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EDM Height Traversing Levelling Survey Report

Apia, Western Samoa, May 2013

S. J. K. Yates, A. Lal

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GEOSCIENCE AUSTRALIA
RECORD 2014/25

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Australian Government
Geoscience Australia

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1 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 Navigational Satellite System (CGNSS) station in Apia, Western Samoa from 21st May to 2nd June 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 Apia, which runs approximately 5.5 km from the tide gauge sensor to the CGNSS antenna. Previous levelling surveys have been conducted along the route using this technique in 2006, 2008, 2010, 2011 and 2013.

In addition, precise differential levelling surveys were performed along the deep bench mark array from 1992 to 2004 by the National Tidal Centre Australia (NTCA). This report contains a comparison between the 2013 and 2011 EDM height traversing results as well as a combined comparison since the first levelling survey.

2 The Survey

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

- SAM16 – SEAFRAME Project Plaque Bench mark
- SAM17 – SEAFRAME Sensor Bench mark
- BM201 – Deep driven BM, held fixed, located at the rear of the X Bar along the Apia Port Road.
- BM210 – Deep Driven Bench mark along Matafagatele Street inside LDS Church grounds.
- BM212 – Deep Driven Bench mark located at the end of Matafagatele Street and the start of the Main East Coast Road inside the Church compounds.
- BM213 – Deep Driven Bench mark outside a shop at the corner of the Main East Coast Road and Vaivase Road.
- BM214 – Deep Driven Bench mark located corner of Vaivase and Fuaipolu Roads.
- BM215 – Deep Driven Bench mark located inside church grounds, Plantation Road.
- BM220 – Deep Driven Bench mark located in front of Apia Park entrance gate
- SAMO – CGNSS reference point
- SAMO RM1 – CGNSS reference mark
- SAMO RM4 – CGNSS reference mark
- SAMO RM3 – CGNSS reference mark
- SAMOBM – Level reference bench mark for the GNSS pillar

All the deep bench marks were located and found in good order and undisturbed. Also included in the survey were the permanent holding marks; SAM317, SAM166, SAM309, SAM180, SAM104, SAM105, SAM168, SAM307, SAM311, SAM170, SAM300, SAM301, SAM 187, SAM318, SAM308, SAM318, SAM303, SAM313, SAM304, SAM314, SAM305, SAM315, SAM139, SAM310 and SAM316.

Marks SAM317 and SAM318 are new holding marks established in 2013 and consist of cup shaped stainless steel bolts drilled in concrete and glued in place with quality epoxy resin.

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; 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 2013 reduced levels are detailed later in this report.

2.1 Bench Mark Locality Diagram



2.2 The Western Samoa Datum

The Datum for the survey is Mean Sea Level (1993) as established by the National Tidal Centre Australia.

The reference point for this survey is BM201 derived in 1993.

Reduction of the data has been calculated holding BM201 fixed at 1.3292 m.

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 Apia 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 Samoa 2013 Reduced Levels

Table 2.1 Apia, Samoa – Reduced levels and heights difference relative to BM201

Date: 22nd May to 1st June 2013

Datum: Mean Sea Level

Point ID	Reduced Level 2013	Type
BM201	1.32920	Stainless Steel Rod in Ground
SAM317	2.35798	Stainless Steel Pin in Concrete
SAM166	2.21730	Stainless Steel Pin in Concrete
SAM309	1.94263	Spike in Bitumen
SAM16	2.37280	Stainless Steel Pin in Concrete
SAM17	4.15700	Stainless Steel Pin
SAM180	2.19378	Stainless Steel Pin in Concrete
SAM104	2.13621	Stainless Steel Pin in Concrete
SAM105	2.10837	Stainless Steel Pin in Concrete
SAM168	1.78381	Stainless Steel Pin in Concrete
SAM307	1.72728	Stainless Steel Pin in Concrete
BM210	1.25385	Stainless Steel Rod in Ground
SAM311	2.09004	Stainless Steel Pin in Concrete
SAM170	1.94638	Stainless Steel Pin in Concrete
SAM300	1.45625	Stainless Steel Pin in Concrete
BM220	1.52153	Stainless Steel Rod in Ground
SAM301	1.61895	Stainless Steel Pin in Concrete

Point ID	Reduced Level 2013	Type
SAM187	1.37890	Masonry Nail in Concrete
SAM318	1.32165	Stainless Steel Pin in Concrete
SAM319	1.48170	Steel Pin in Concrete
BM212	1.38665	Stainless Steel Rod in Ground
SAM303	2.09112	Stainless Steel Pin in Concrete
SAM313	1.76564	Stainless Steel Pin in Concrete
BM213	1.18411	Stainless Steel Rod in Ground
SAM304	1.69869	Stainless Steel Pin in Concrete
SAM314	3.65678	Masonry Nail in Concrete
BM214	8.11896	Stainless Steel Rod in Ground
SAM305	10.00738	Stainless Steel Pin in Concrete
SAM315	9.87025	Stainless Steel Pin in Concrete
SAM139	17.66525	Stainless Steel Rod in Ground
BM215	21.61044	Stainless Steel Rod in Ground
SAM310	29.76698	Stainless Steel Pin in Concrete
SAM316	30.30625	Stainless Steel Pin in Concrete
SAMOBM	38.19008	Stainless Steel Pillar Pin
*SAMO	38.91828	Pillar Plate (ARP)

**The RL of the Reference Point SAMO (ARP) is derived from adding the static height difference of 0.7282 m (SAMOBM to SAMO) to the levelled RL of SAMOBM.*

2.6 Survey Support

Ms. Siosina Lui from the Ministry of Natural Resources & Environment provided valuable assistance in obtaining customs clearances for the surveying equipment. This is a lengthy process and seems to be becoming more time consuming throughout most countries in the Pacific. The project is using Calcy Pacific Agencies as the local customs agent broker to make necessary arrangements for customs clearance.

Senior Surveyor Mr. Petanaia Taulu and Assistant Surveyor, Mr. Phillip Laulu from the Survey Department, provided us with valuable field assistance and support during the field survey.

Other personnel consulted during the visit were Mr. Austelaia Titimaea (CEO) from the Meteorology Division of the Ministry of Natural Resources & Environment.

2.7 Issues

Avoid levelling between SAM317 and the tide gauge bench mark during offloading of ships or increased port activity. Access inside the Ports Authority area is strictly prohibited and it is necessary to arrange security passes through the Weather Office or the Lands and Surveys staff well in advance.

The Ports Authority area is closed on Saturdays, however, security is still on the gate. This is the best day to perform the survey.

Levelling along the reclaimed area around the wharf and along Matafagatele Street, especially around Apia Park Stadium should be carried out during quiet traffic periods. It is recommended to avoid areas with drainage systems underneath the footpath in that area as the heavy trucks which drive past cause significant ground shake.

3 Comparisons

3.1 Comparisons between 2013 and 2011 EDM Surveys

Table 3.1 Apia, Western Samoa 2013 EDM Height Traversing Levelling Comparison 2013- 2011. BM201 - adopted fixed height OF 1.3292 m

From	To	Levelled Ht. Diff.	RL 2013	Misclose (mm)	Dist. (km)	1mm√k	RL 2011	Difference (mm) 2013 - 2011
BM201			1.3292					
SAM317	SAM317	1.0288	2.3580	0.080	0.096	0.310		New Mark
SAM166	SAM166	-0.1407	2.2173	-0.095	0.183	0.428	2.2183	-1.00
SAM309	SAM309	-0.2747	1.9426	-0.163	0.186	0.431	1.9457	-3.07
SAM16	SAM16	0.4302	2.3728	-0.068	0.051	0.226	2.3733	-0.50
	SAM17	1.7842	4.1570	0.000	0.020	0.142	4.158	-1.00
SAM317			2.3580					
SAM180	SAM180	-0.1642	2.1938	0.013	0.111	0.334	2.1939	-0.12
SAM104	SAM104	-0.0576	2.1362	0.013	0.094	0.307	2.1361	0.11
SAM105	SAM105	-0.0278	2.1084	0.200	0.069	0.262		New Mark
SAM168	SAM168	-0.3246	1.7838	0.171	0.071	0.266	1.7832	0.61
SAM307	SAM307	-0.0565	1.7273	-0.435	0.214	0.462	1.7268	0.48
BM210	BM210	-0.4734	1.2539	-0.021	0.029	0.169	1.2519	1.95
SAM311	SAM311	0.8362	2.0900	0.063	0.203	0.450	2.0889	1.14
SAM170	SAM170	-0.1437	1.9464	0.363	0.154	0.392	1.9442	2.18
SAM300	SAM300	-0.4901	1.4562	-0.400	0.199	0.446	1.4569	-0.65
BM220	BM220	0.0653	1.5215	-0.150	0.185	0.431	1.5181	3.43
SAM301	SAM301	0.0974	1.6190	0.440	0.206	0.454	1.6151	3.85
SAM187	SAM187	-0.2401	1.3789	-0.040	0.192	0.439	1.3757	3.20
SAM318	SAM318	-0.0573	1.3216	-0.150	0.182	0.426		New Mark
SAM319	SAM308	0.1601	1.4817	0.333	0.098	0.314		New Mark
BM212	BM212	-0.0950	1.3867	-0.090	0.168	0.410	1.3811	5.55
SAM303	SAM303	0.7045	2.0911	-0.210	0.212	0.461	2.0866	4.52
SAM313	SAM313	-0.3255	1.7656	0.403	0.206	0.454		New Mark
BM213	BM213	-0.5815	1.1841	-0.290	0.202	0.450	1.1791	5.01
SAM304	SAM304	0.5146	1.6987	-0.067	0.075	0.275	1.6938	4.89
SAM314	SAM314	1.9581	3.6568	0.440	0.200	0.447	3.6519	4.88
BM214	BM214	4.4622	8.1190	-0.220	0.172	0.414	8.1143	4.66

From	To	Levelled Ht. Diff.	RL 2013	Misclose (mm)	Dist. (km)	1mm√k	RL 2011	Difference (mm) 2013 - 2011
SAM305	SAM305	1.8884	10.0074	-0.300	0.145	0.381	10.0022	5.18
SAM315	SAM315	-0.1371	9.8702	-0.050	0.184	0.429	9.8651	5.15
SAM139	SAM139	7.7950	17.6653	-0.190	0.157	0.396	17.6605	4.75
BM215	BM215	3.9452	21.6104	-0.217	0.091	0.302	21.6043	6.14
SAM310	SAM310	8.1565	29.7670	-0.388	0.167	0.408	29.7612	5.78
SAM316	SAM316	0.5393	30.3063	-0.483	0.224	0.474	30.3006	5.65
	SAMOBM	7.8838	38.1901	0.100	0.214	0.462	38.1836	6.48
			Misclose for all bays levelled =	-1.409	4.962	2.228		
SAMOBM			38.1901					
	RM1	-1.73073	36.4594	-0.038	0.036	0.189	36.4524	6.96
SAMOBM			38.1901					
	RM4	-0.7821	37.4080	0.019	0.027	0.164	37.4015	6.49
SAMOBM			38.1901					
	RM3	-1.22224	36.9678	0.013	0.034	0.185	36.9614	6.45

3.2 Combined Comparisons 1993 to 2013

Table 3.2 Apia, Western Samoa - Comparison of the RL's for Precise Differential Levelling (1993 - 2006) and EDM Height Traversing (2006 – 2013)

