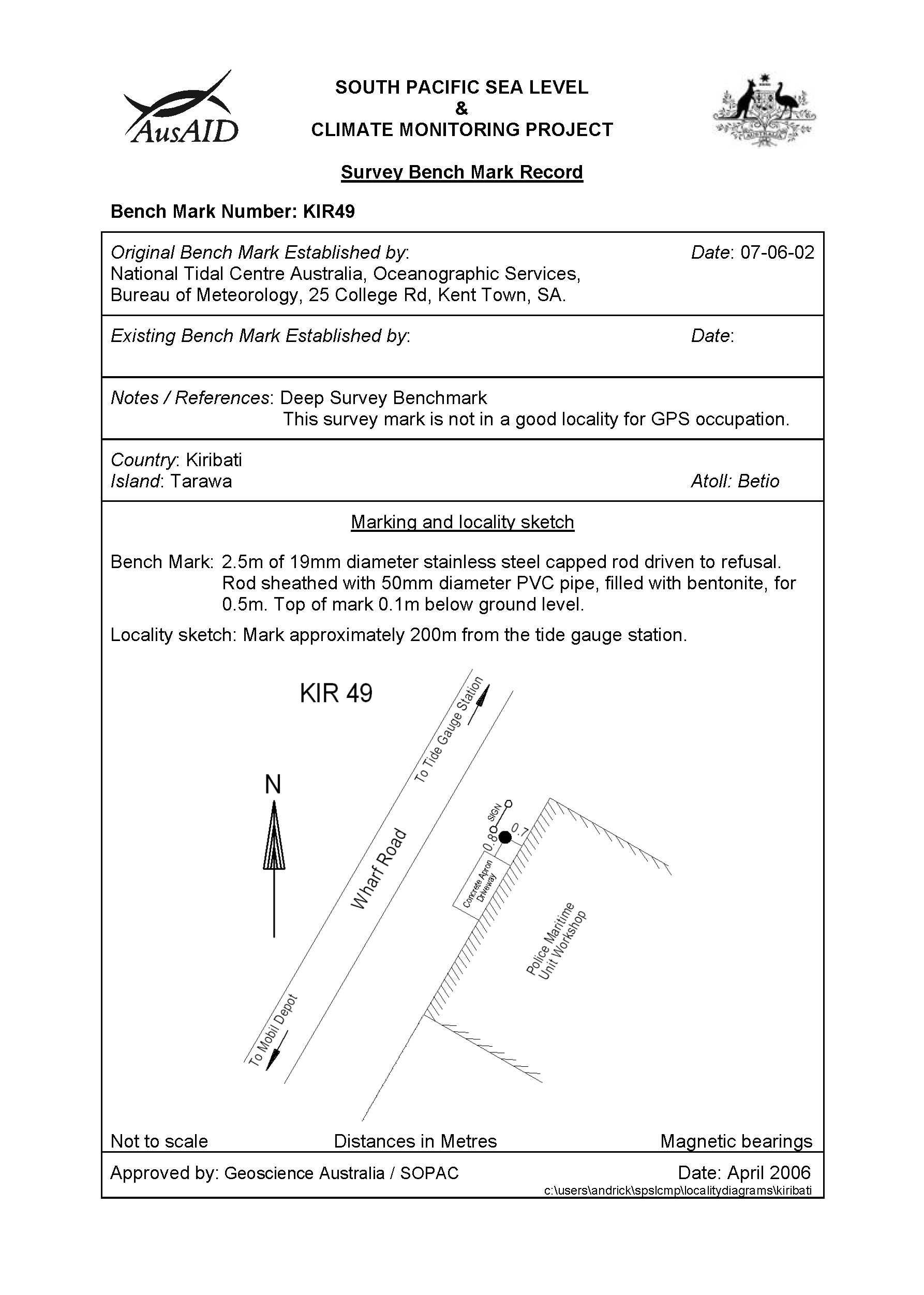






