EDM Height Traversing Levelling Survey Report

Funafuti, Tuvalu, July 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 Funafuti, Tuvalu from 18th – 25th July 2013.

Personnel involved in the survey were Steve Yates, Project Officer, 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 Funafuti, which runs approximately 4km from the tide gauge sensor to the CGNSS Station. Previous levelling surveys have been conducted along the route using this technique in 2005, 2007, 2009, 2010 and 2012.

In addition, precise differential levelling surveys were performed along the deep bench mark array from 1993 to 2005 by the National Tidal Centre Australia (NTCA) and the survey in 2005 included a comparison between the precise differential levelling and EDM height traversing technique. 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.

# The Survey

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

BM22 – reference deep driven bench mark

BM23 – deep driven bench mark

BM24 – deep driven bench mark

BM26 – deep driven bench mark

BM27 – deep driven bench mark

BM28 – deep driven bench mark

TUV19 – SEAFRAME sensor bench mark

TUV20 – SEAFRAME Project plaque bench mark

TUVABM – reference bench mark for the GNSS pillar

Also included in the survey were temporary holding marks – TUV102, TUV42, TUV103, TUV44, TUV107, TUV104, TUV101, TUV105, TUV61, TUV48, TUV49, TUV74, TUV73, TUV106, TUV71 and TUV69.

The Continuous GNSS (CGNSS) Reference Point - TUVA and the two CGNSS Reference Marks - RM2 and RM3 were also levelled. Unfortunately RM1, CGNSS Reference Mark was removed from the ground due to excavation works otherwise 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 – Funafuti



## The Tuvalu Datum

The Datum for the survey is the University of Hawaii Tide Staff Zero (TSZ).

Reduction of the data has been calculated holding BM22 fixed at 3.22540 metres TSZ, this value was determined by the NTCA in 1993 by:

Adopting the height of UH 1 (RL = 3.0072 metres TSZ)

Adopting the height of BM22 as derived from the 1993 survey (RL = 3.22540 metres)

## 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 Funafuti 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.

## Tuvalu 2013 Reduced Levels

Table 2.1 Funafuti, Tuvalu – Reduced levels 2013 survey  
Date: 18 – 25 July 2013  
Datum: TSZ (1993)

| Point ID | Reduced Level 2013 | Type |
| --- | --- | --- |
| BM22 | 3.2254 | Stainless Steel Rod in Ground |
| TUV102 | 3.7604 | Stainless Steel Pin in Concrete |
| TUV42 | 3.7605 | Stainless Steel Pin in Concrete |
| TUV103 | 3.5773 | Stainless Steel Pin in Concrete |
| TUV19 | 3.4893 | Stainless Steel Pin in Concrete |
| TUV20 | 4.4585 | Stainless Steel Pin |
| TUV44 | 3.3249 | Stainless Steel Pin in Concrete |
| TUV107 | 2.7287 | Stainless Steel Pin in Concrete |
| BM23 | 3.1372 | Stainless Steel Rod in Ground |
| TUV104 | 2.9832 | Stainless Steel Pin in Concrete |
| TUV101 | 3.0905 | Stainless Steel Pin in Concrete |
| TUV105 | 2.8240 | Stainless Steel Pin in Concrete |
| TUV61 | 2.8766 | Stainless Steel Rod in Ground |
| TUV48 | 3.0606 | Stainless Steel Pin in Concrete |
| TUV49 | 3.2472 | Stainless Steel Pin in Concrete |
| TUV74 | 2.5841 | Stainless Steel Pin in Concrete |
| BM24 | 3.7955 | Stainless Steel Rod in Ground |
| TUV73 | 2.2977 | Stainless Steel Pin in Concrete |
| TUV106 | 2.2070 | Stainless Steel Pin in Concrete |
| TUV71 | 2.2400 | Stainless Steel Pin in Concrete |
| BM28 | 2.2160 | Stainless Steel Rod in Ground |
| TUV69 | 2.2144 | Stainless Steel Pin in Concrete |
| BM27 | 2.2154 | Stainless Steel Rod in Ground |
| TUVABM | 2.7413 | Stainless Steel Pillar Pin |
| \*TUVA | 3.7045 | Pillar Plate (ARP) |
| P-S | 2.4176 | Top of Tuvalu Met. Office Pressure Sensor |
| BM26 | 3.1072 | Stainless Steel Rod in Ground |
| TUVARM2 | 2.1584 | Stainless Steel Rod in Ground |
| TUVARM3 | 1.9312 | Stainless Steel Rod in Ground |

\*The RL of the Reference Point TUVA (ARP) is derived from adding the static height difference of 0.9631m (TUVABM to TUVA) to the 2013 levelled RL of TUVABM.

## Survey Support

Due to a recent change in field procedures, field survey technician, Samisoni Finikaso, was hired to carry the Leica total station in the carry case during the survey. This was arranged through the kind assistance of Mr Fa’atasi Malologa, Director – Lands and Survey.

The Director of Tuvalu Meteorological Service, Ms Hilia Va’ave and her staff provided valuable support during our visit.

## Issues

Please note that due to fewer flights and unreliable air freight services for cargo to Funafuti, it is advisable to pre-book two (2) cargo seats for the survey equipment to and from Funafuti as DHL cannot guarantee the air freight to arrive.

RM1 was found to be destroyed therefore in the next survey visit; it has to be replaced with a new Reference Mark 4.

## Description of Marks – Funafuti, Tuvalu

BM22 – reference deep driven bench mark (within Catholic Church Compound)

BM23 – deep driven bench mark (along the road on lagoon side)

BM24 – deep driven bench mark (on the north end of airport runaway)

BM26 – deep driven bench mark (on south corner of Vaiaku Lagi Hotel)

BM27 – deep driven bench mark (within airport compound)

BM28 – deep driven bench mark (in front of Mosque)

TUV19 – SEAFRAME sensor bench mark (on the old wharf)

TUV20 – SEAFRAME Project plaque bench mark (on the old wharf)

TUVABM – reference bench mark for the CGNSS pillar (within meteorology compound)

TUVA RM2 – CGNSS Pillar reference bench mark (within meteorology compound)

TUVA RM3 – CGNSS Pillar reference bench mark (within meteorology compound)

TUVA – CGNSS Pillar bench mark (within meteorology compound)

Holding pins along survey route from tide gauge to CGNSS (as listed previously) are all stainless steel bolts, drilled in concrete and glued in place.

# Comparisons

## Comparisons between 2013 and 2012 EDM Surveys

Table 3.1 Results of Funafuti, Tuvalu 2013 EDM Height Traversing Comparison 2013 – 2012. BM22 - adopted fixed height of 3.22540m

| From | To | Levelled  Ht. Diff. | RL 2013 | Misclose  (mm) | Dist. (km) | 1mm√k | RL 2012 | Difference (mm)  2013 - 2012 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| BM22 |  |  | 3.2254 |  |  |  |  |  |
| TUV102 | TUV102 | 0.5350 | 3.7604 | 0.389 | 0.207 | 0.455 | 3.7613 | -0.93 |
| TUV42 | TUV42 | 0.0001 | 3.7605 | -0.301 | 0.119 | 0.344 | 3.7612 | -0.69 |
| TUV103 | TUV103 | -0.1832 | 3.5773 | -0.231 | 0.157 | 0.397 | 3.5768 | 0.55 |
| TUV19 | TUV19 | -0.0881 | 3.4893 | -0.176 | 0.082 | 0.286 | 3.4881 | 1.18 |
|  | TUV20 | 0.9693 | 4.4585 | 0.051 | 0.013 | 0.114 | 4.4576 | 0.94 |
| BM22 |  |  | 3.2254 |  |  |  |  |  |
| TUV44 | TUV44 | 0.0995 | 3.3249 | -0.342 | 0.190 | 0.436 | 3.3255 | -0.62 |
| TUV107 | TUV107 | -0.5961 | 2.7287 | -0.150 | 0.119 | 0.345 | New Mark | New Mark |
| BM23 | BM23 | 0.4085 | 3.1372 | 0.103 | 0.181 | 0.426 | 3.1381 | -0.89 |
| TUV104 | TUV104 | -0.1540 | 2.9832 | 0.403 | 0.177 | 0.420 | 2.9844 | -1.20 |
| TUV101 | TUV101 | 0.1073 | 3.0905 | -0.345 | 0.199 | 0.446 | 3.0911 | -0.62 |
| TUV105 | TUV105 | -0.2664 | 2.8240 | -0.430 | 0.215 | 0.463 | 2.8241 | -0.07 |
| TUV61 | TUV61 | 0.0525 | 2.8766 | -0.006 | 0.111 | 0.333 | 2.8767 | -0.13 |
| TUV48 | TUV48 | 0.1841 | 3.0606 | -0.011 | 0.119 | 0.344 | 3.0603 | 0.35 |
| TUV49 | TUV49 | 0.1866 | 3.2472 | 0.065 | 0.161 | 0.401 | 3.2470 | 0.23 |
| TUV74 | TUV74 | -0.6631 | 2.5841 | 0.164 | 0.085 | 0.291 | 2.5838 | 0.35 |
|  | BM24 | 1.2113 | 3.7955 | 0.097 | 0.108 | 0.329 | 3.7955 | -0.01 |
| TUV74 |  |  | 2.5841 |  |  |  |  |  |
| TUV73 | TUV73 | -0.2865 | 2.2977 | 0.308 | 0.201 | 0.449 | 2.2980 | -0.33 |
| TUV106 | TUV106 | -0.0907 | 2.2070 | 0.353 | 0.199 | 0.446 | 2.2074 | -0.39 |
| TUV71 | TUV71 | 0.0330 | 2.2400 | -0.055 | 0.099 | 0.315 | 2.2414 | -1.35 |
| BM28 | BM28 | -0.0240 | 2.2160 | 0.074 | 0.106 | 0.326 | 2.2161 | -0.08 |
| TUV69 | TUV69 | -0.0016 | 2.2144 | 0.046 | 0.205 | 0.453 | 2.2154 | -0.96 |
| BM27 | BM27 | 0.0009 | 2.2154 | 0.136 | 0.152 | 0.389 | 2.2161 | -0.72 |
| TUVABM | TUVABM | 0.5260 | 2.7413 | -0.045 | 0.144 | 0.379 | 2.7418 | -0.46 |
|  | P-S | -0.3237 | 2.4176 | 0.177 | 0.035 | 0.186 | New Mark | New Mark |
| BM27 |  |  | 2.21538 |  |  |  |  |  |
|  | BM26 | 0.89183 | 3.10722 | -0.124 | 0.121 | 0.347 | 3.1077 | -0.48 |
|  |  |  | Misclose for all bays levelled = | 0.149 | 3.504 | 1.872 |  |  |