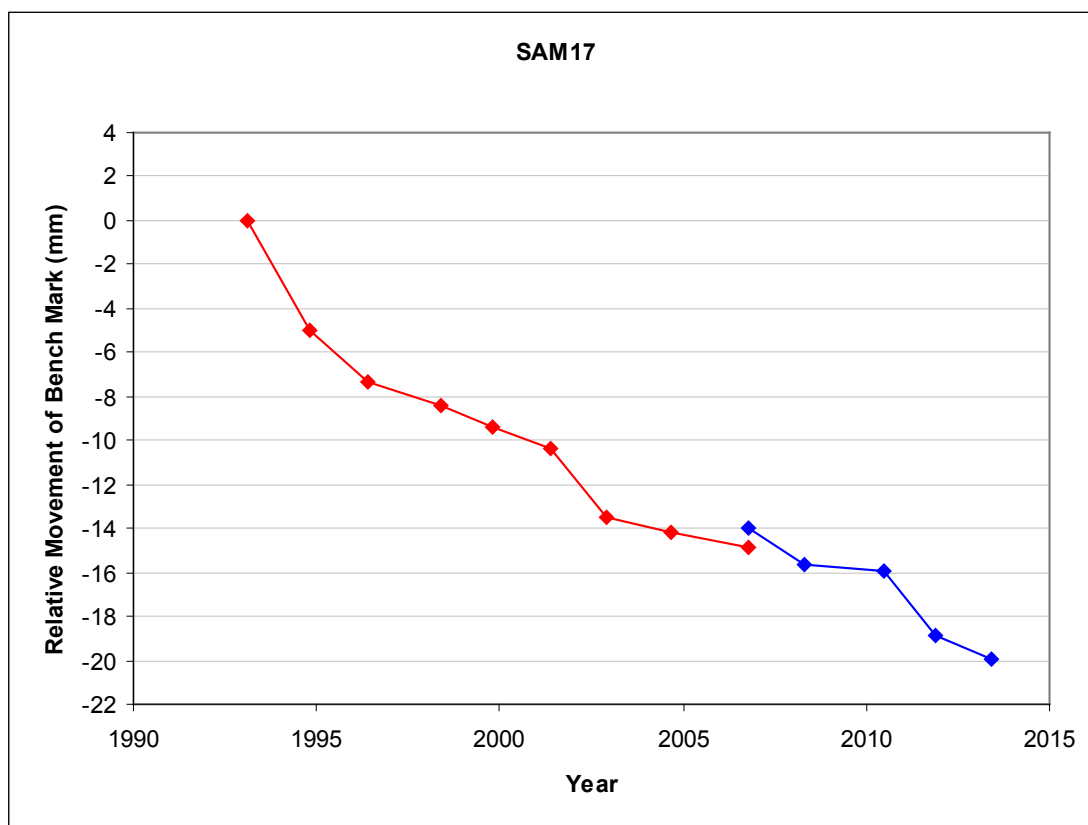
Year	SAM16	SAM17	BM210	BM220	BM212	BM213	BM214	BM215	SAMOBM
1993.1	2.3843	4.1769							
1994.8	2.3812	4.1719							
1996.4	2.3796	4.1696							
1998.4	2.3783	4.1685							
1999.8	2.3777	4.1675							
2001.4	2.3768	4.1665							
2002.9	2.3751	4.1634	1.2535		1.3846	1.1826	8.1172	21.6076	38.1869
2004.7	2.3757	4.1627	1.2538		1.3864	1.1842	8.1189	21.6103	38.1889
2006.8	2.3739	4.162	1.2546		1.3884	1.1874	8.1223	21.6130	38.1926
2006.8	2.3751	4.1629	1.2557		1.3898	1.1876	8.1218	21.6128	38.1921
2008.3	2.3744	4.1613	1.2542	1.5237	1.3880	1.1861	8.1215	21.6131	38.1919
2010.5	2.3742	4.1610	1.2537	1.5221	1.3884	1.1865	8.1217	21.6122	38.1914
2011.9	2.3733	4.1580	1.2519	1.5181	1.3811	1.1791	8.1143	21.6043	38.1836
2013.4	2.3728	4.1570	1.2539	1.5215	1.3867	1.1841	8.1190	21.6104	38.1901

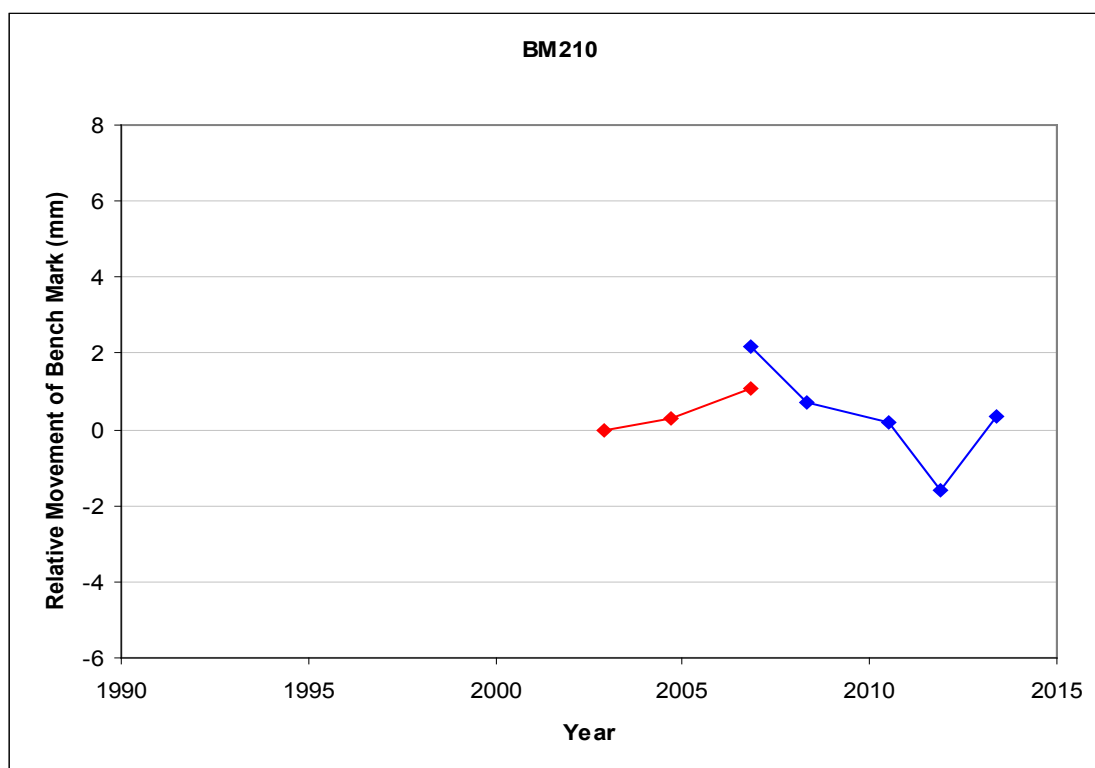
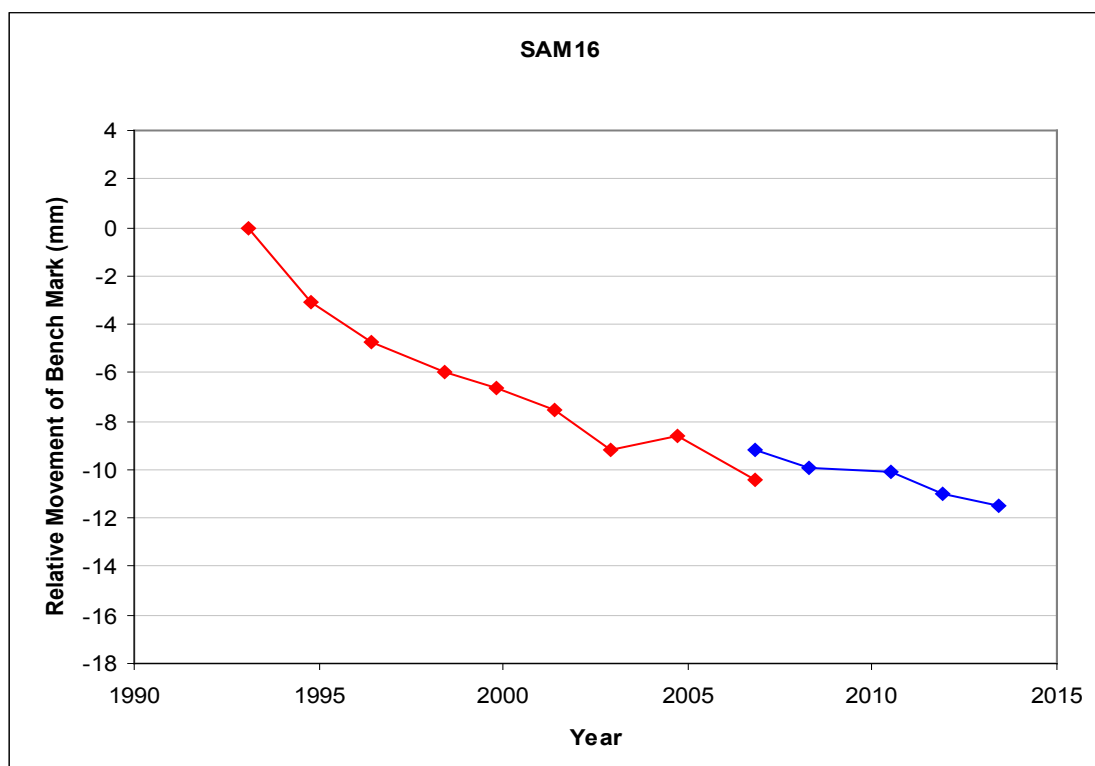
3.3 Time Series of Bench Mark Movement relative to Fixed Deep Bench Mark BM201

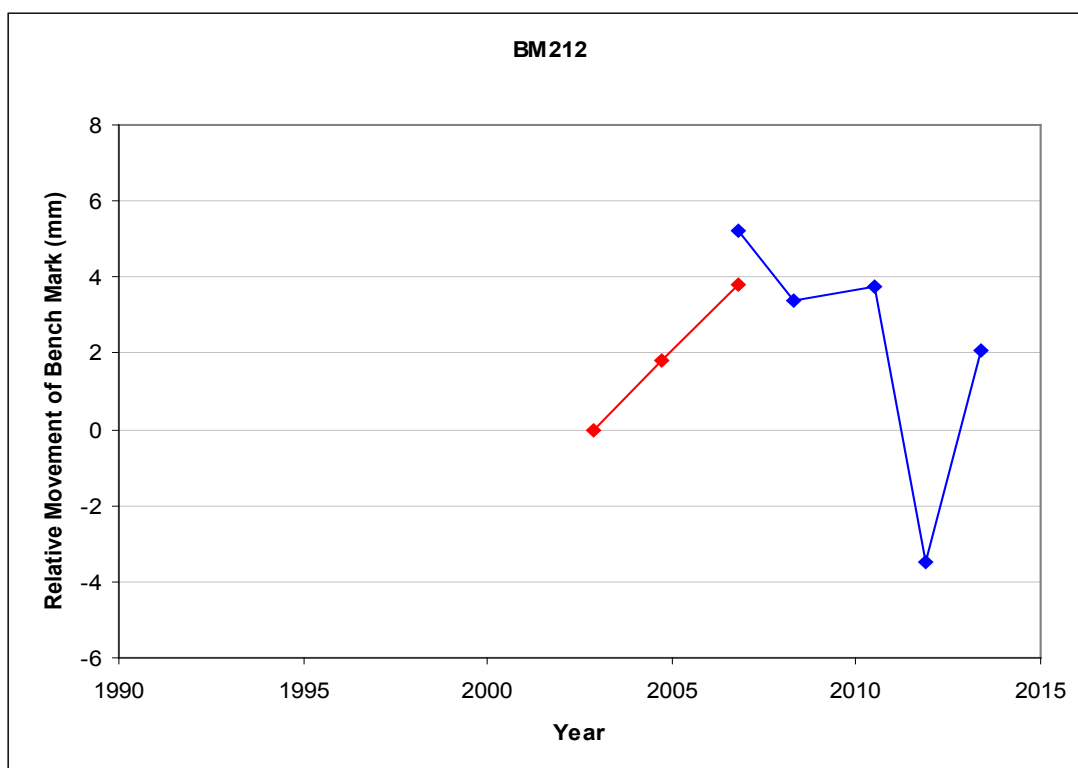
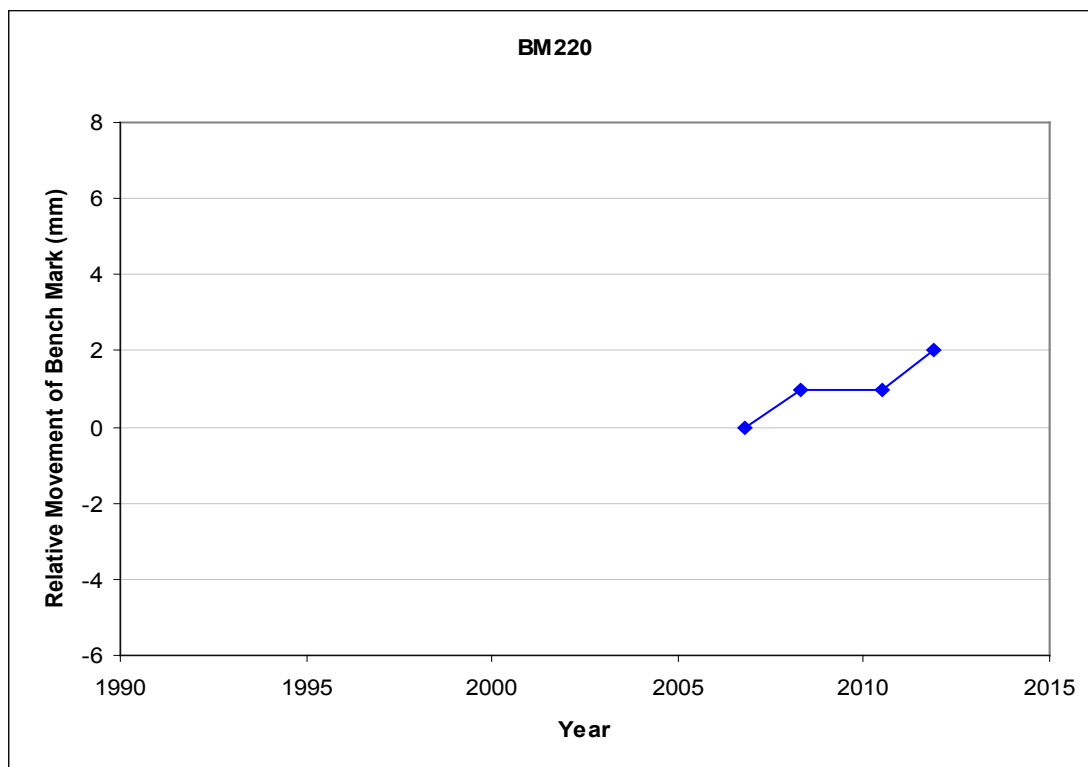
Please note the graph below, there has been a gradual drop in SAM17 and SAM16 (Tide gauge Station) since 1995. This could be caused by the ports area being reclaimed land; but this theory has yet to be confirmed.