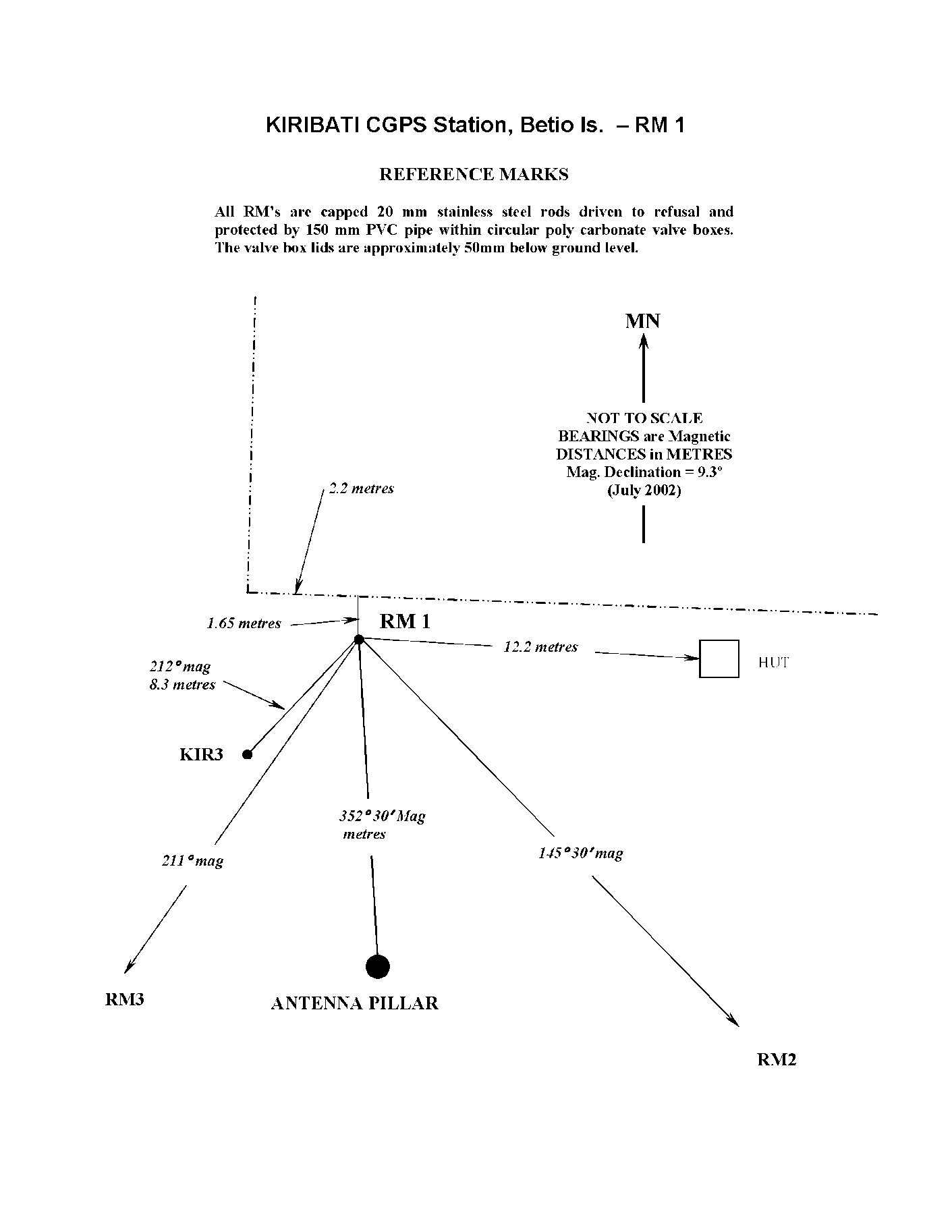


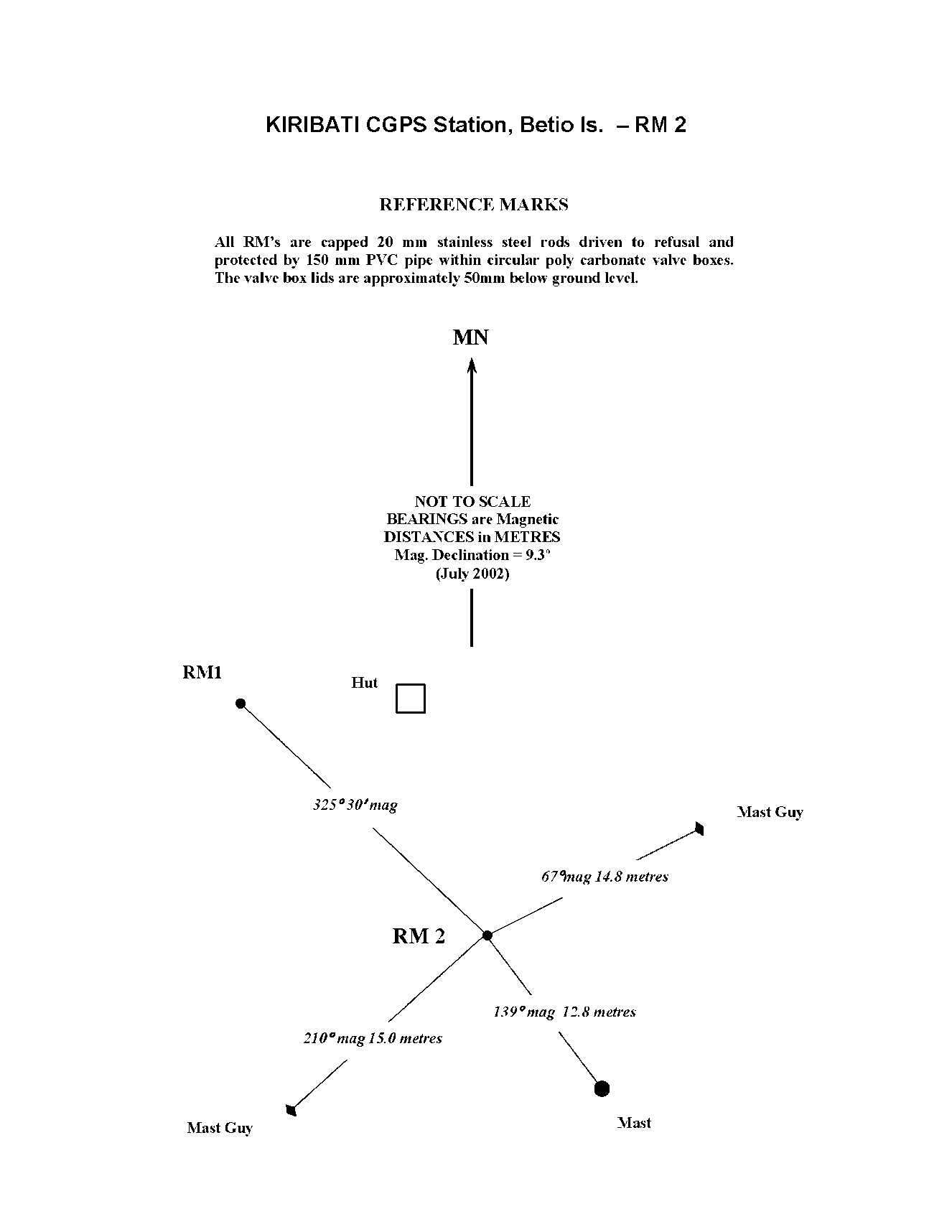