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

| From | To | Levelled  Ht. Diff. | RL 2013 | Misclose  (mm) | Dist. (km) | 1mm√k | RL 2012 | Difference (mm)  2013 - 2012 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TUVABM |  |  | 2.74134 |  |  |  |  |  |
|  | RM2 | -0.58289 | 2.15845 | -0.039 | 0.047 | 0.217 | 2.159 | -0.55 |
| TUVABM |  |  | 2.74134 |  |  |  |  |  |
|  | RM3 | -0.81016 | 1.93117 | -0.001 | 0.057 | 0.239 | 1.932 | -0.83 |

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 2013 survey. All indications show that no immediate or significant displacement of any of the deep driven bench marks has occurred.

Table 3.2 Funafuti, Tuvalu – Deep Bench Mark final RL's for Precise Differential Levelling (1993 - 2005) and EDM Height Traversing (2005 - 2013).

| Year | BM22 | BM23 | BM24 | BM26 | BM27 | BM28 | TUVABM | TUV19 | TUV20 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1993.21 | 3.2254 | 3.1385 | 3.7982 |  |  |  |  | 3.4813 | 4.4599 |
| 1994.46 | 3.2254 | 3.1394 | 3.7968 |  |  |  |  | 3.4826 | 4.4603 |
| 1995.46 | 3.2254 | 3.1392 | 3.7972 |  |  |  |  | 3.4833 | 4.4609 |
| 1997.96 | 3.2254 | 3.1387 | 3.7958 |  |  |  |  | 3.4834 | 4.4608 |
| 1998.54 | 3.2254 | 3.1383 | 3.7953 |  |  |  |  | 3.4848 | 4.4615 |
| 2000.13 | 3.2254 | 3.1386 | 3.7951 |  |  |  |  | 3.4842 | 4.4600 |
| 2001.63 | 3.2254 | 3.1390 | 3.7952 |  |  |  |  | 3.4848 | 4.4599 |
| 2003.38 | 3.2254 | 3.1391 | 3.7960 | 3.1099 | 2.2165 |  | 2.7414 | 3.4851 | 4.4593 |
| 2005.63 | 3.2254 | 3.1386 | 3.7959 | 3.1102 | 2.2176 |  | 2.7425 | 3.4864 | 4.4592 |

| Year | BM22 | BM23 | BM24 | BM26 | BM27 | BM28 | TUVABM | TUV19 | TUV20 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2005.63 | 3.2254 | 3.1393 | 3.7964 | 3.1099 | 2.2177 |  | 2.7432 | 3.4867 | 4.4593 |
| 2007.21 | 3.2254 | 3.1393 | 3.7962 | 3.1079 | 2.2157 |  | 2.7407 | 3.4879 | 4.4596 |
| 2009.06 | 3.2254 | 3.1397 | 3.7966 | 3.1082 | 2.2162 | 2.2171 | 2.7418 | 3.4877 | 4.4588 |
| 2010.08 | 3.2254 | 3.1394 | 3.7976 | 3.1108 | 2.2184 | 2.2188 | 2.7442 | 3.4889 | 4.4592 |
| 2012.41 | 3.2254 | 3.1381 | 3.7955 | 3.1077 | 2.2161 | 2.2161 | 2.7418 | 3.4881 | 4.4576 |
| 2013.55 | 3.2254 | 3.1372 | 3.7955 | 3.1072 | 2.2154 | 2.2160 | 2.7413 | 3.4893 | 4.4585 |

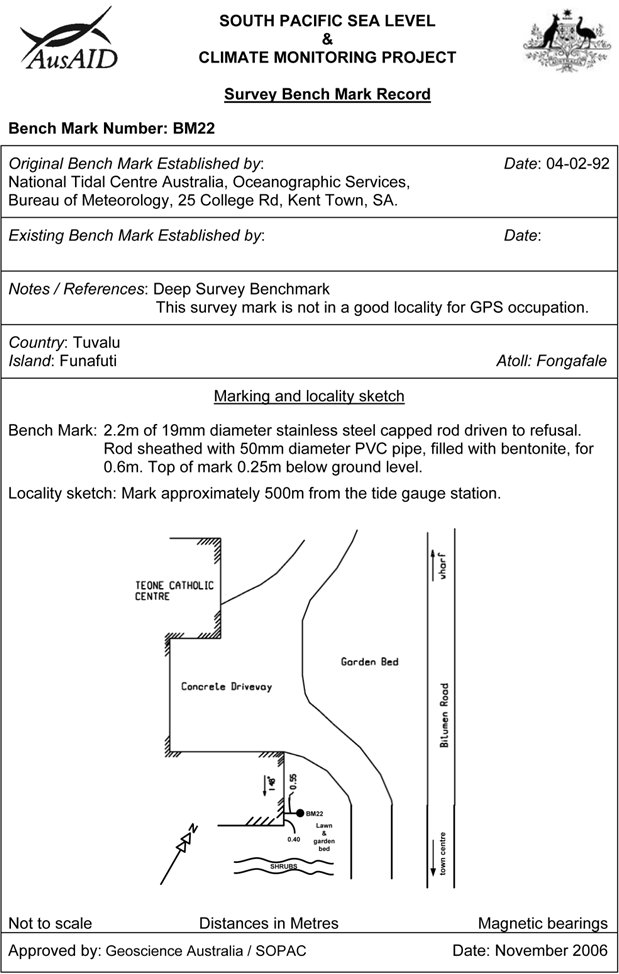
The 2013 RL of TUVA is 3.7045

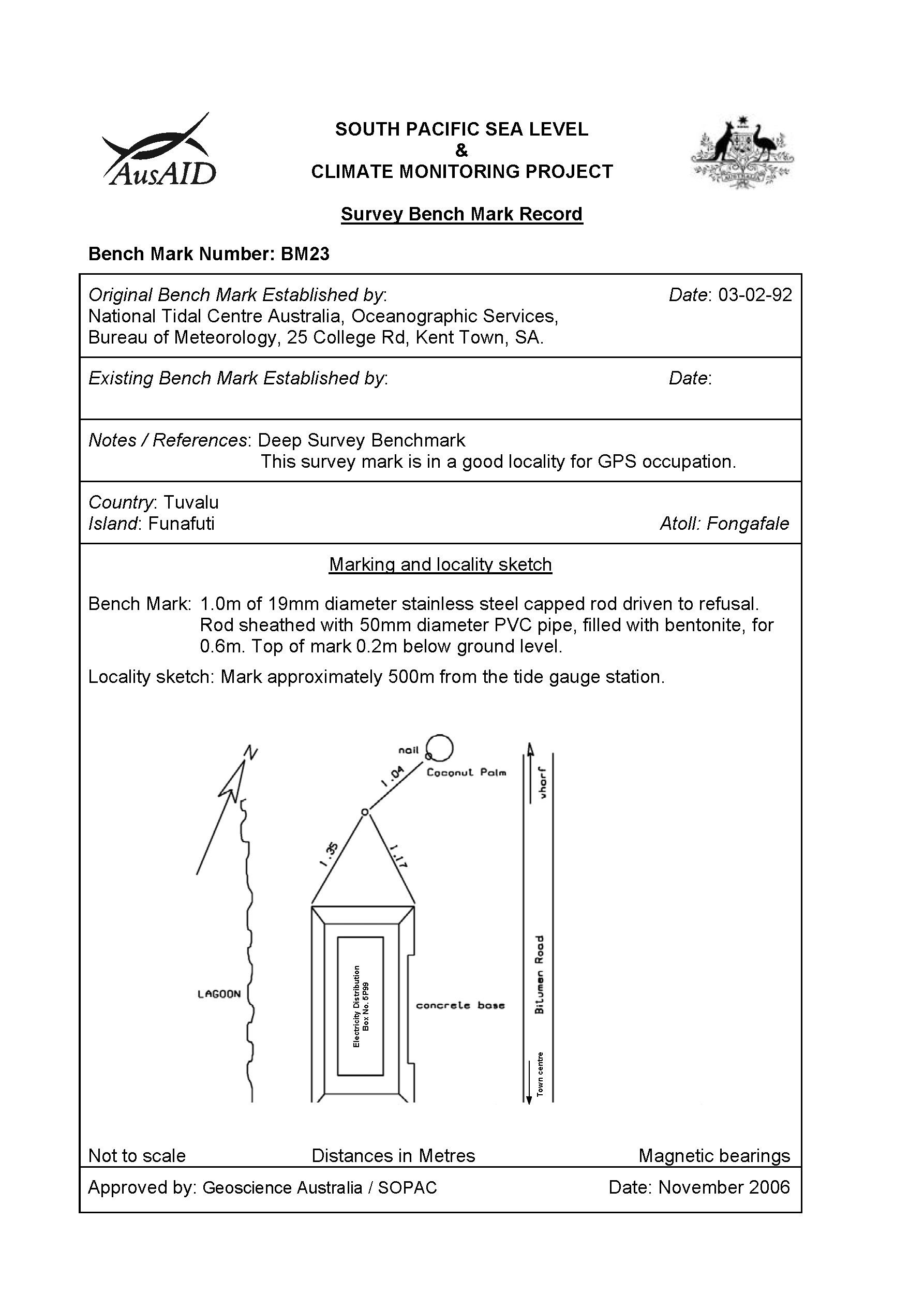
\*The RL of the Reference Point TUVA (ARP) is derived from adding the static height difference of 0.9631m (TUVABM to TUVA) to the 2013 levelled RL of TUVABM.