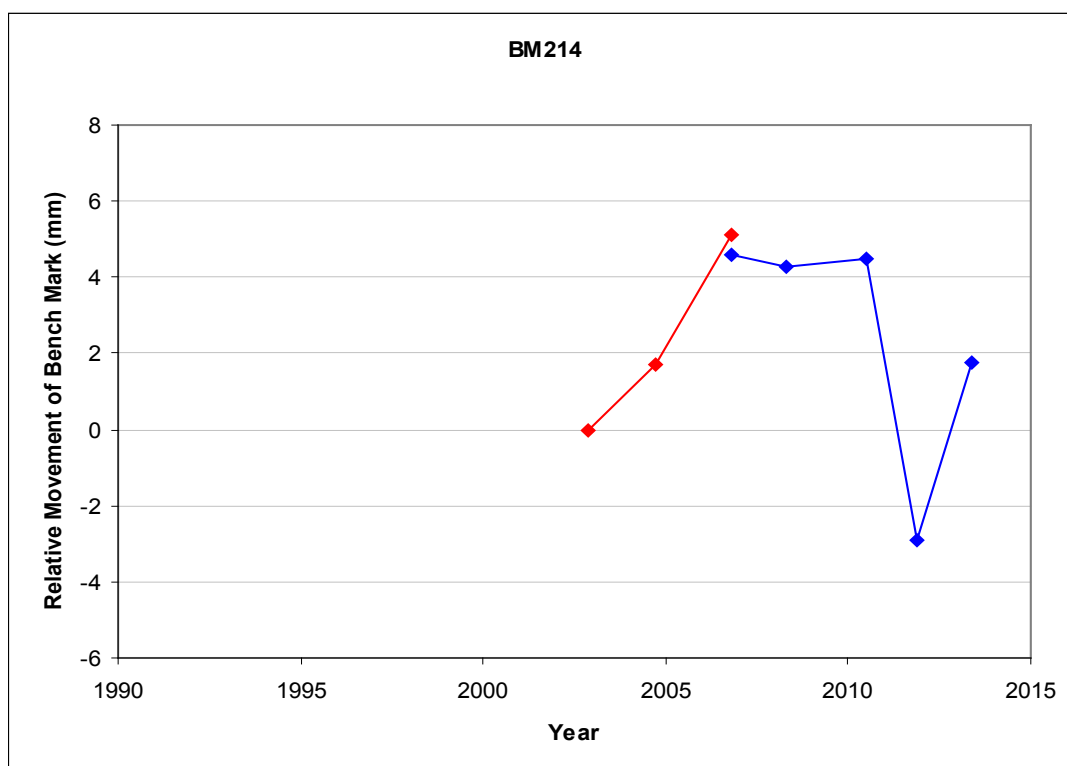
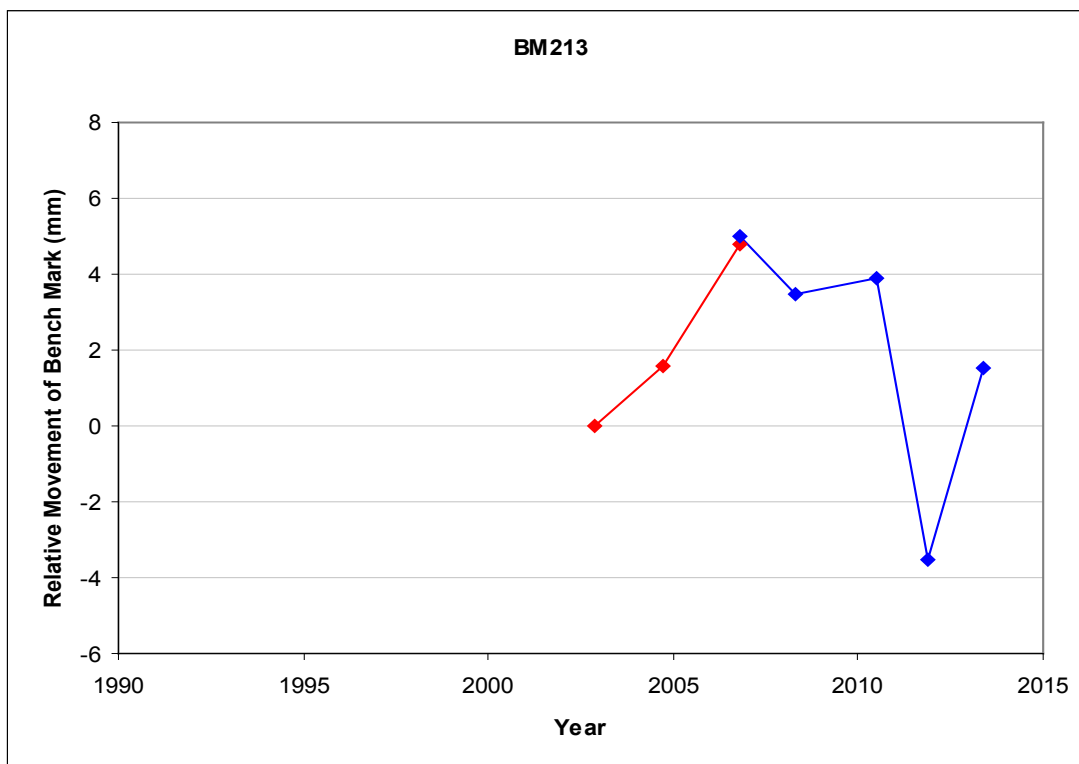
The purpose of these surveys is twofold: firstly, to provide accurate changes in land height to be used in computations of absolute sea level rise and secondly to provide accurate assessments of relative sea level rise. This is an excellent example to highlight the importance of measuring land height variations and the impact they can have on absolute sea level rise measurements. Furthermore, it provides useful information regarding localised deformation and the potential relative sea level height impacts.

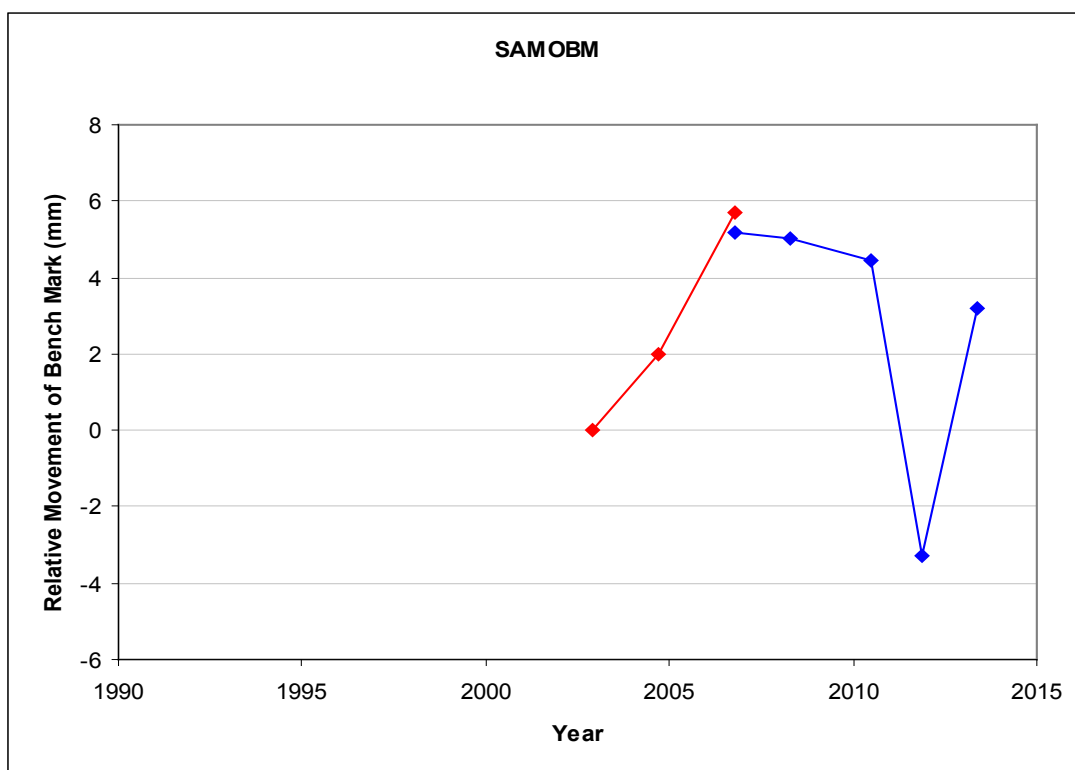
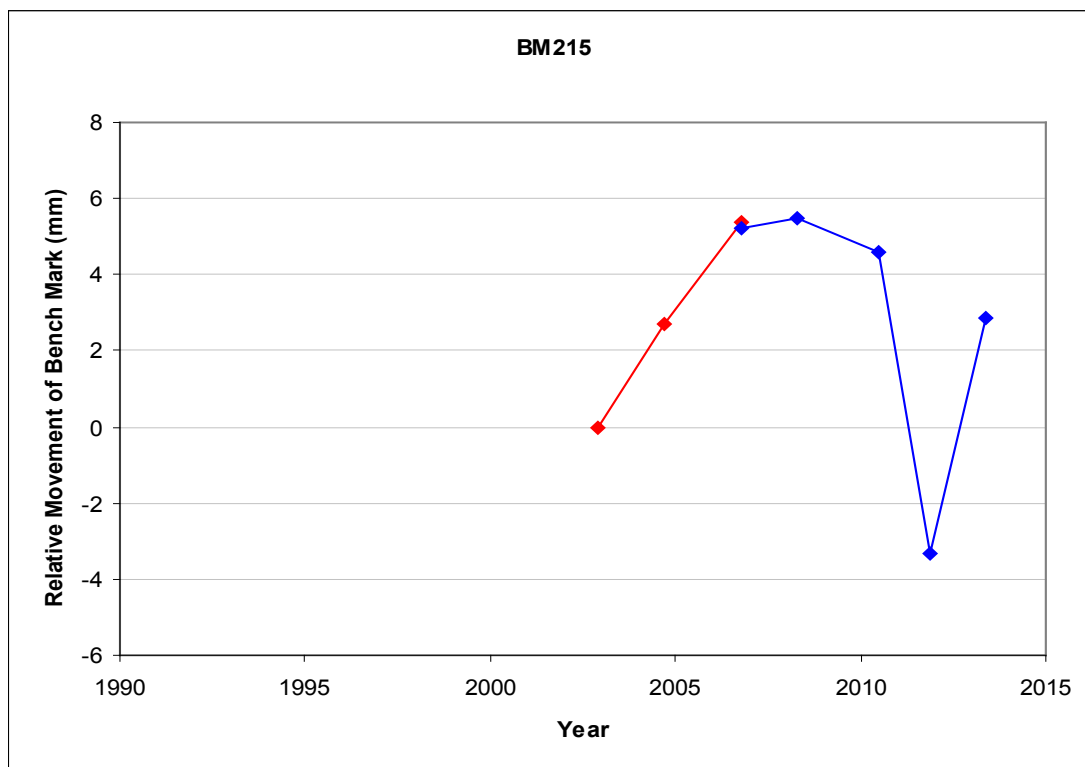
Precise Differential Levelling: 1995 - 2006 ◆ — ◆
EDM Height Traversing: 2005 onwards ◆ — ◆