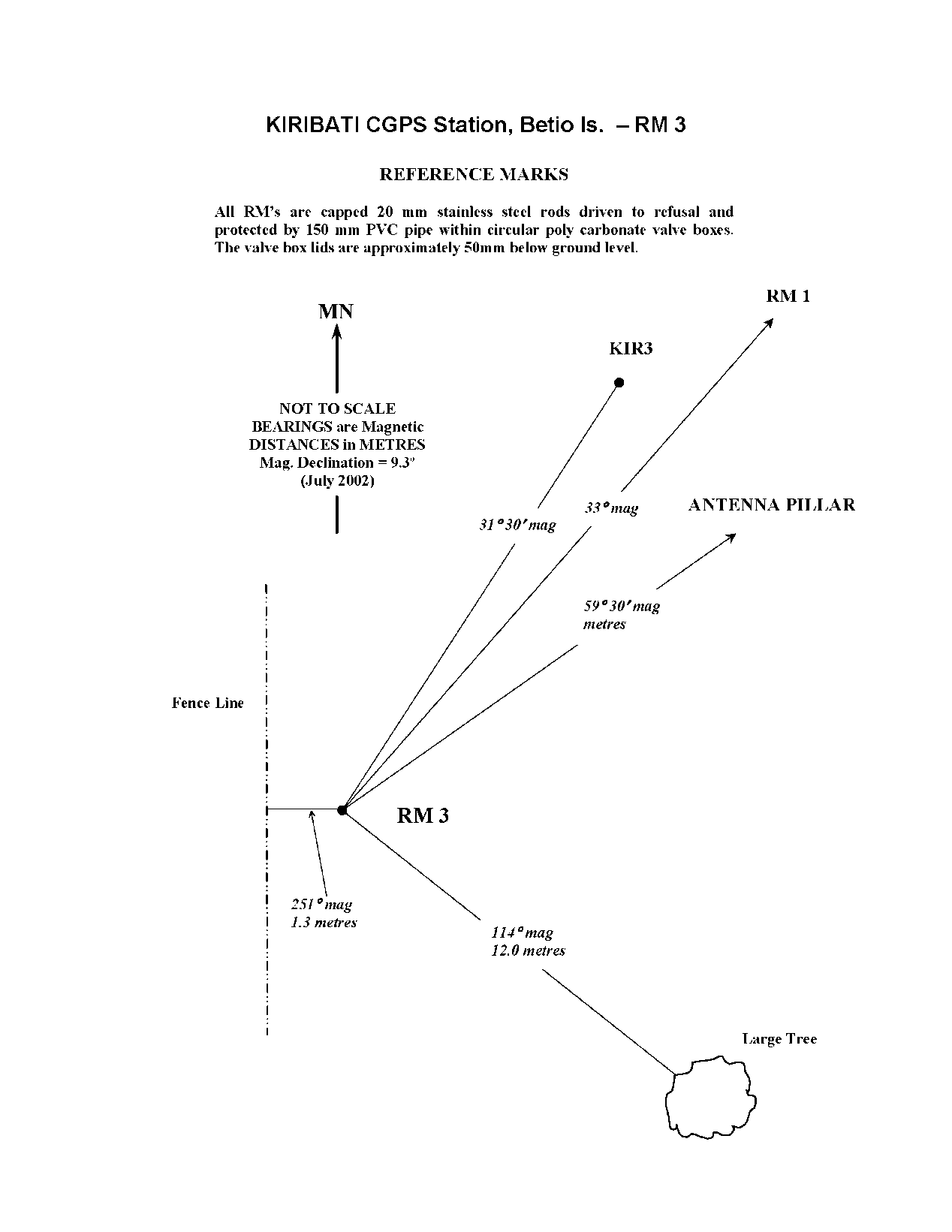


# Reference Mark Locality