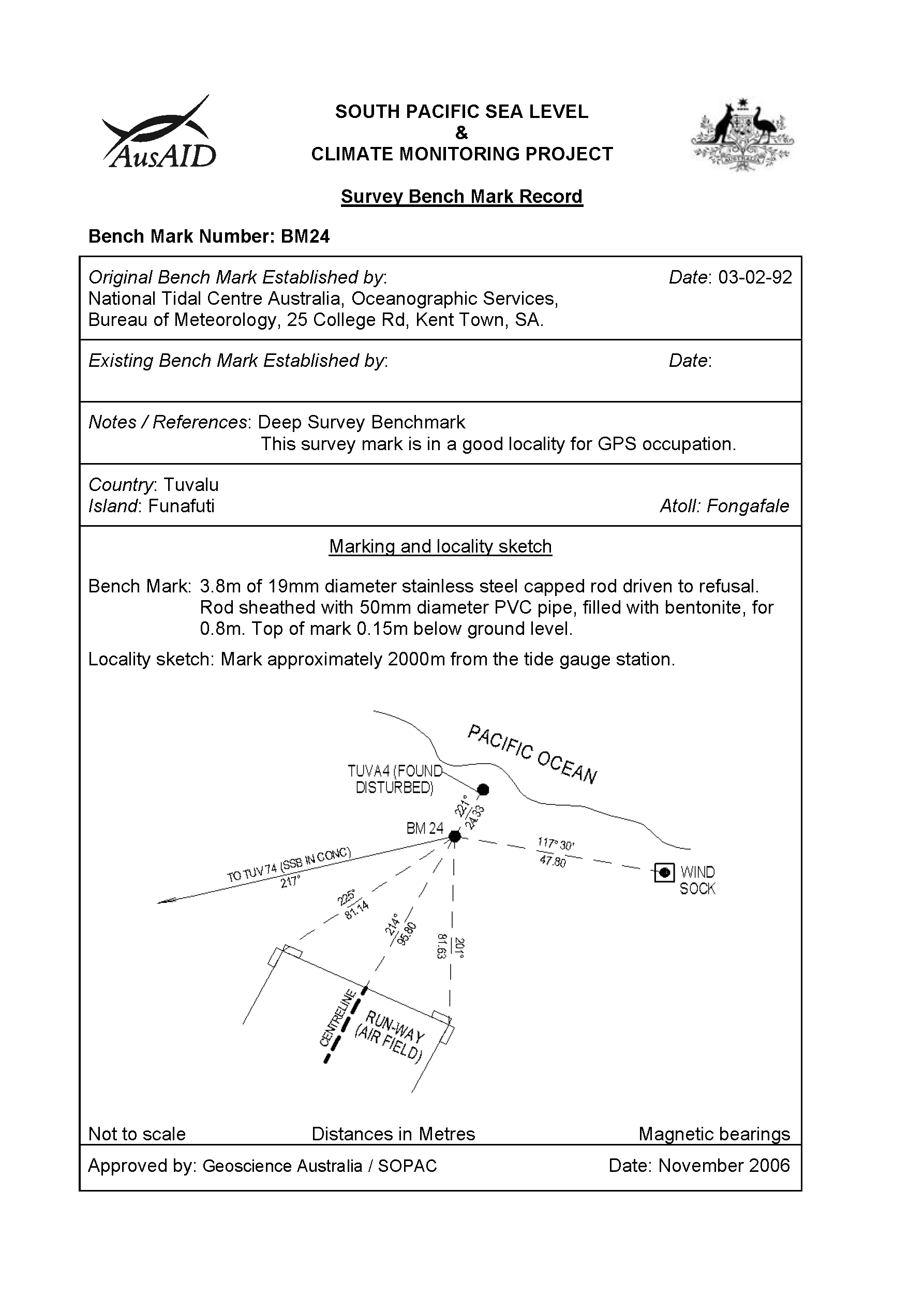
## Time Series of Bench Mark movement relative to Fixed Deep Bench Mark BM22

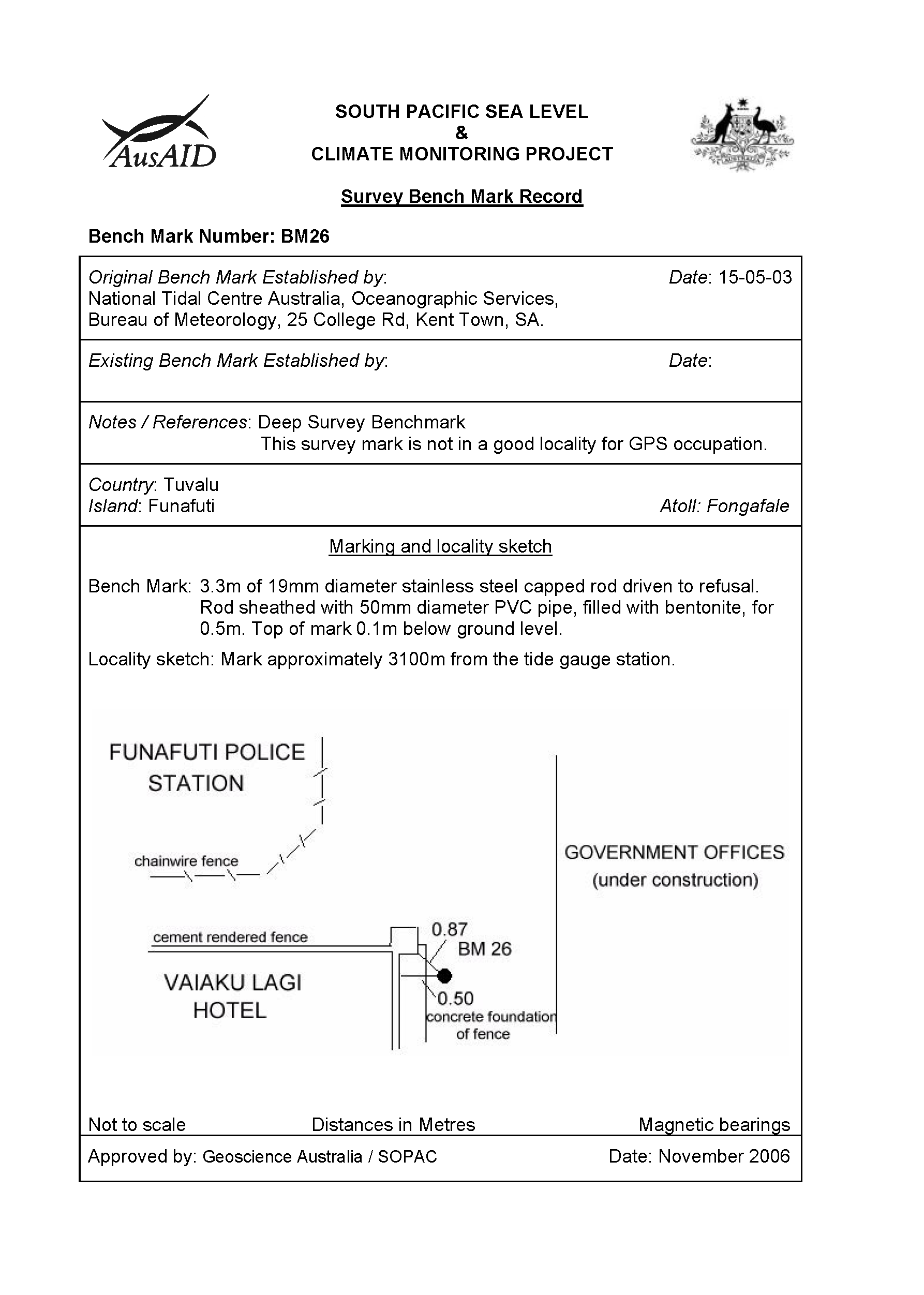
Precise Differential Levelling: 1993 - 2005   
EDM Height Traversing: 2005 onwards

