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Reducing Vulnerability of Pacific ACP States

SAMOA

TECHNICAL REPORT ON AGGREGATE SOURCES ASSESSMENT IN SELECTED PARTS OF UPOLU AND SAVAI'I ISLANDS

Some facets of aggregate extraction in Samoa.

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EXECUTIVE SUMMARY

The construction boom in Samoa in the last decade has resulted in increasing demand on sand and gravel, which in turn, puts pressure on accessible coastal aggregate resources. Beach sand mining was prevalent in various parts of Upolu Island in the efforts of developers to meet those demands. Additionally, there is an ad hoc approach to developing aggregate resources whereby resource assessments and feasibility studies are ignored.

Coastal erosion was evident at some places as a result of ongoing beach sand mining. With the recent scaling up of lagoon-based dredge operations, beach sand mining has subsided in most places and seawalls have had to be constructed along the foreshore of some prominent mining areas. Be that as it may, it is essential to ensure that material being extracted for construction purposes meet certain requirements prior to use. In order to achieve this, it is important to devise appropriate policies and guidelines, and subsequently implement them to ensure the issues pertaining to sustainable aggregate resource development and management in Samoa are adequately addressed.

This report presents the outcomes of the aggregate surveys that were conducted on the islands of Upolu and Savai'i, Samoa, in March 2004 and October 2005. A nation-wide aggregate survey was requested during the 1st SOPAC-EU Project Multi-stakeholder Consultation Meeting that was held in Apia in April 2003. Both terrestrial and marine aggregate sources were investigated during the surveys. Field assessments involved inspection of active and potential sites, geological mapping, and onsite strength test using the Schmidt Hammer and sample collection.

For terrestrial sites, each source was inspected and in 2004 rock samples from the active quarries of Alafua and Saleimoa were collected and sent to Fiji for geotechnical tests. Basic tests that were carried out are porosity, density, and strength. In 2005 in-situ rock sources were tested using the Schmidt Hammer.

The marine aggregate survey was focused on the active and potential dredge sites in Upolu and Savai'i to determine the quality of sand and gravel at source through grain size and composition analyses. On Upolu, dredged sediment samples were collected from Vaiusu, Vaitele and Mulifanua dredge sites in 2004; and in 2005 surface sediment samples were collected from the seabed of Mulifanua, Aleipata and the mouth of the Vaisigano River. Additionally, a number of surface sediment samples were collected from Salelologa Harbour in Savai'i.

The results of the geological and geotechnical assessments of the terrestrial aggregate sources suggest that Saleimoa and Lemafa are good sources for high-stress applications such as road-sealing chips. Selective extraction is required at Alafua for this purpose. In Savai'i, crushed fresh lava flows from Puapua and Vaisala can potentially be used for sealing chips but the resource volumes at both sites are limited. However, a portion of the Saleaula lava field can support a medium-scale quarry operation.

Due to the relatively high percentage of *halimeda* in the sands of Vaitele and Mulifanua, sediments extracted from these two sites are considered unsuitable for construction. However, they can be used for other applications such as landfill and reclamation. The other sites, namely, Vaiusu, Aleipata, and Salelologa possess relatively good quality material with coral and shell fragments being the major constituents. Terrestrially-derived material that occur at the mouth of the Vaisigano River are of excellent quality but due to the limited volume of the resource, it cannot sustain a large-scale extraction operation.

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1. INTRODUCTION

Beach sand mining has been prevalent in various parts of Upolu Island in the last decade as the demands from developers and others continued to grow. Coastal erosion was evident at some places as a result of ongoing beach sand mining. With the recent scaling up of lagoon-based dredge operations, beach sand mining has subsided but still remains an issue. Additionally, it is essential to ensure that material being extracted for construction purposes meet certain requirements prior to use.

At the time of the surveys sand and gravel that are used for construction purposes in Samoa were extracted from both terrestrial and shallow marine sources with minor extractions in rivers and beaches. Major aggregate extraction operations seem to concentrate near Apia and the surrounding areas. This is common in most Pacific Island Countries (PICs) where building constructions and major infrastructure developments are being carried out in and around urban and peri-urban areas. The high demand for aggregate in these areas has prompted developers to try to identify additional accessible resources that occur at proximal distances from these major markets.

The assessment of aggregate resources is essential in determining the quality and quantity of the resource prior to development. Once the potential of an aggregate source is confirmed, a feasibility study may be instituted to ascertain the viability of an extraction operation and to determine the likely social and environmental impacts; and subsequently present appropriate mitigating measures. This among other things such as quality control are crucial to the use of better quality sand and gravel on specific applications that will ensure the structural integrity of buildings and public infrastructures in the country.

This report presents the procedures and the outcomes of the assessments that were carried out in March 2004 and October 2005 on selected terrestrial and marine-based aggregate sources. It highlights certain aspects of development and management that need to be addressed in order to achieve long-term sustainability of the aggregate industry in Samoa.

1.1 Geology of Samoa

1.1.1 Brief Regional Setting

The Samoan island chain consists of high volcanic islands, atolls and submerged reef banks, and seamounts near the southwest margin of the Pacific Plate (Figure 1). The chain trends in a southeastern direction and the islands are unusually volcanically active on both the eastern and western end of the chain. This has complicated the existing results of geological studies that are consistent with a hot spot origin similar to Hawai'i (Keating, 1992).