Diagram

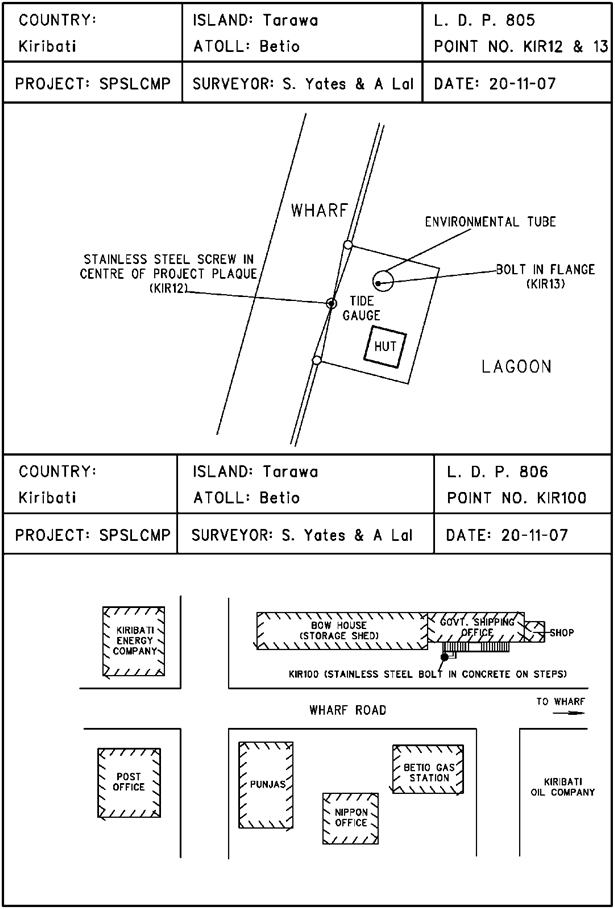