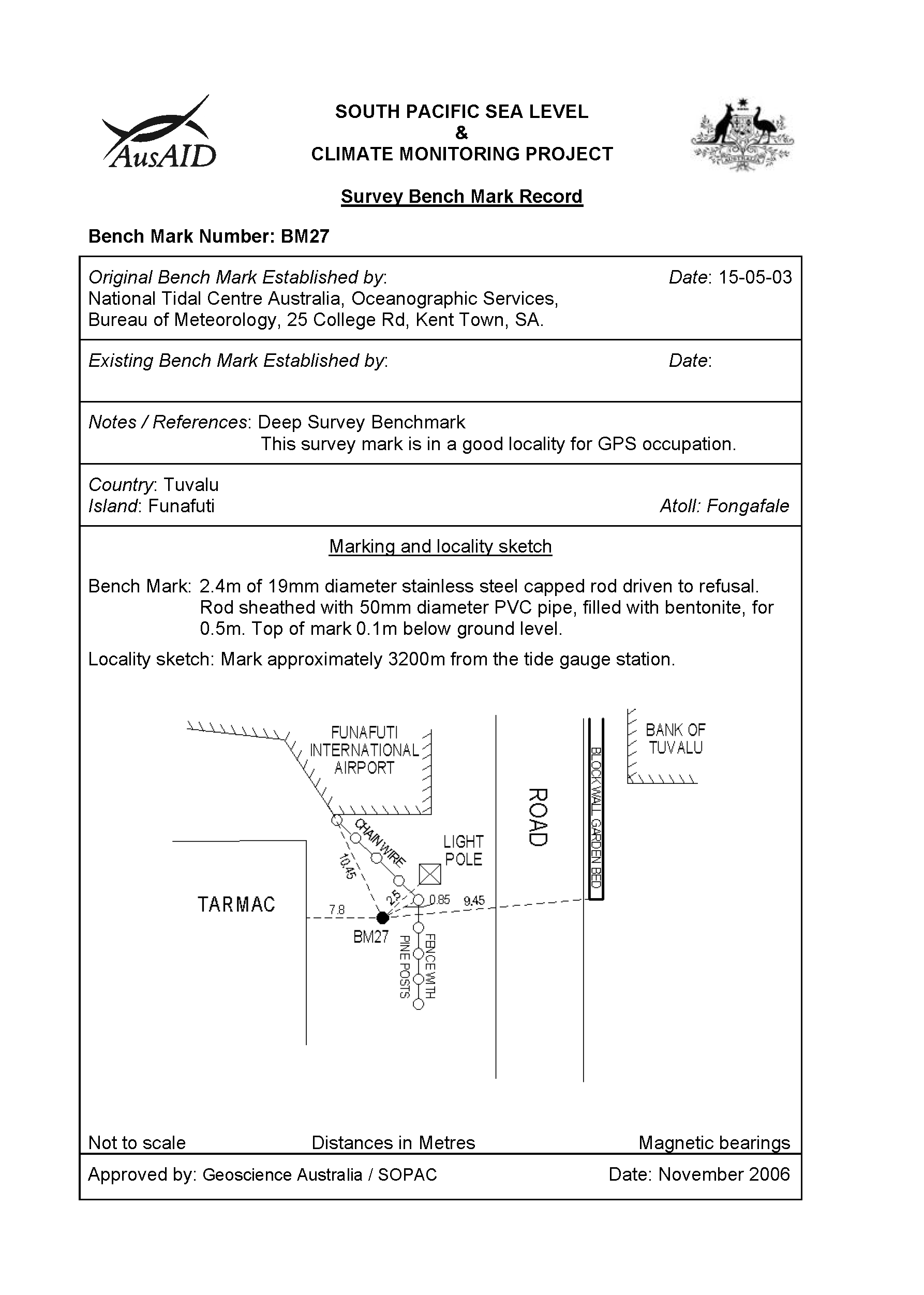
# Deep Bench Mark Locality Diagrams

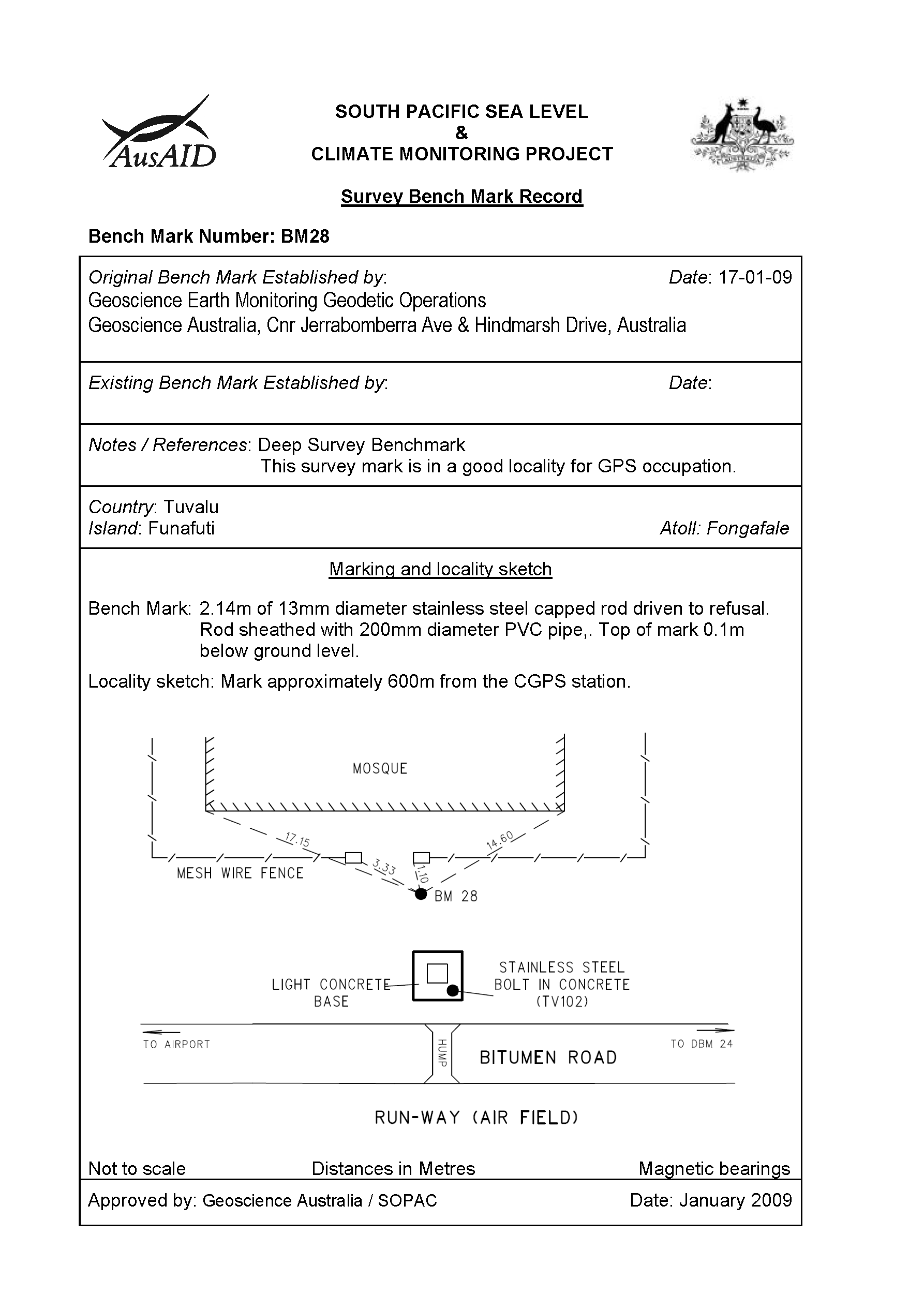