4 Deep Bench Mark Locality Diagrams



SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT



Survey Bench Mark Record

Bench Mark Number: BM201

<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> 27-11-91
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
--	--------------

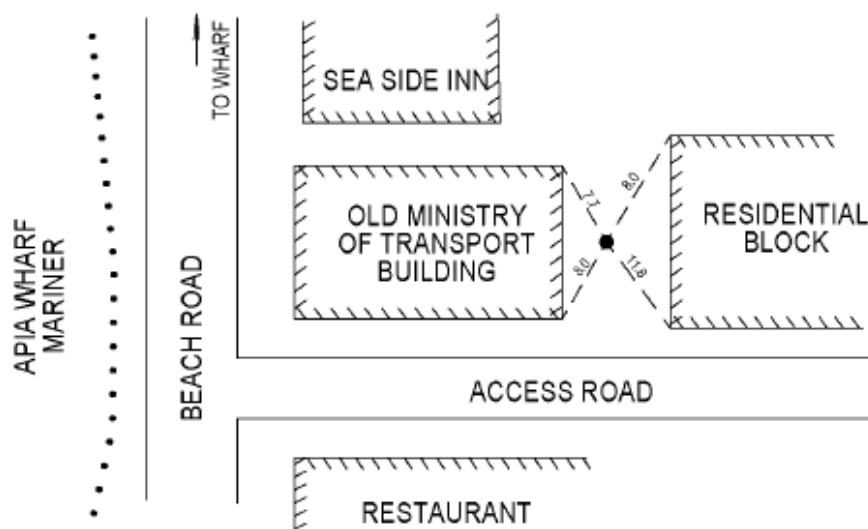
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
--

<i>Country:</i> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
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Marking and locality sketch

Bench Mark: 7.4m of 19mm diameter stainless steel capped rod driven to refusal.
Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for
1.2m. Top of mark 0.2m below ground level.

Locality sketch: Mark approximately 400m from the tide gauge station.



Not to scale Distances in Metres Magnetic bearings

Approved by: Geoscience Australia / SOPAC Date: December 2006
c:\users\andrick\spslcmp\localitydiagrams\samoa



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



Survey Bench Mark Record

Bench Mark Number: BM210

<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> Nov 2002
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
--	--------------

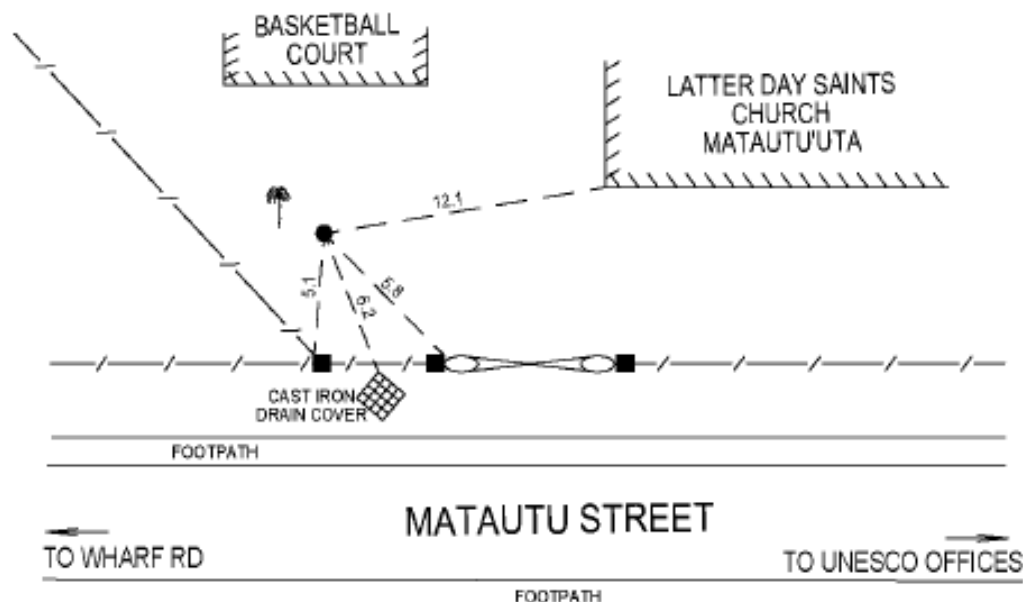
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
--

<i>Country:</i> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
---	-------------------

Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark 0.15m below ground level.

Locality sketch: Mark approximately 1200m from the tide gauge station.



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

Date: December 2006

c:\users\landrick\spslcmpl\localitydiagrams\samoa



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



Survey Bench Mark Record

Bench Mark Number: BM220

<i>Original Bench Mark Established by:</i> National Geospatial Reference Systems Geospatial & Earth Monitoring Division (GEMD) Geoscience Australia	<i>Date:</i> May 2008
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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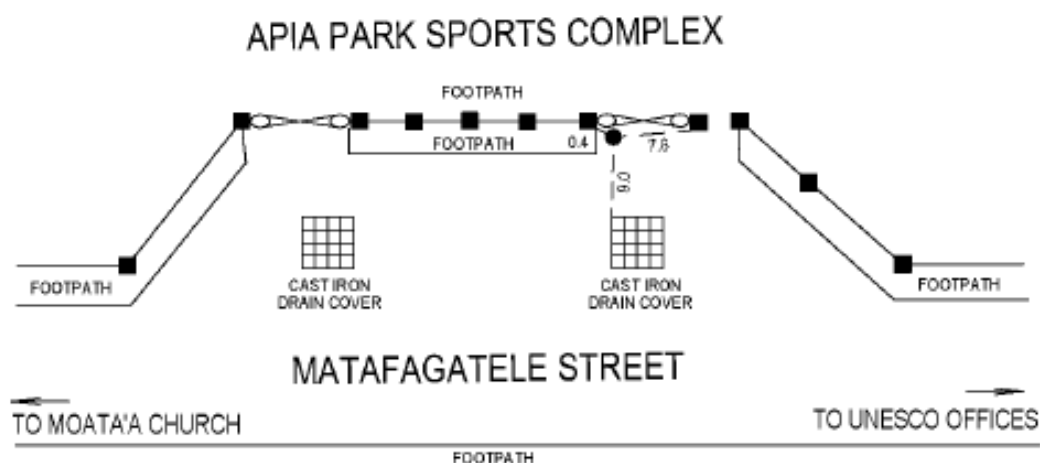
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
--

<i>Country:</i> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
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Marking and locality sketch

Bench Mark: 5.3m 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 2000m from the tide gauge station.



Not to scale	Distances in Metres	Magnetic bearings
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Approved by: Geoscience Australia / SOPAC	Date: May 2008
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c:\users\andrick\spslcmp\localitydiagrams\samoa



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



Survey Bench Mark Record

Bench Mark Number: BM212

<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> Nov 2002
<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> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
<u>Marking and locality sketch</u> Bench Mark: 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark 0.1m below ground level. Locality sketch: Mark approximately 2800m from the tide gauge station. MOATA'A CONGREGATIONAL CHRISTIAN CHURCH concrete garden retaining wall 1.20 0.80 LAWN cement & stone wall MATAFAGATELE STREET Not to scale Distances in Metres Magnetic bearings	
Approved by: Geoscience Australia / SOPAC	
Date: December 2006 c:\users\landrick\spslcmpl\localitydiagrams\samoa	



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



Survey Bench Mark Record

Bench Mark Number: BM213

<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> Nov 2002
--	-----------------------

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

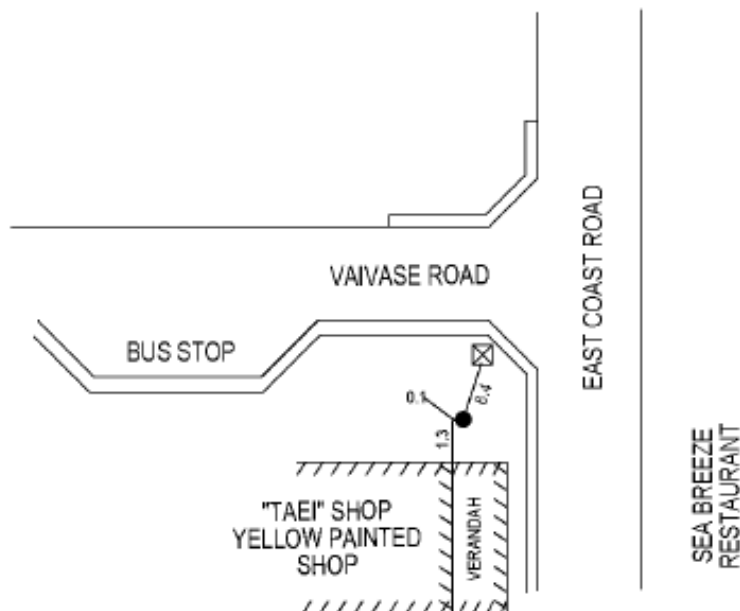
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is not in a good locality for GPS occupation.
--

<i>Country:</i> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
---	-------------------

Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark 0.5m below ground level.

Locality sketch: Mark approximately 3450m from the tide gauge station.



Not to scale	Distances in Metres	Magnetic bearings
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Approved by: Geoscience Australia / SOPAC	Date: December 2006 c:\users\landrick\spslcmp\localitydiagrams\samoa
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**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: BM214

<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> Nov 2002
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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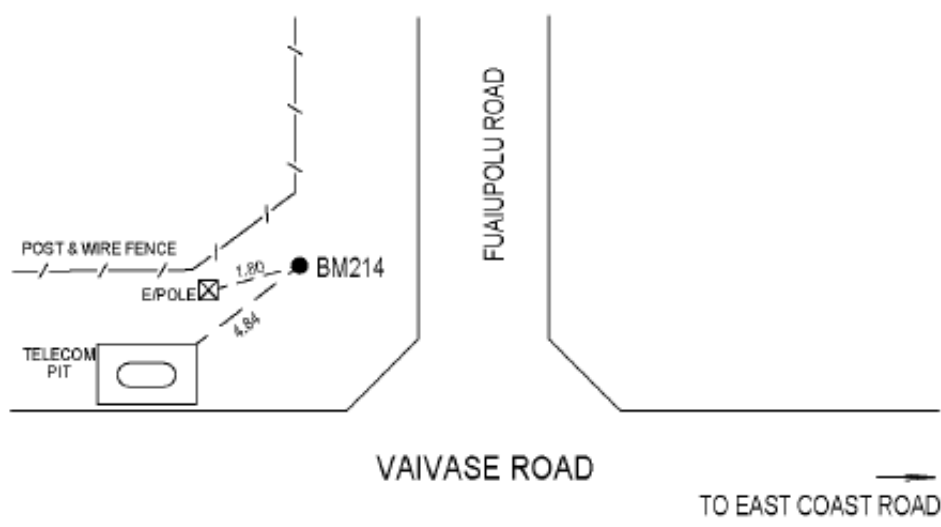
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
--

<i>Country:</i> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
---	-------------------

Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark on ground level.