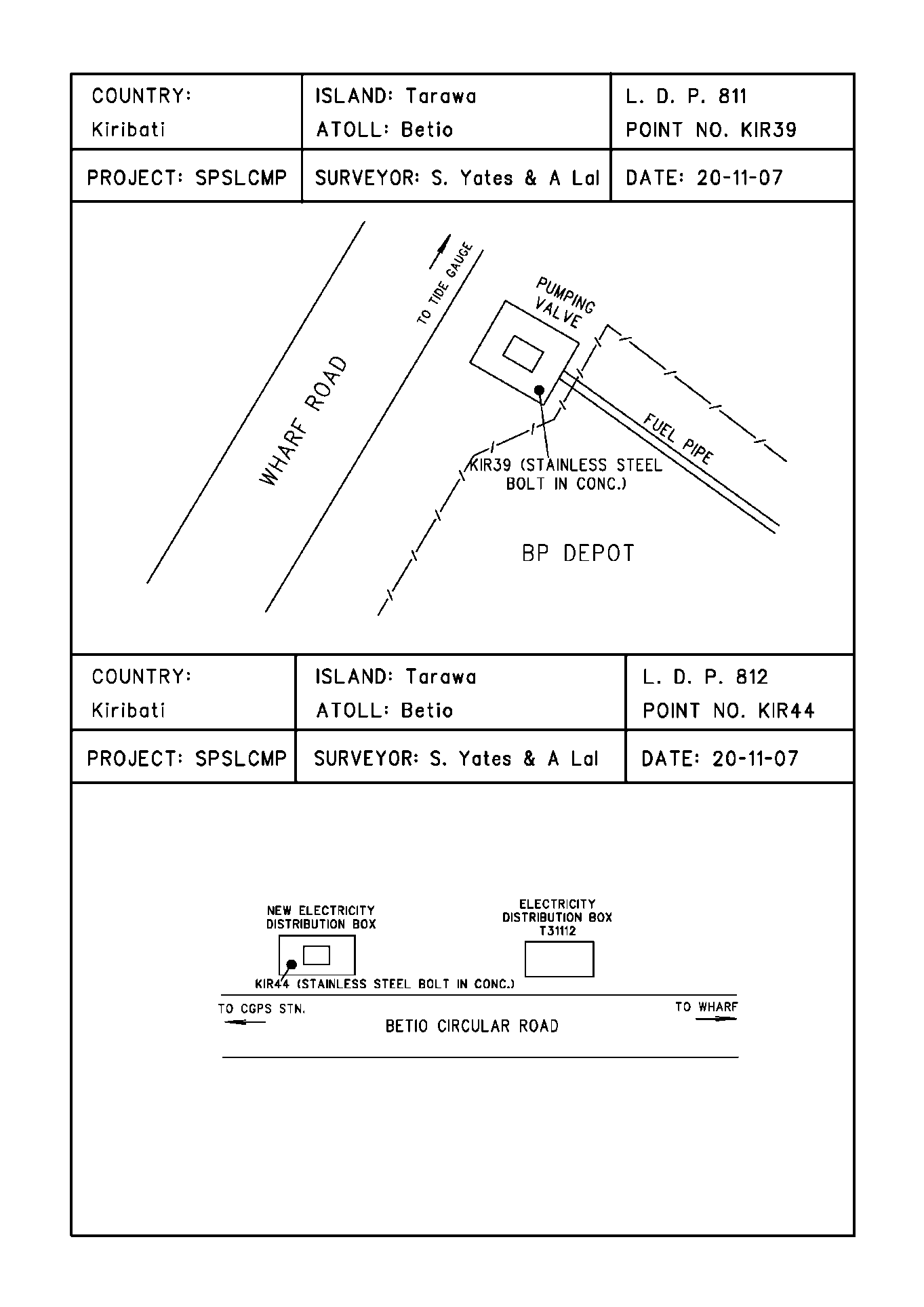


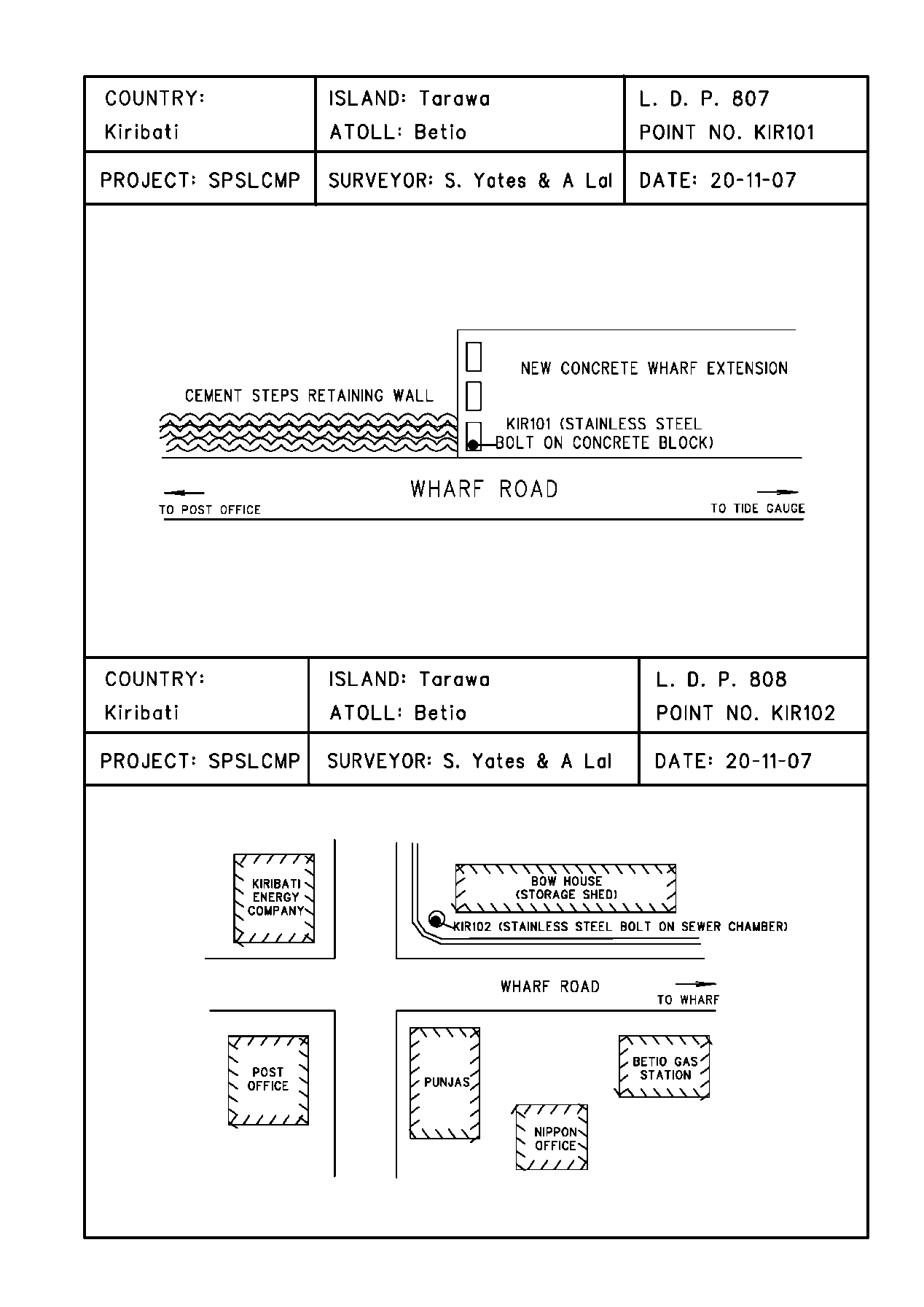