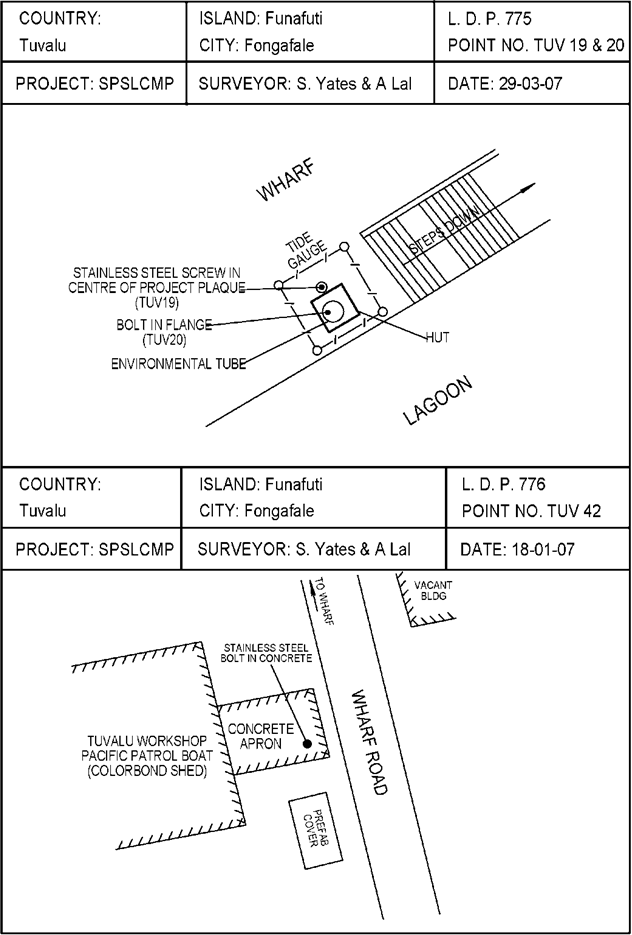


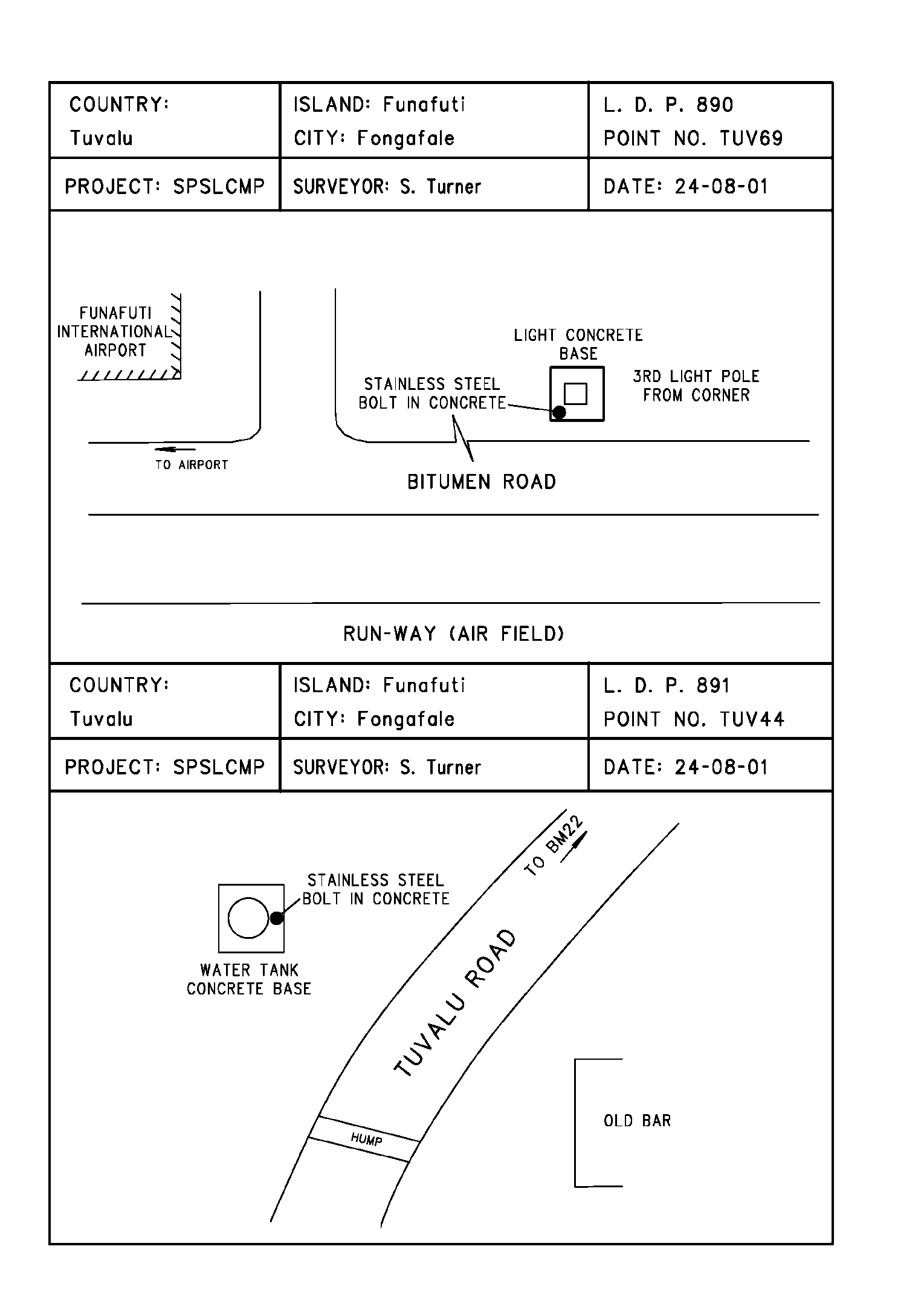


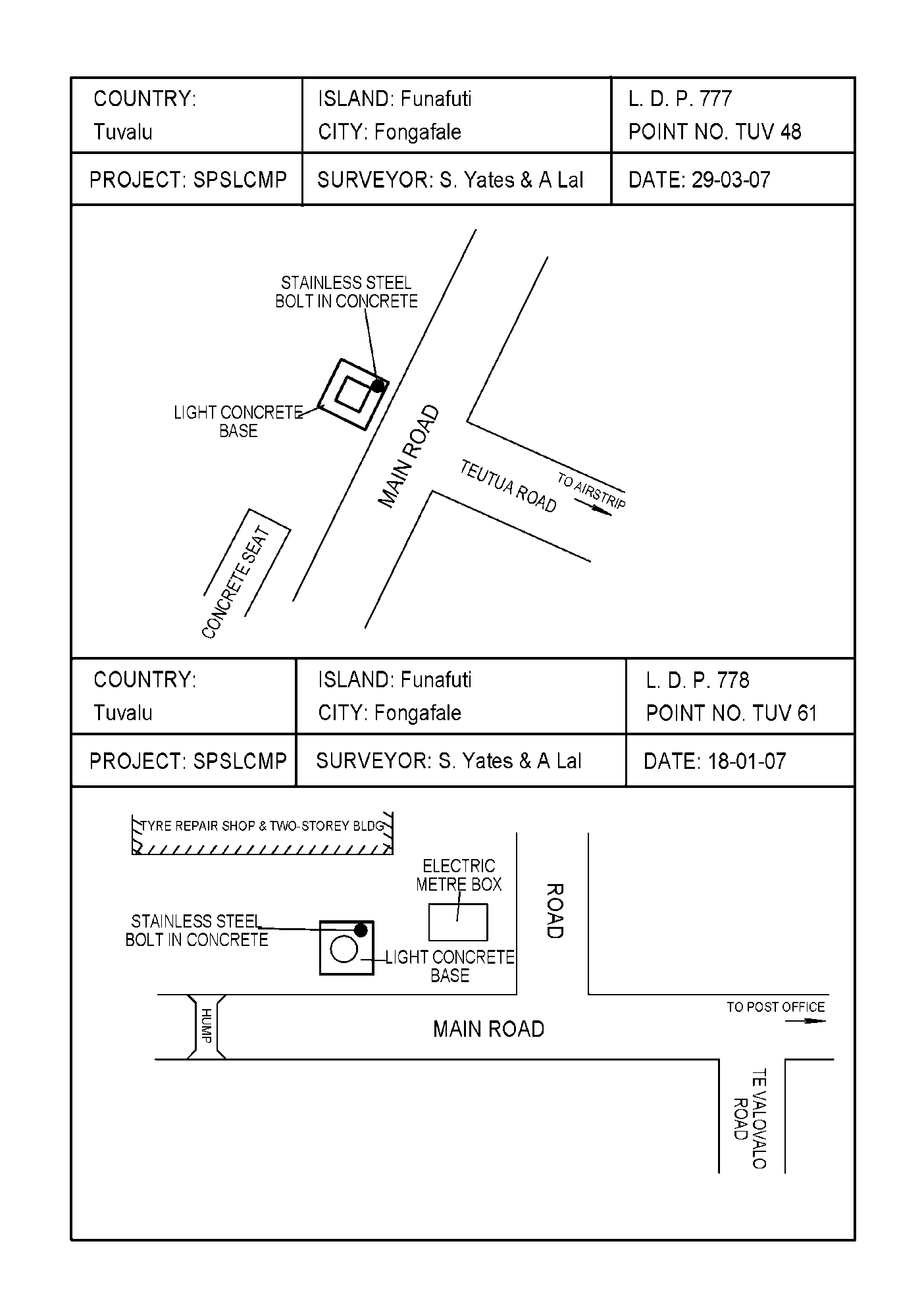