Locality sketch: Mark approximately 3900m from the tide gauge station.



Not to scale	Distances in Metres	Magnetic bearings
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Approved by: Geoscience Australia / SOPAC	Date: December 2006 c:\users\andrick\spslcmp\localitydiagrams\samoa
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**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: BM215

<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> Nov 2002
--	-----------------------

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

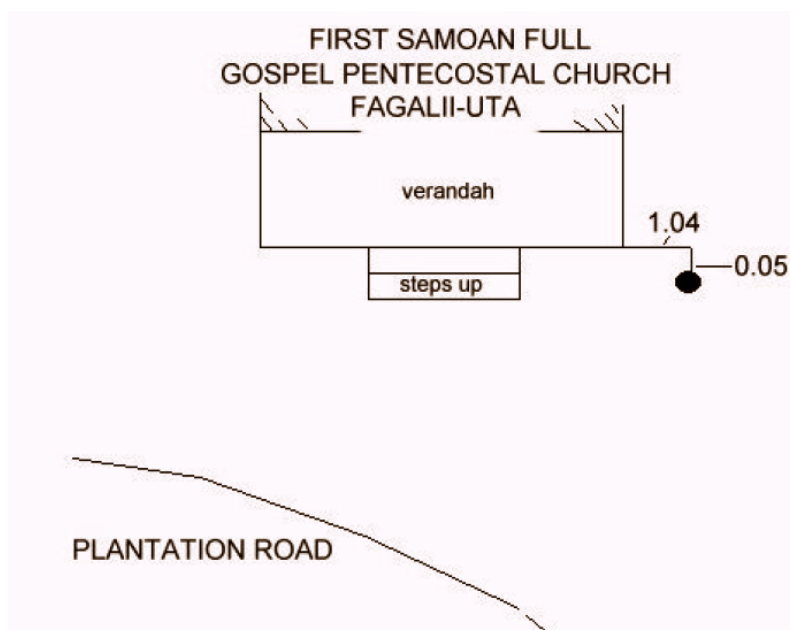
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is not in a good locality for GPS occupation.
--

<i>Country:</i> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
---	-------------------

Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark 0.2m below ground level.

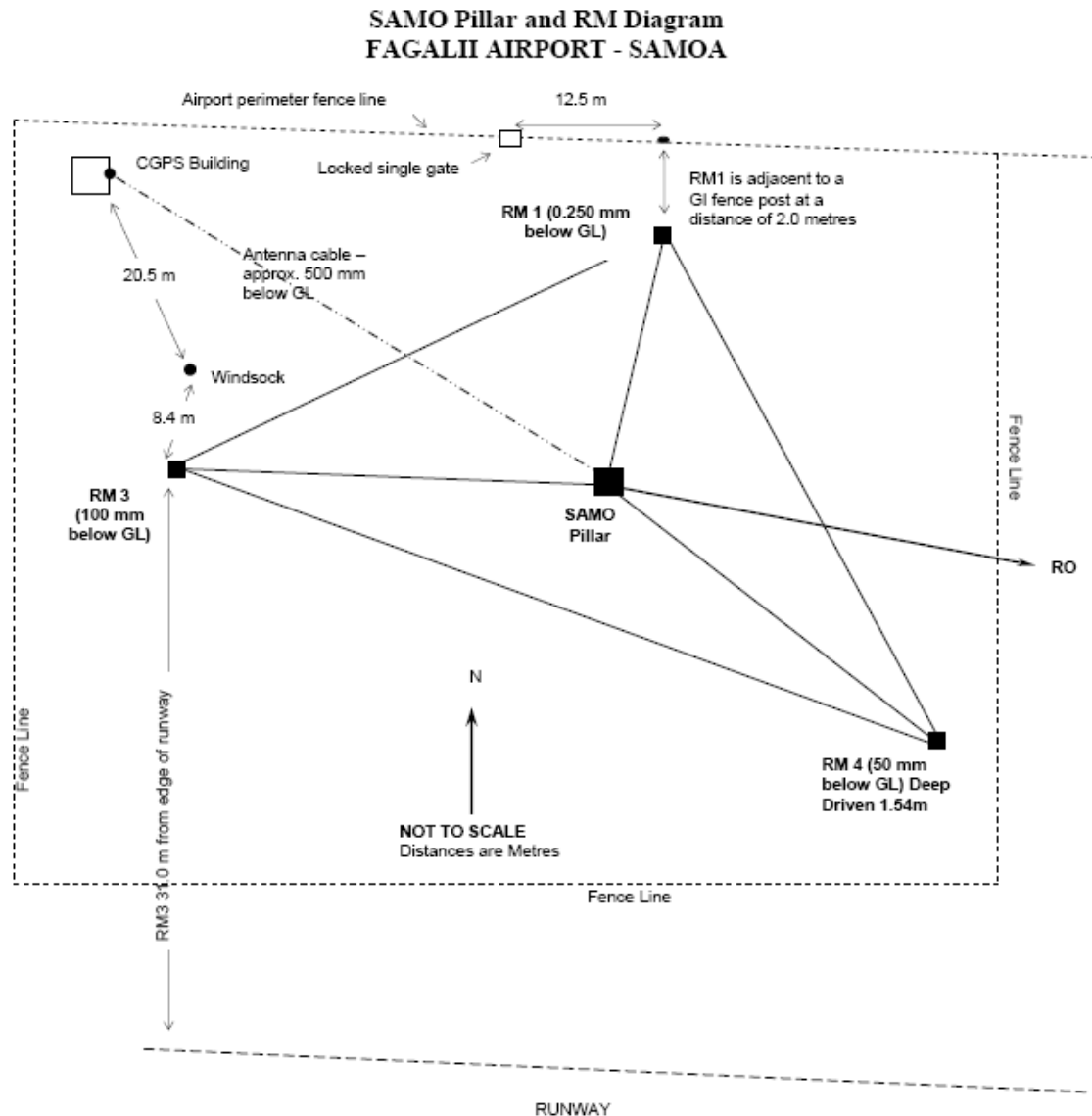
Locality sketch: Mark approximately 4500m from the tide gauge station.



Not to scale	Distances in Metres	Magnetic bearings
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Approved by: Geoscience Australia / SOPAC	Date: December 2006
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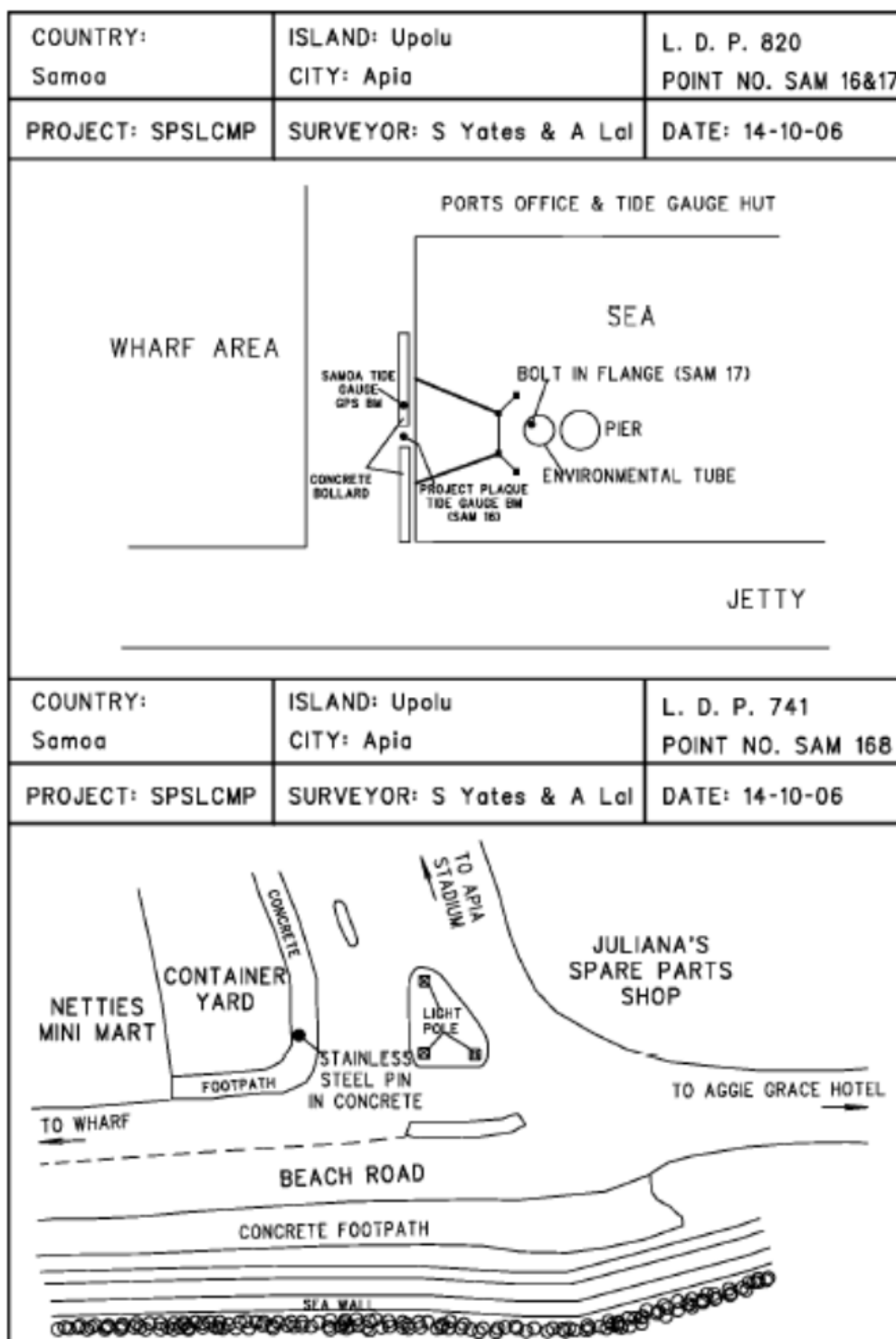
5 Western Samoa Reference Mark Locality Diagram



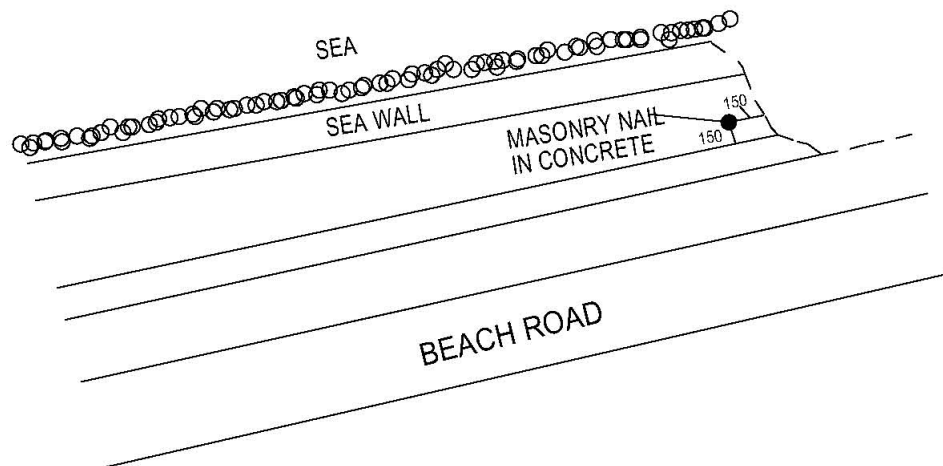
SAMO CGPS Pillar is within the Fagalii Airport compound approximately 4 kilometres SE from Apia City. The Pillar is approximately 250 metres East of the Airport Terminal past the Fuel Depot, and stands 1.5m high and is 0.4m in diameter. A one metre square concrete pad is at the base of the pillar. A stainless steel plate, 250mm in diameter, with a standard threaded 5/8 inch spigot is set in the top of the pillar. All height references are to the stainless steel plate (not to the spigot).

The three (3) Reference Marks and the RO consist of deep driven stainless steel rods, 20mm in diameter with a domed cap. All the reference marks and the RO are below ground level and are protected by irrigation valve boxes.