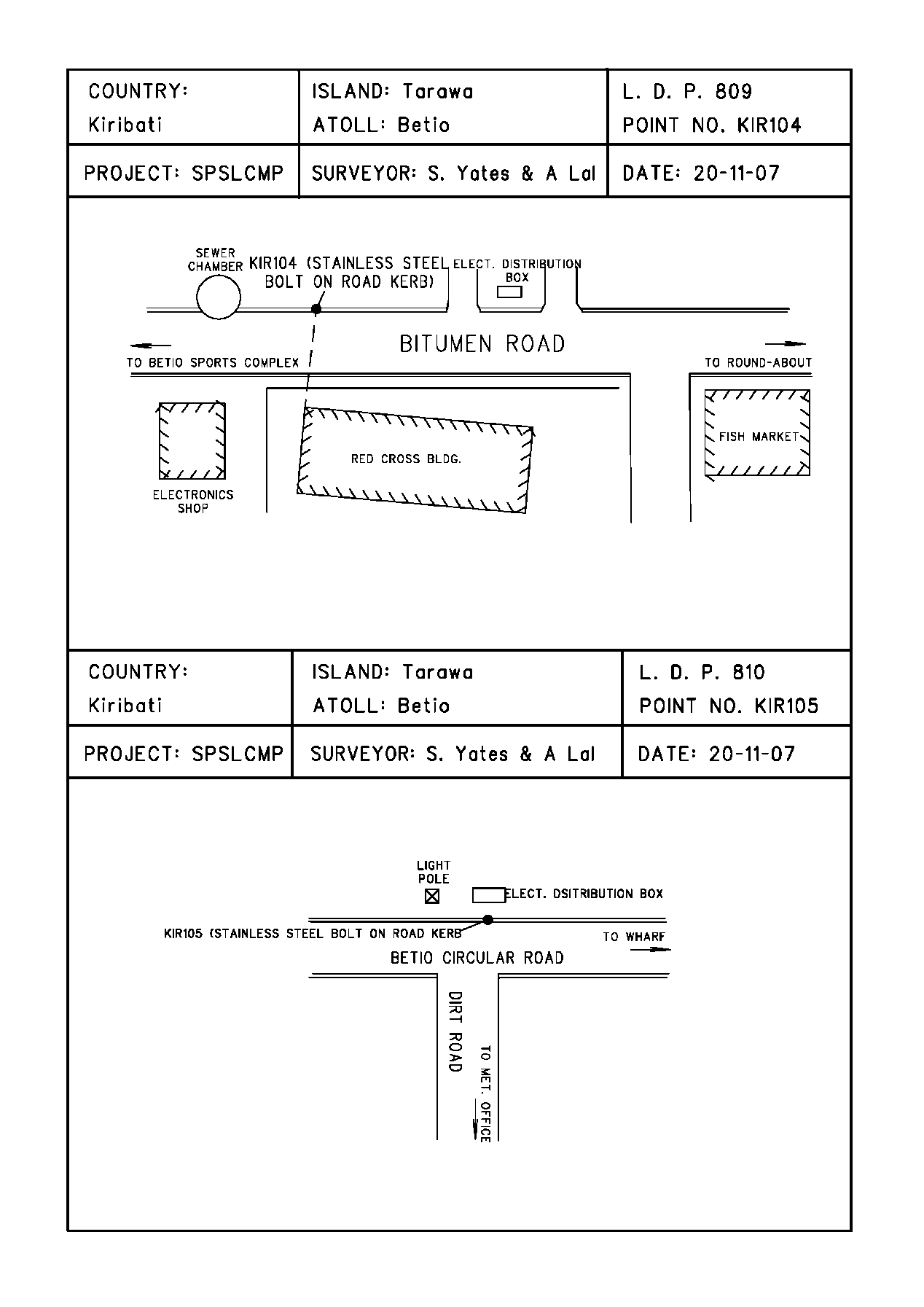