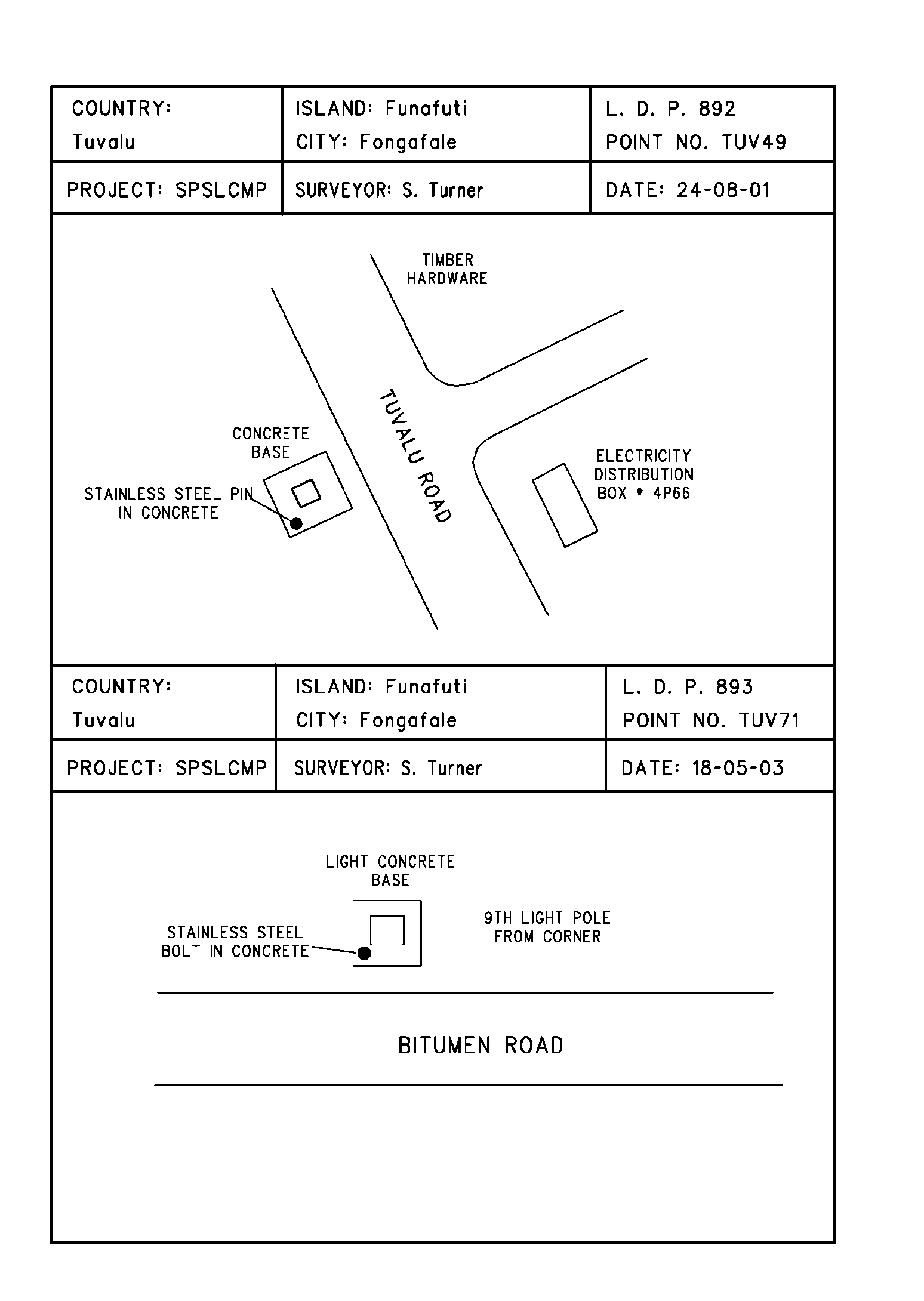


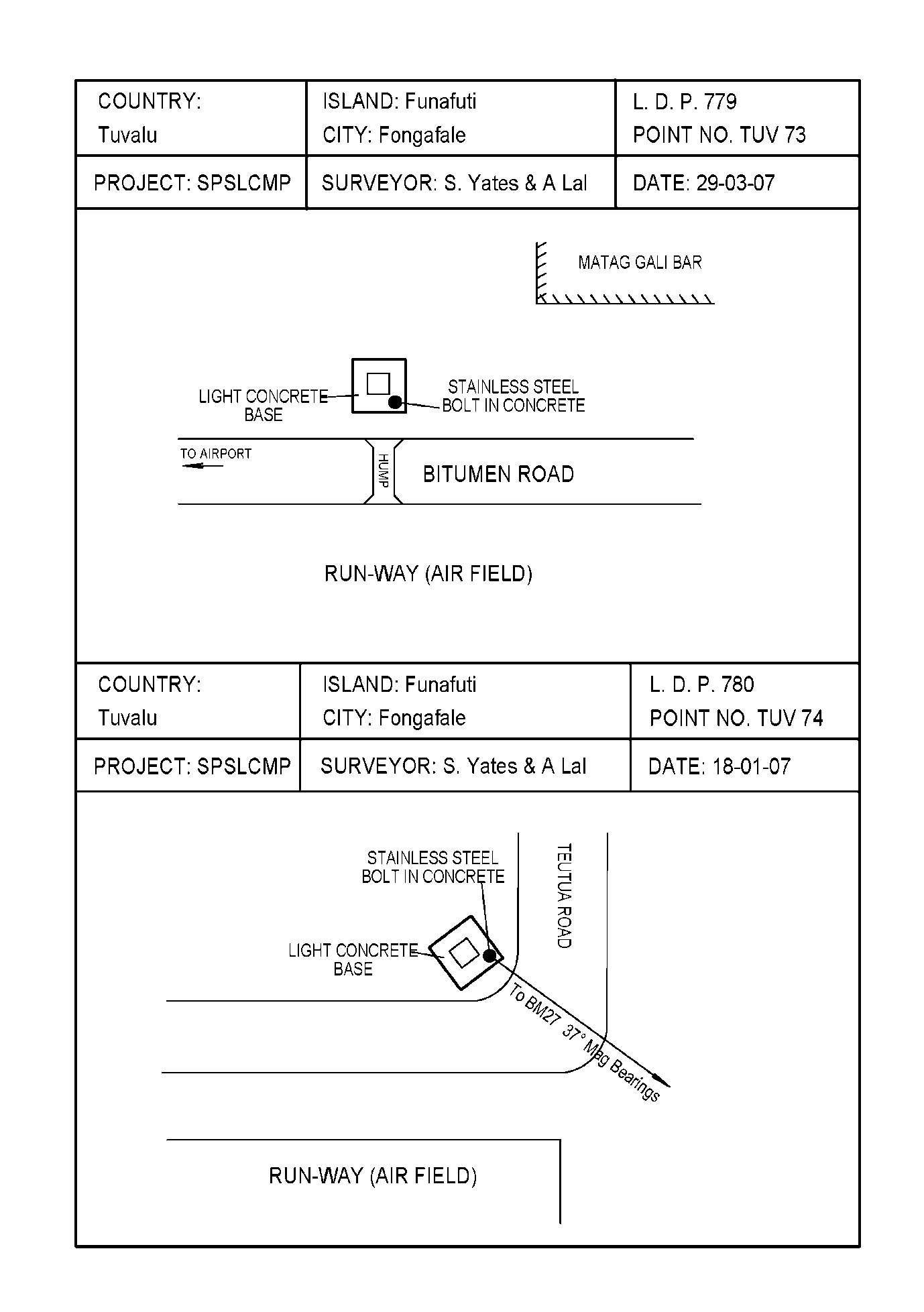
# Temporary Holding Mark Locality Diagrams