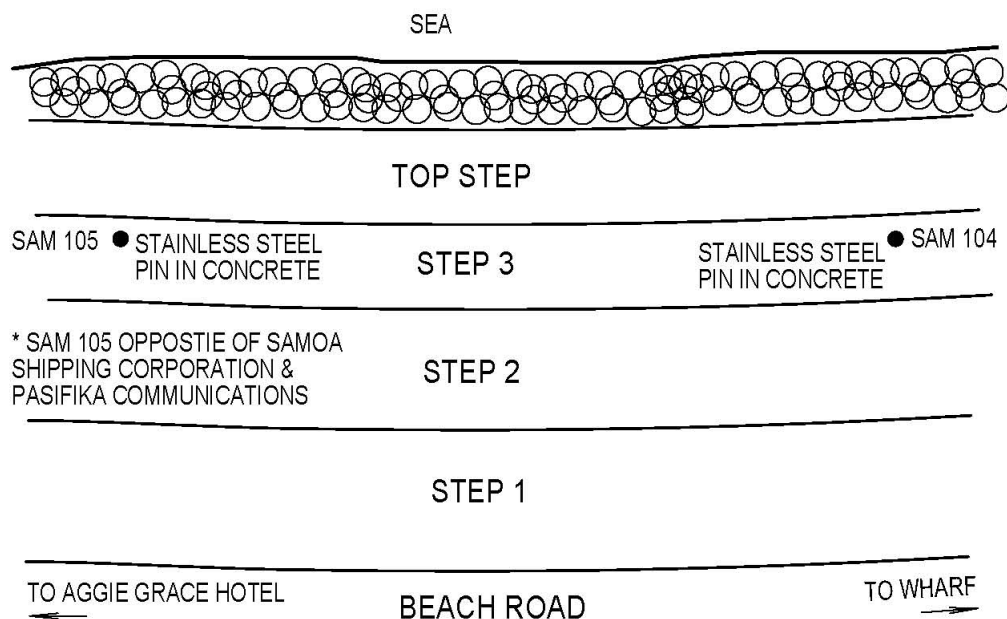
6 Permanent Holding Mark Locality Diagrams



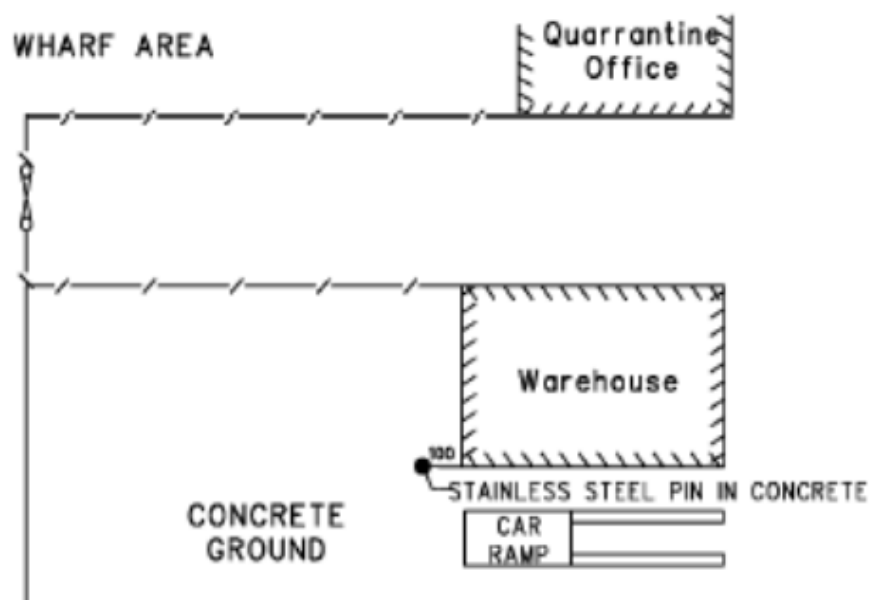
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 739 POINT NO. SAM 180
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 14-10-06



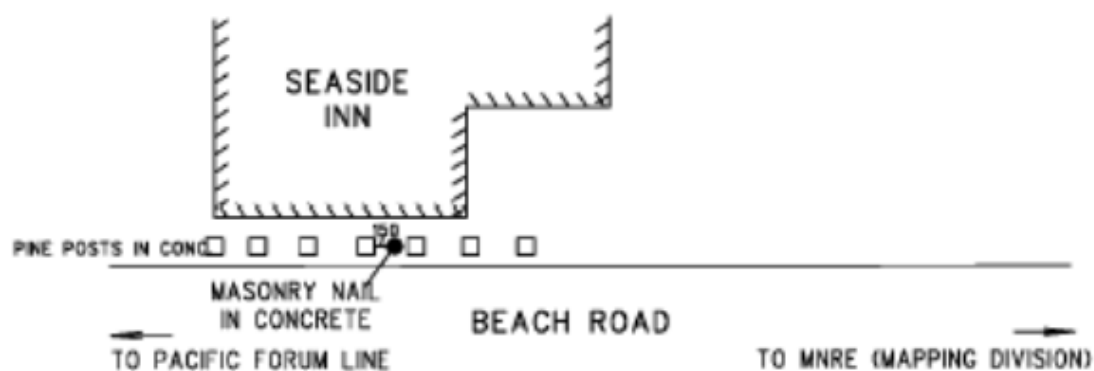
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 740 POINT NO. VARIOUS
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 14-10-06



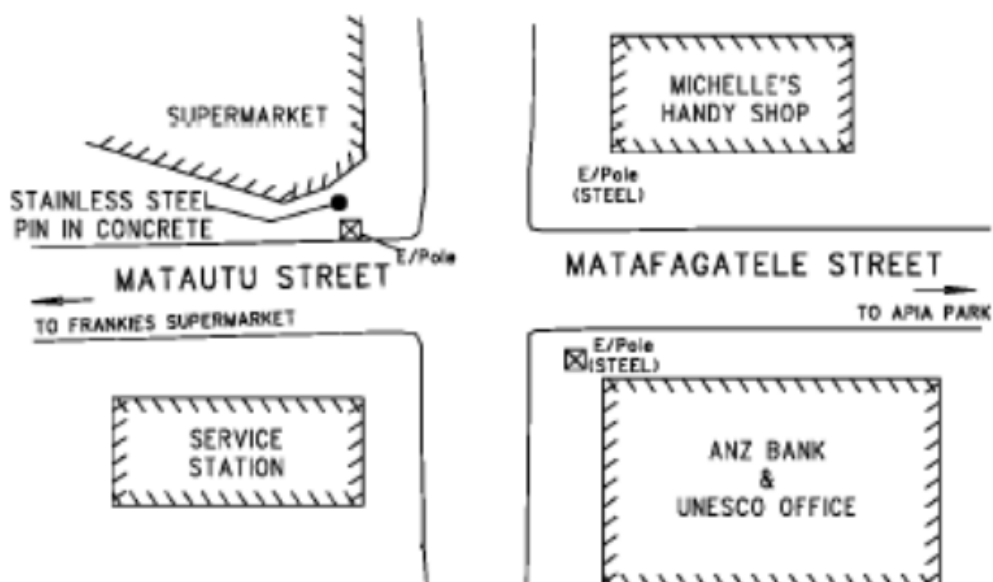
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 736 POINT NO. SAM 166
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 14-10-06



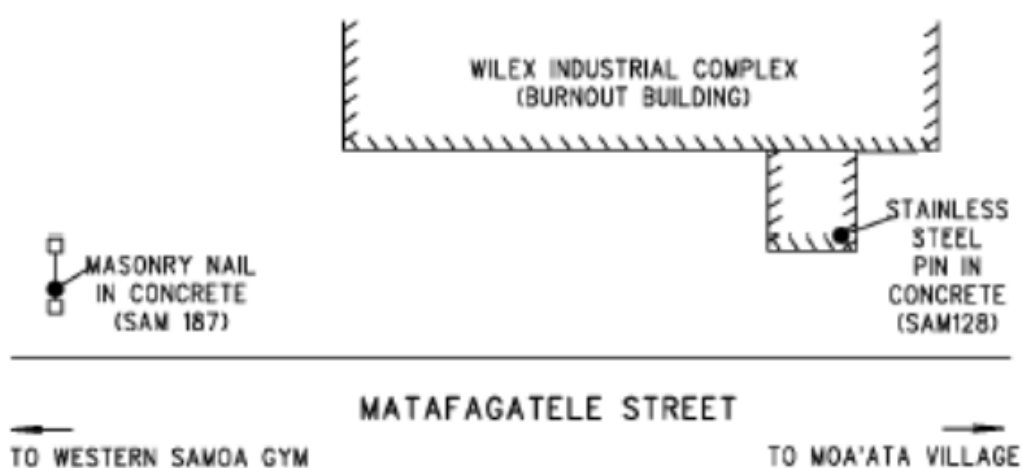
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 738 POINT NO. SAM 186
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 14-10-06

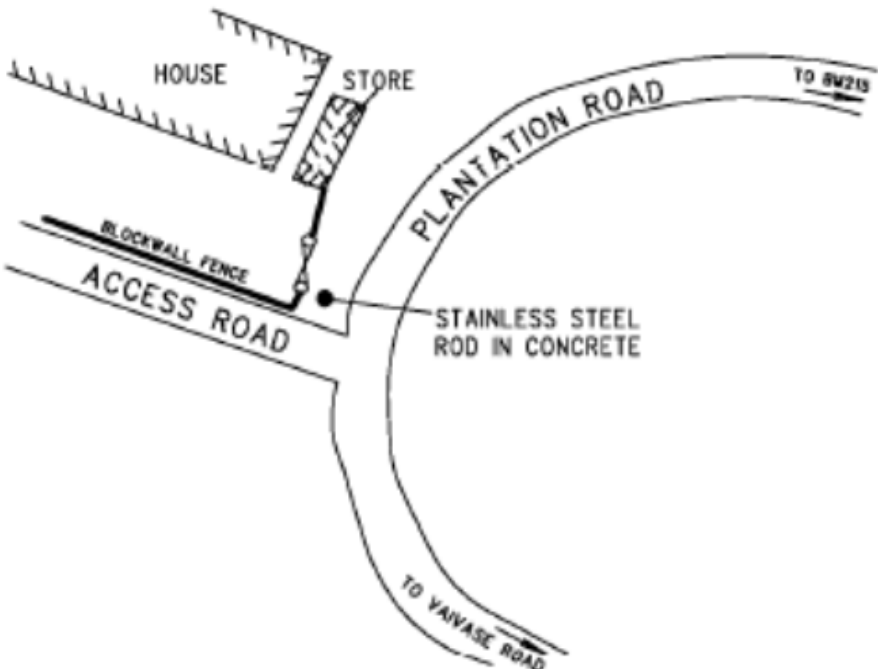
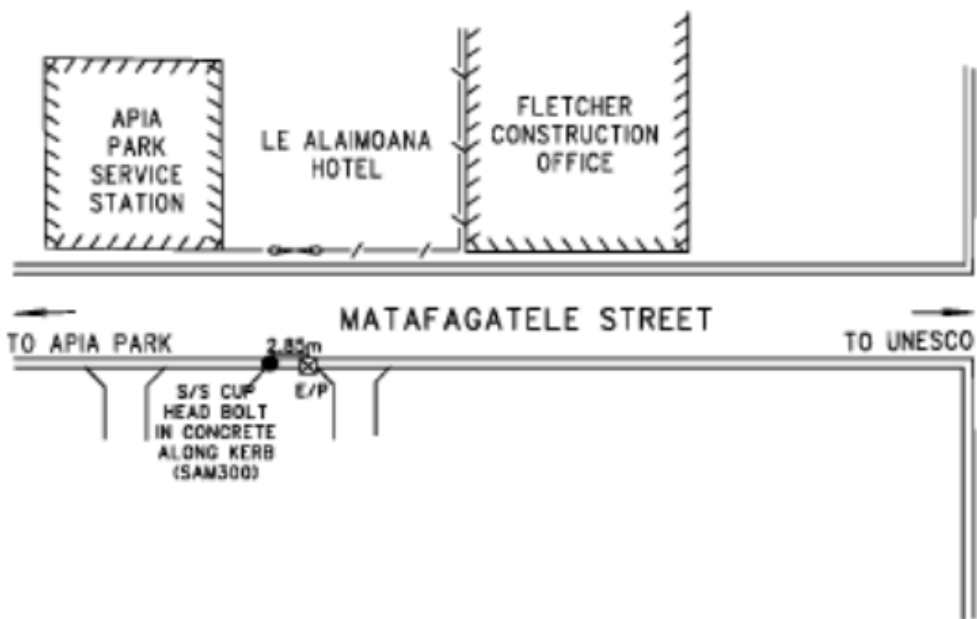


COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 745 POINT NO. SAM 170
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 14-10-06

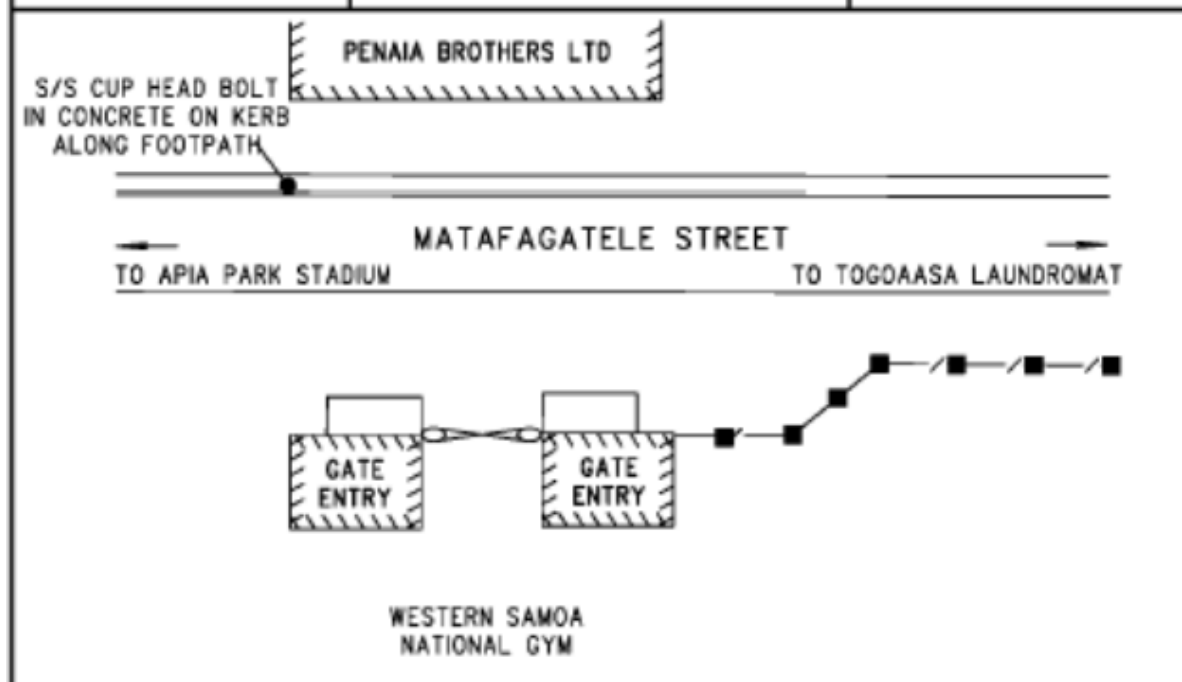


COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 749 POINT NO. VARIOUS
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 14-10-06

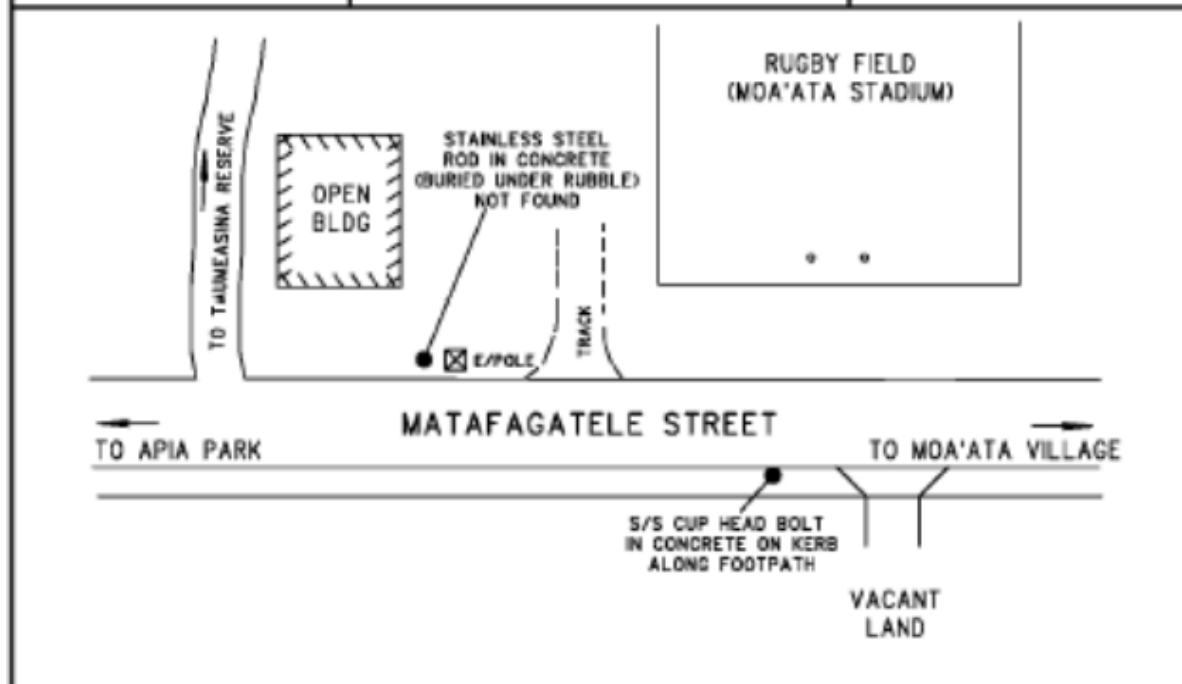


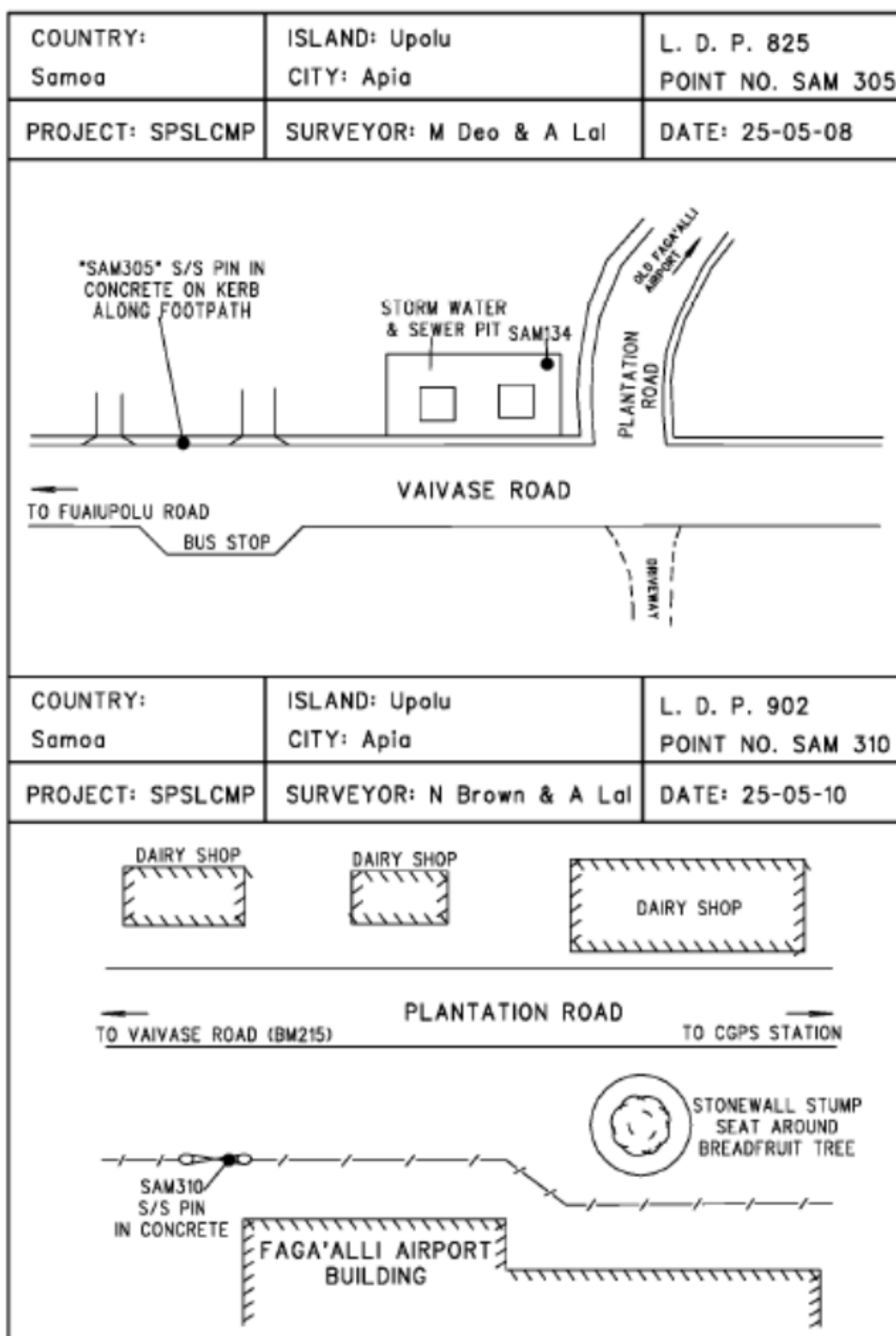
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 762 POINT NO. SAM 139
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 15-10-06
		
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 820 POINT NO. SAM 300
PROJECT: SPSLCMP	SURVEYOR: M Deo & A Lal	DATE: 27-05-08
		

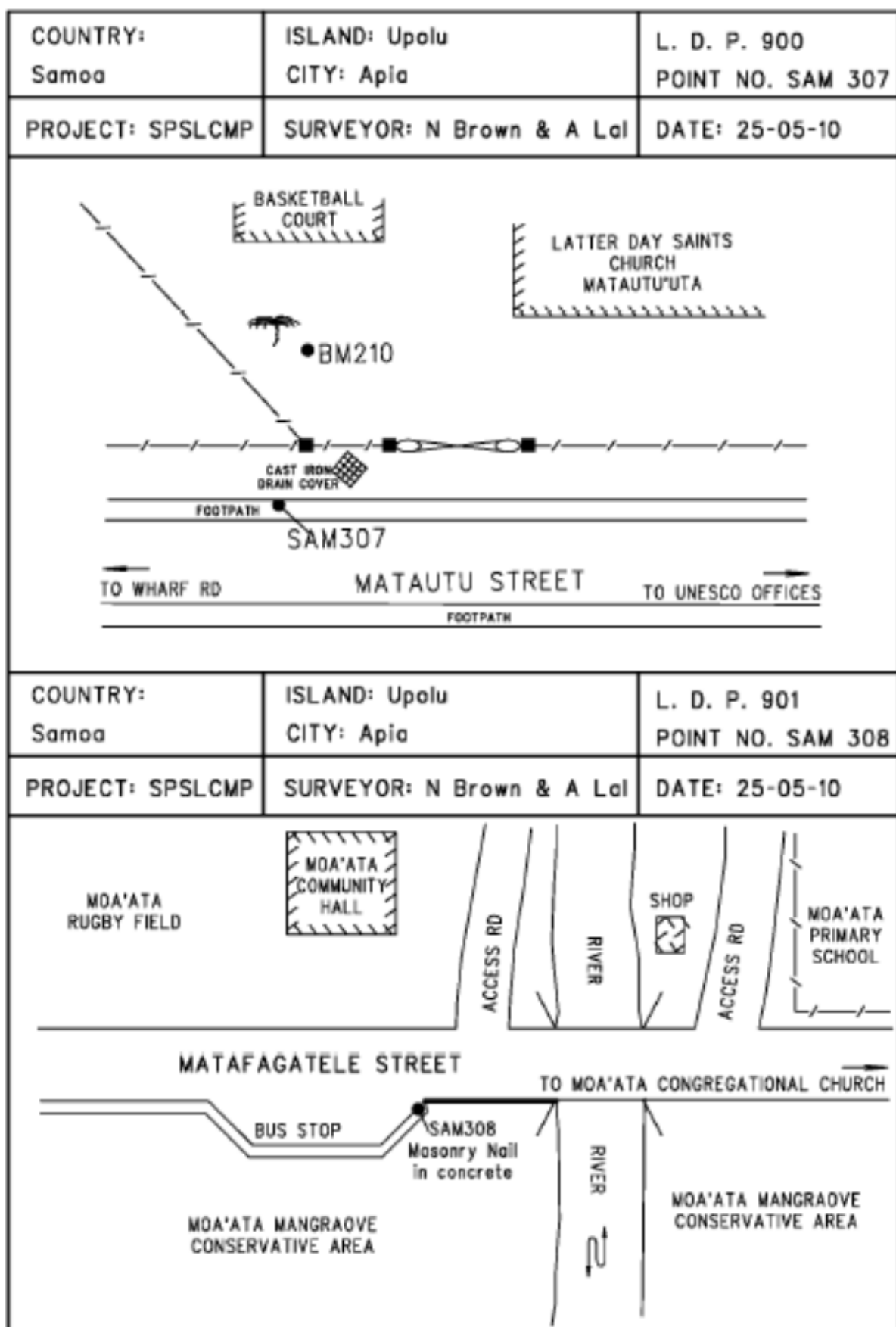
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 821 POINT NO. SAM 301
PROJECT: SPSLCMP	SURVEYOR: M Deo & A Lal	DATE: 25-05-08