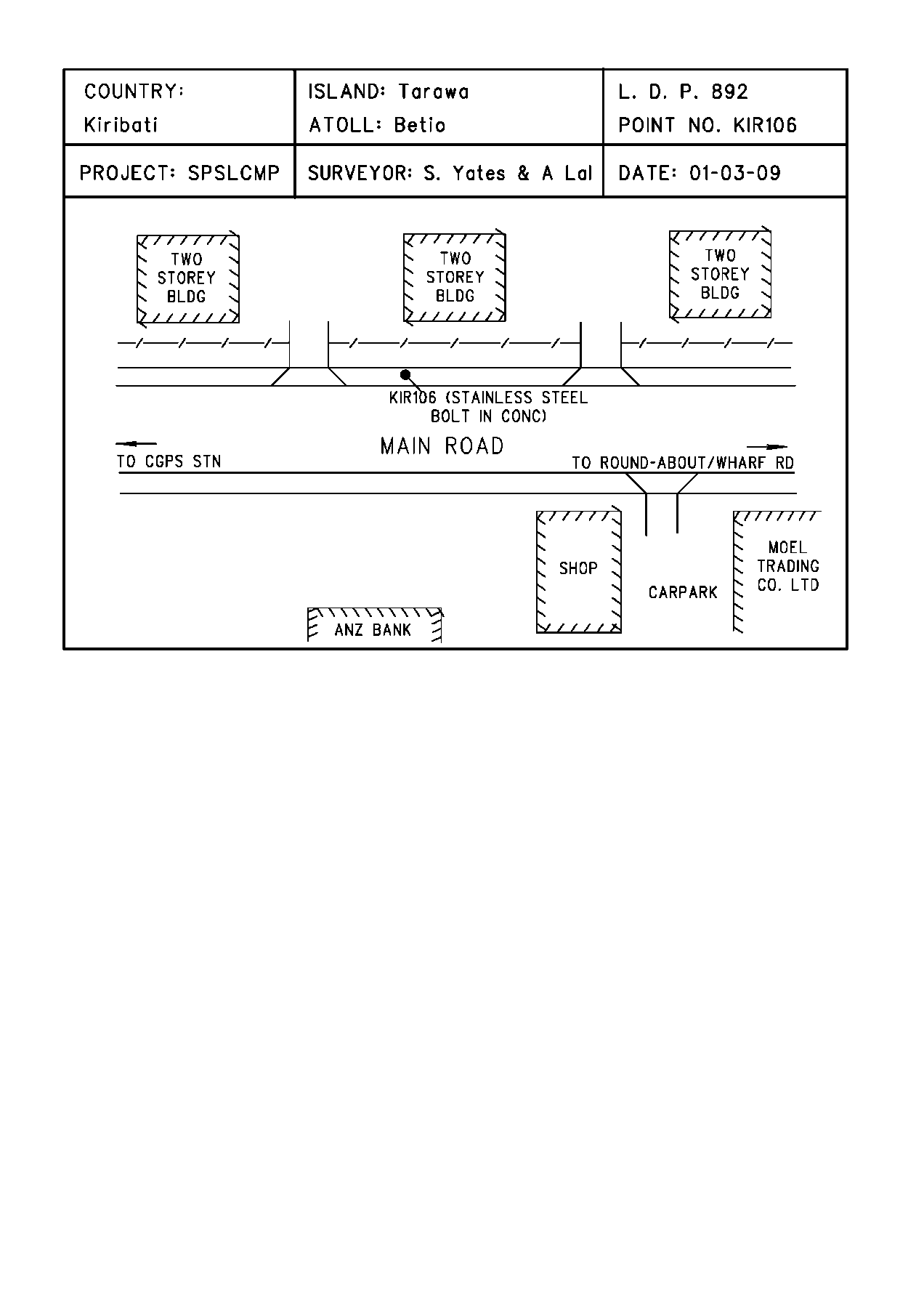
# Temporary Holding Mark Locality Diagrams











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