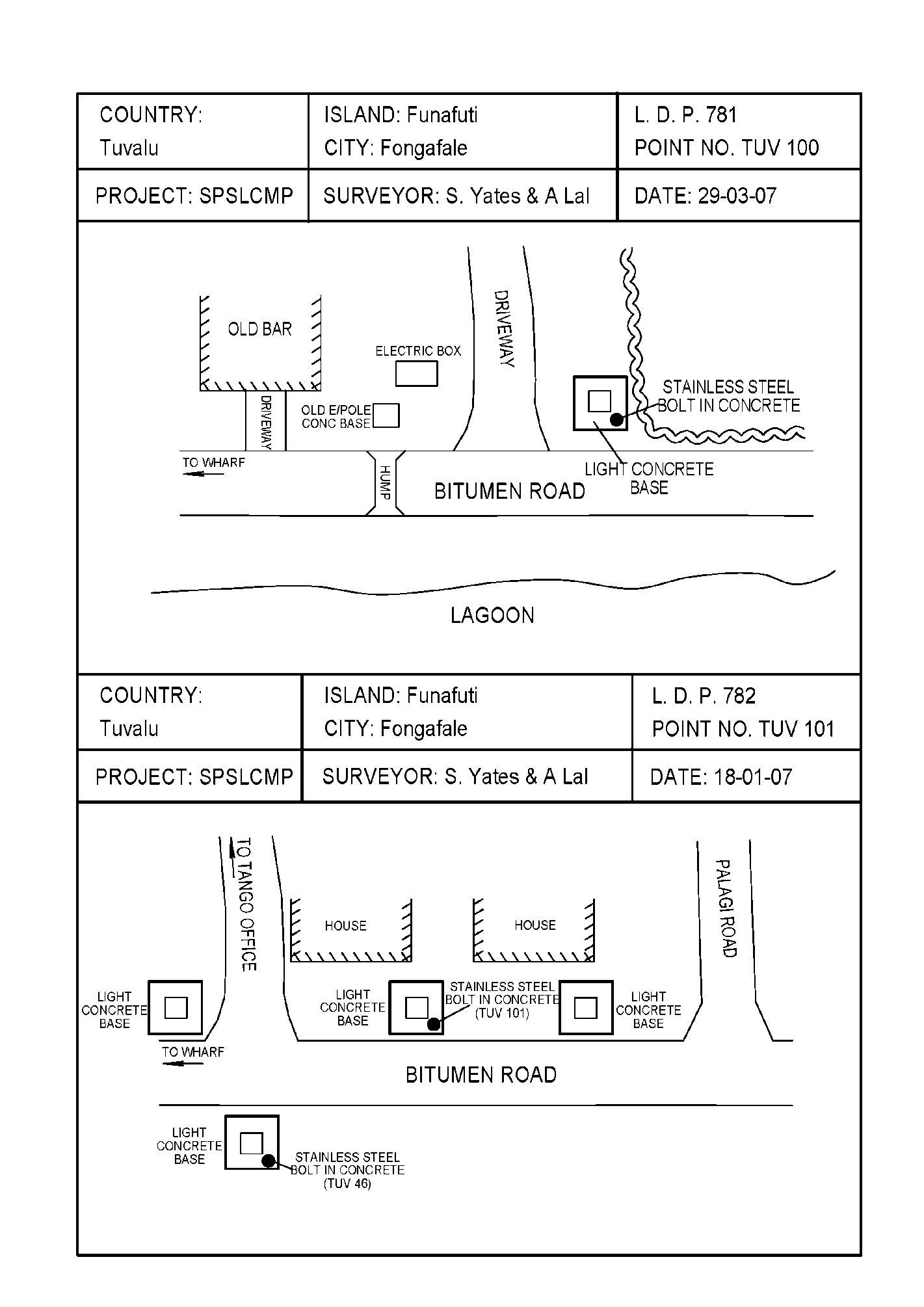


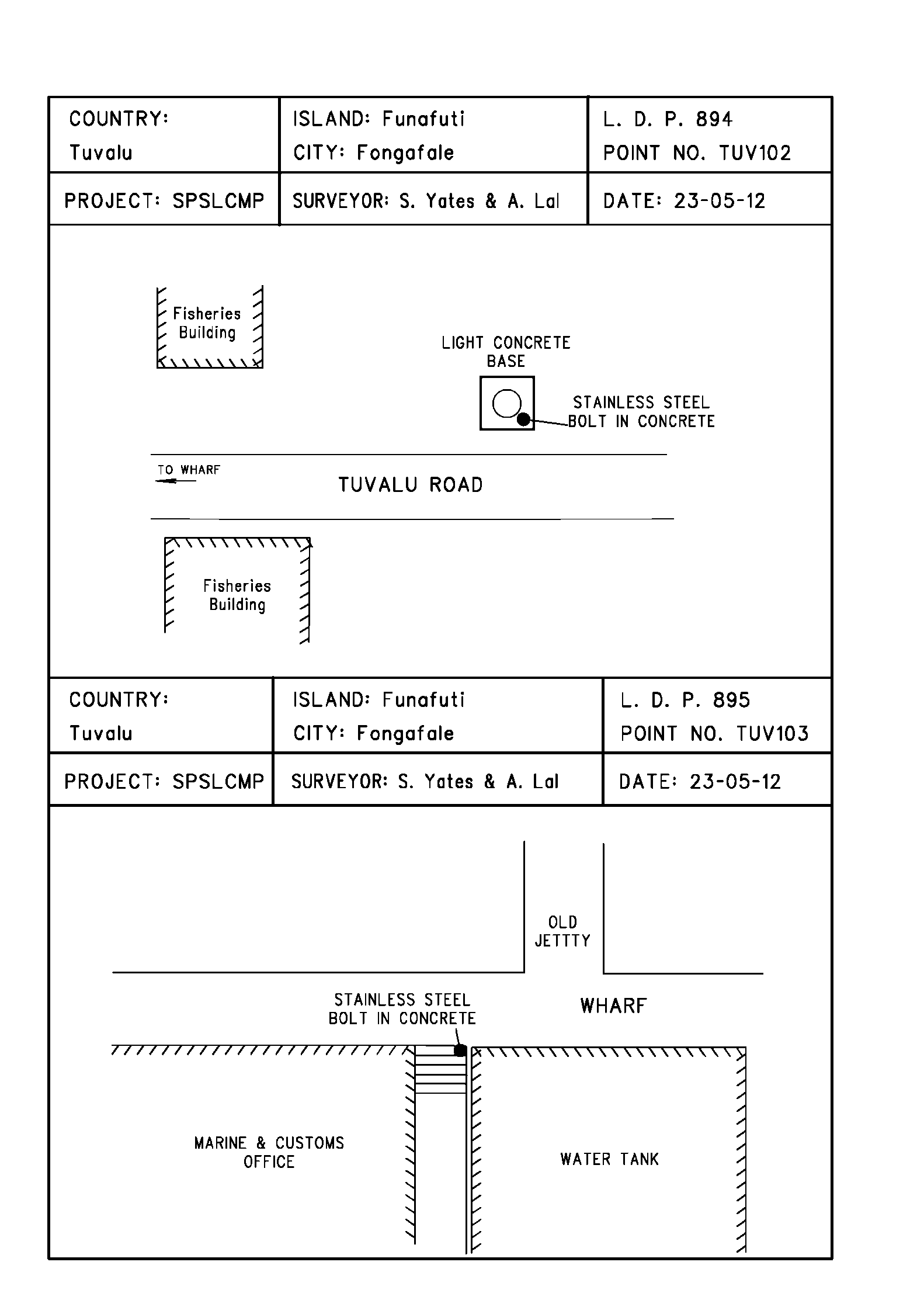


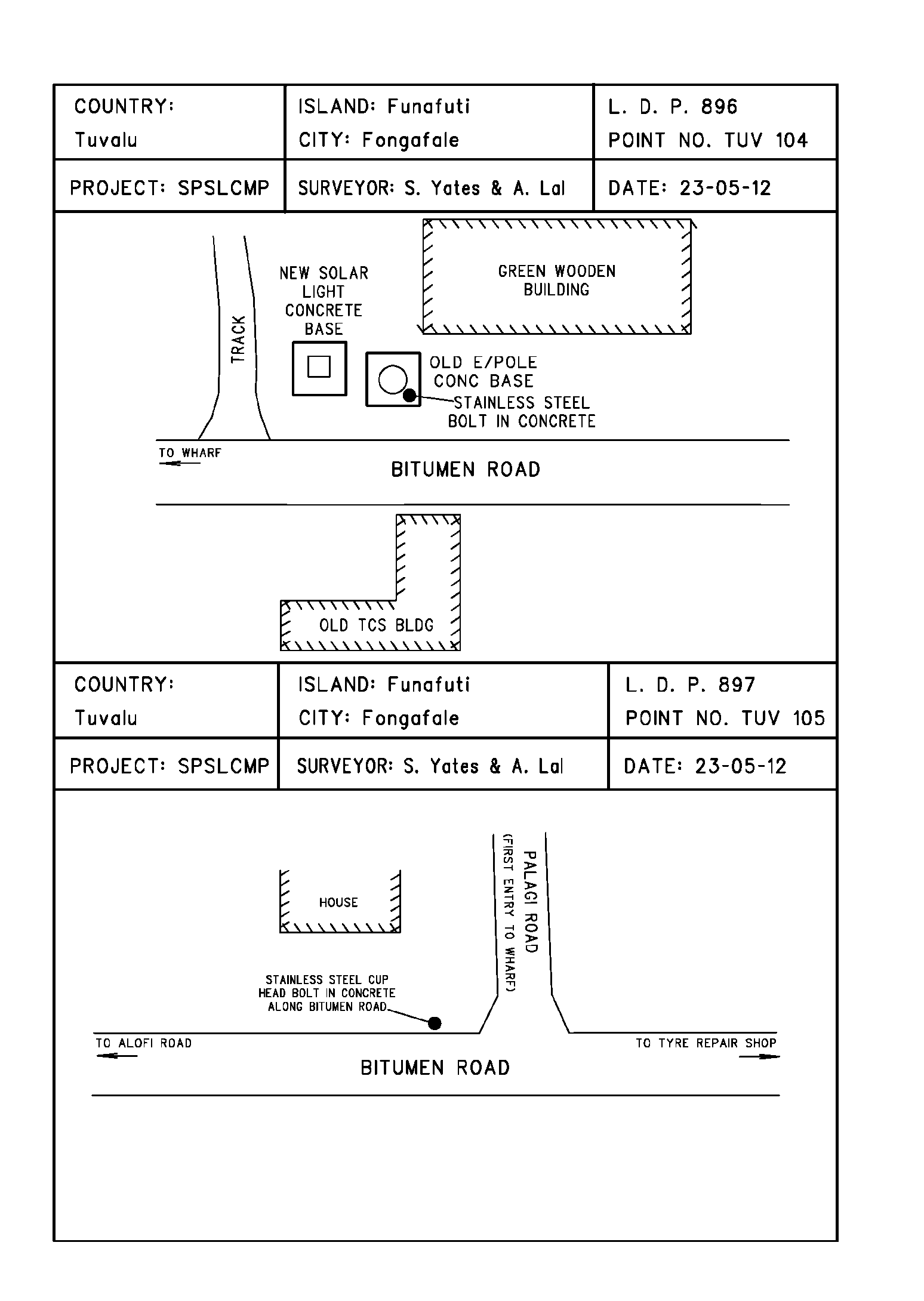




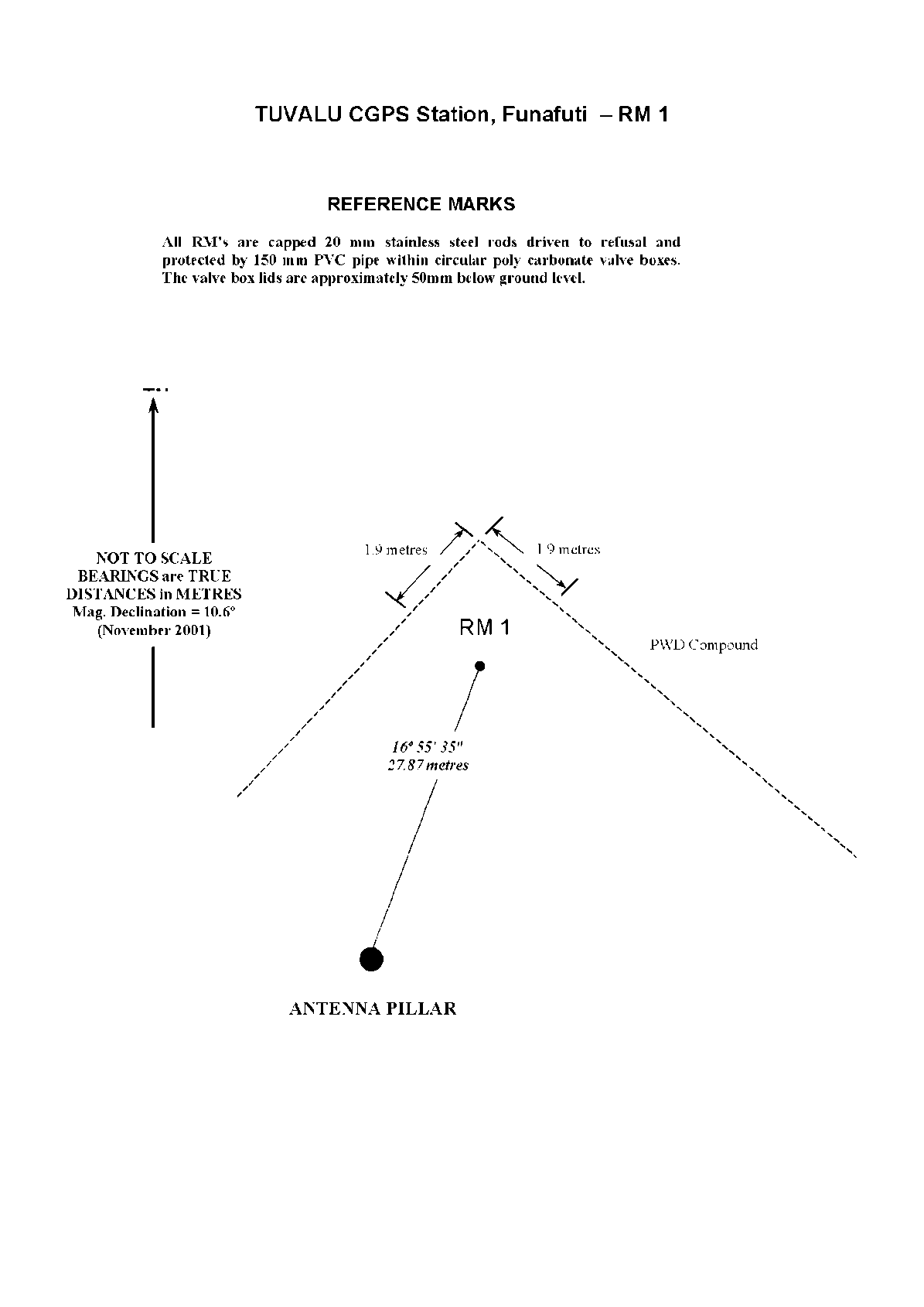