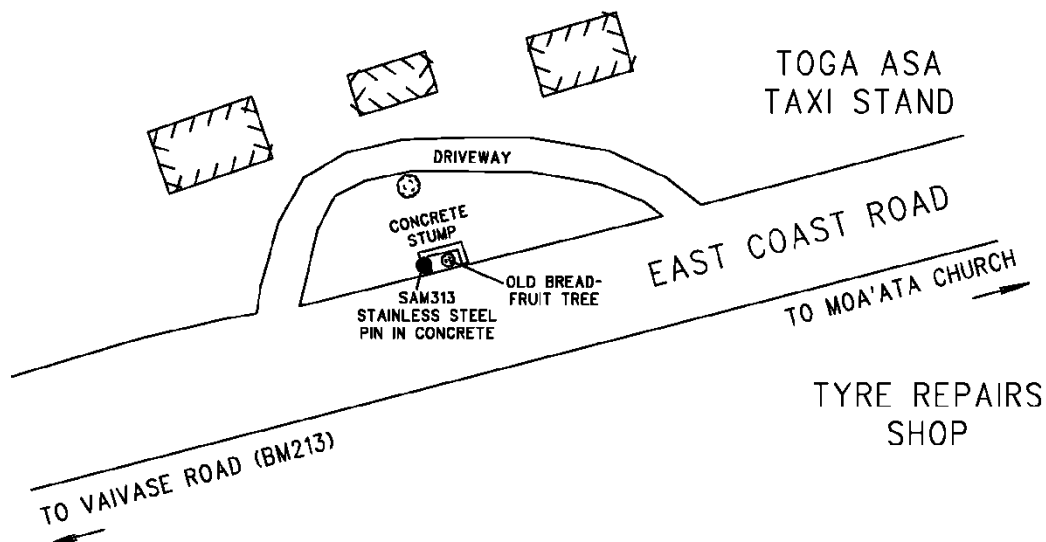
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 822 POINT NO. SAM 302
PROJECT: SPSLCMP	SURVEYOR: M Deo & A Lal	DATE: 25-05-08



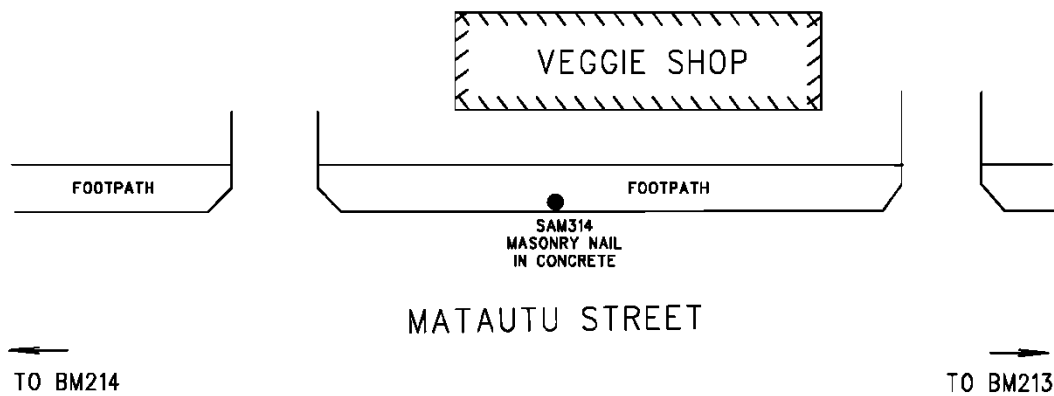




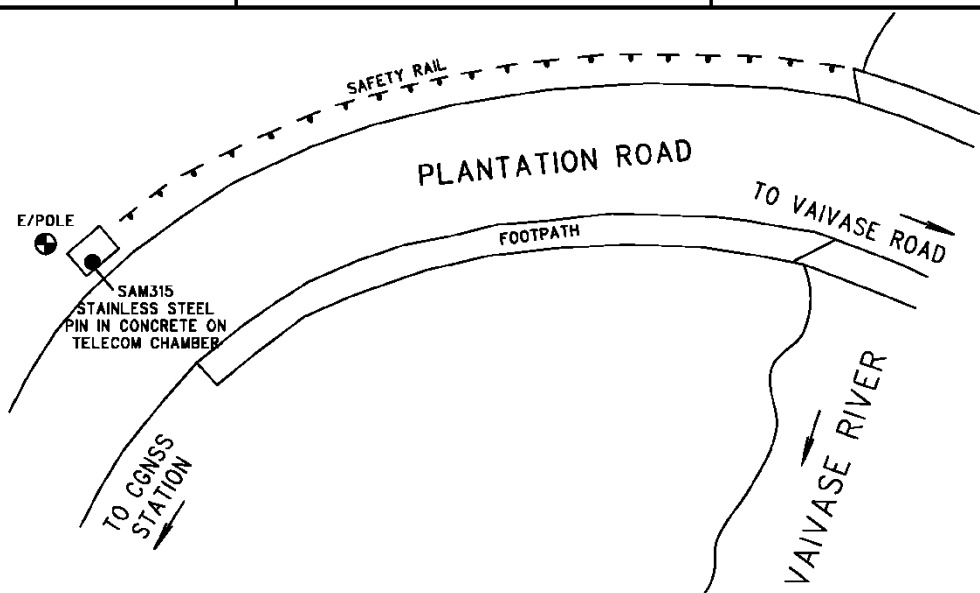
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 905 POINT NO. SAM 313
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 01-11-11



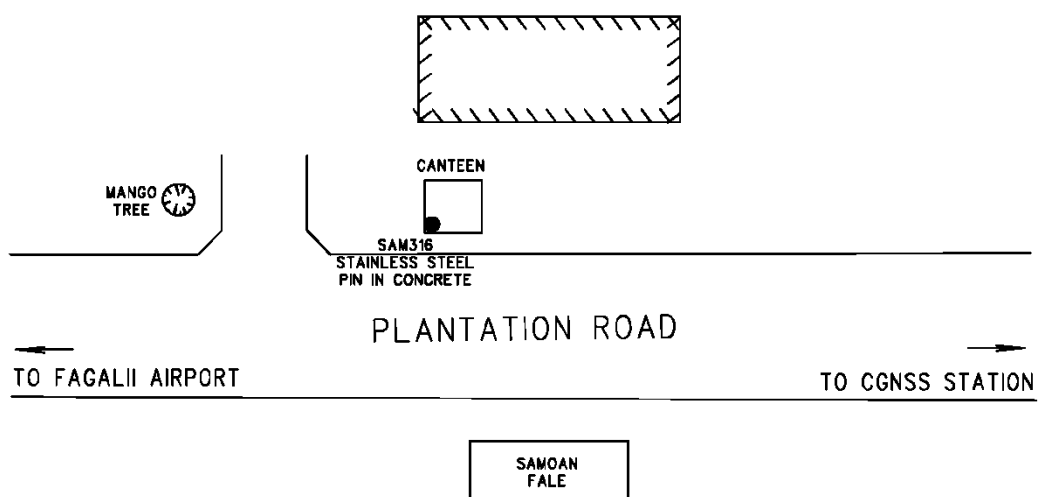
COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 906 POINT NO. SAM 314
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 01-11-11

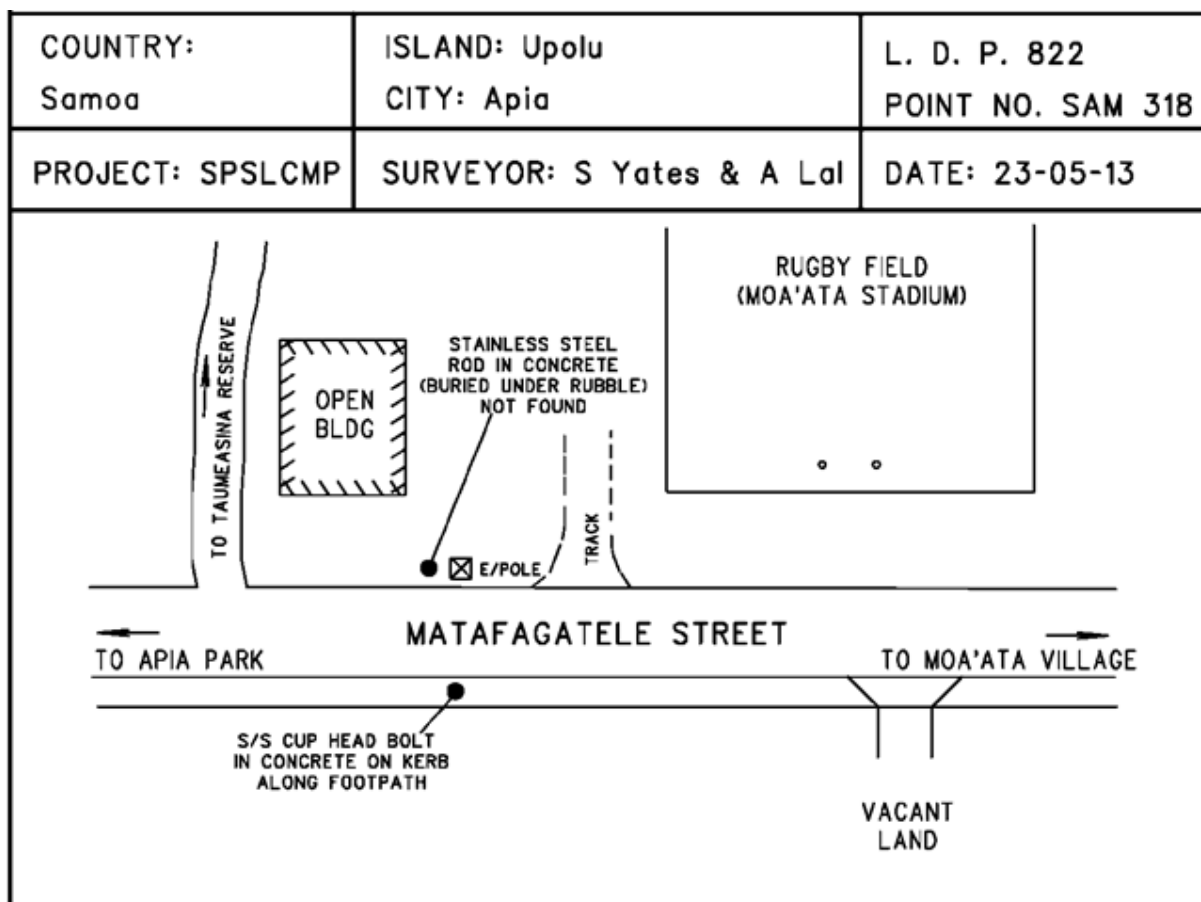


COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 907 POINT NO. SAM 315
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 01-11-11



COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 908 POINT NO. SAM 316
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 01-11-11





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.