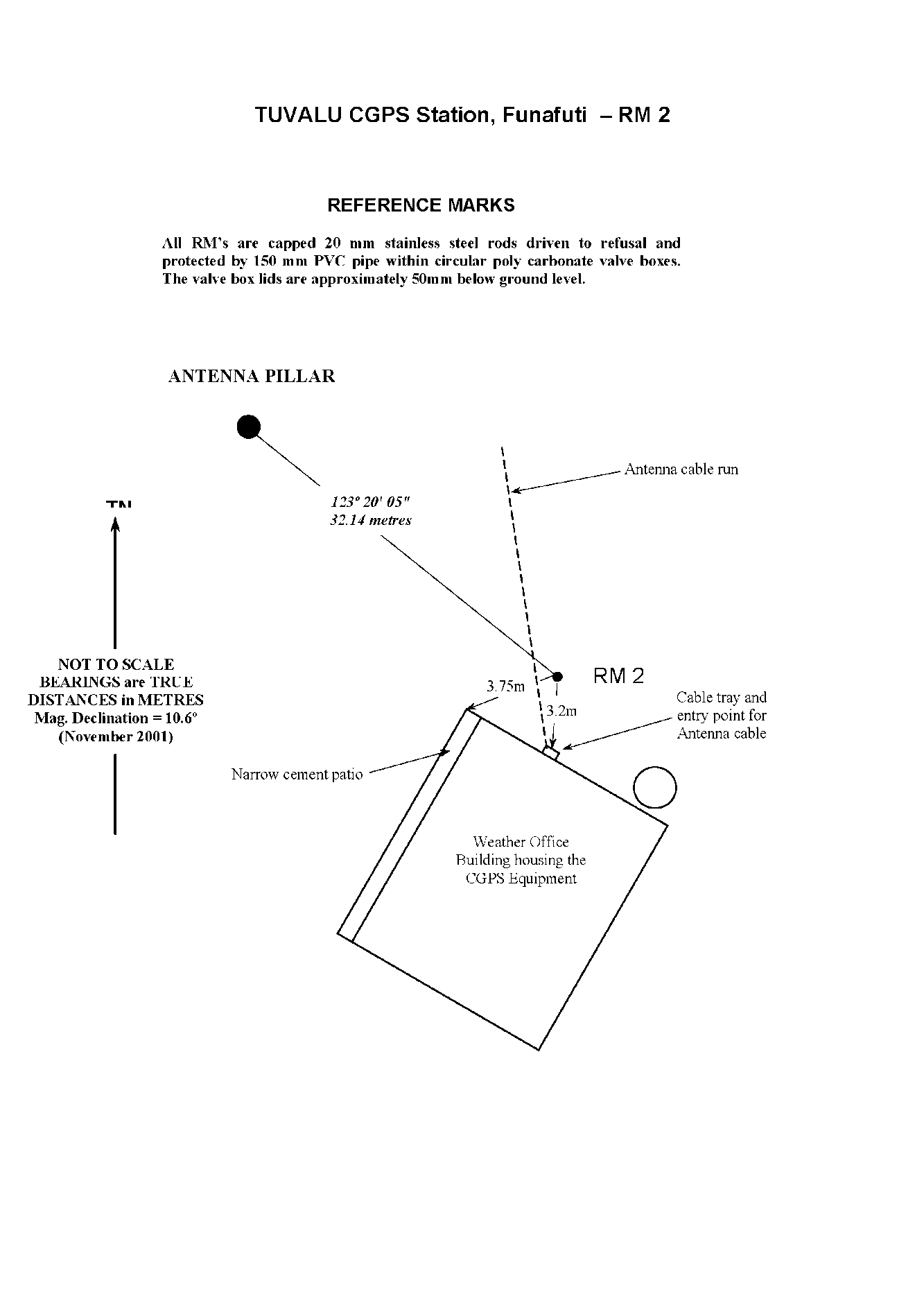


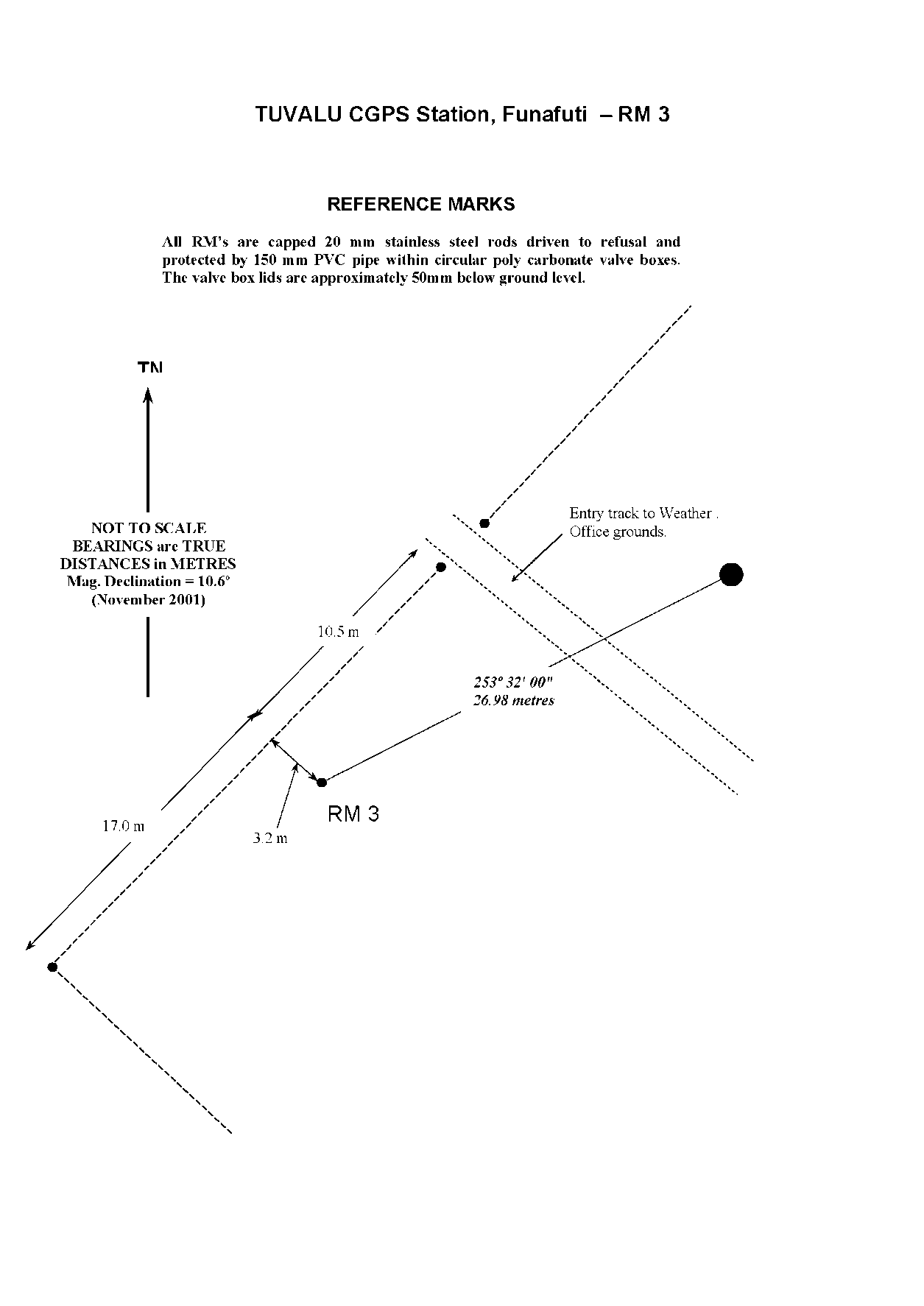




# TUVABM and TUVA Reference Mark Locality Diagrams







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