1.1.2 Summary of the Geology of Upolu and Savai'i

Kear and Wood (1959) recognised six major volcanic formations within the volcanic islands of Samoa. These formations occur in the following chronological order: Fagaloa Volcanics being the oldest, Salani Volcanics, Mulifanua Volcanics, Lefaga Volcanics, Puapua Volcanics, and the youngest of them all is the Aopo Volcanics.

The Fagaloa Volcanics occur predominantly in the northeastern district and the central mountains of Upolu and to a lesser extent in the southwestern part of the island and are found to much lesser extent in northern and south-central Savai'i. They consist of basaltic lava flows of aa and pahoehoe in regular sequence, either non-porphyritic or containing phenocrysts of olivine, augite and feldspar, with associated dykes, tuffs and cone deposits. Rocks of the four most widely distributed volcanic groups (Salani, Mulifanua, Lefaga and Puapua) rest unconformably on the Fagaloa rocks (Kear and Wood, 1959). Most of these younger units are olivine-rich basalts, which strongly resemble one another petrologically (Keating, 1992).

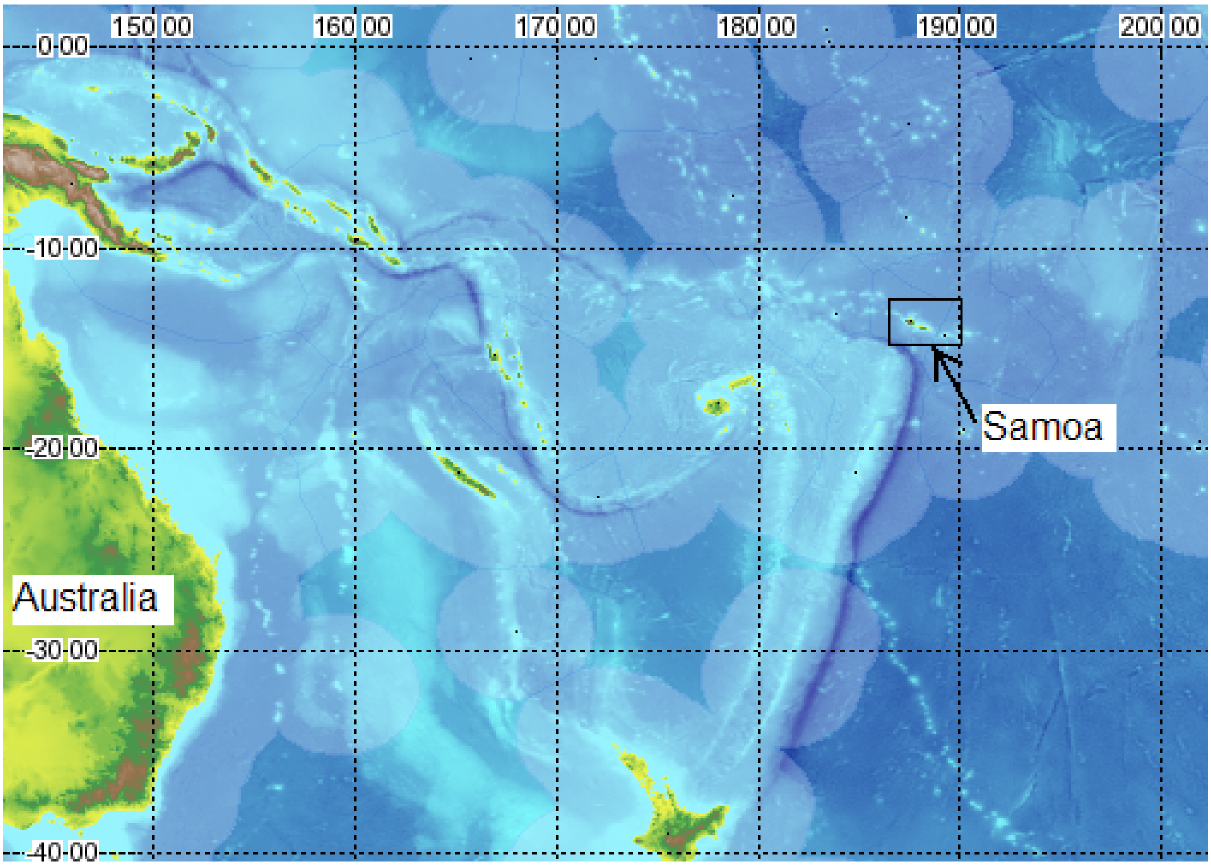

Figure 1. The locality of Samoa in the southwest Pacific region.

The Aopo Volcanics were erupted within the last 200 years, the latest eruption ceasing in 1911. They occur only in northern Savai'i. The lavas are now described as partly weathered massive pahoehoe lava with the occurrence of aa lavas on a much lesser extent in few places. The weathered part is largely restricted to the surface due to prolonged exposure to air and water, whereas the inner part of the lava remains fresh and highly vesicular.

1.1.3 Petrography

An important preliminary aspect of any aggregate investigation is the petrographic examination of representative samples. Identification of the constituents of the sample is usually a necessary step towards recognition of the properties that may be expected to influence the behaviour of the material in its intended use (ASTM C 295 – 98). For the purpose of aggregate sources assessment, a petrographic examination is made for the following reasons (Collis and Fox, 1985):

1. To describe and classify the constituents of the sample.
2. To assess the physical and chemical character of the constituent material.
3. To determine the relative amount of the constituents of the sample. This is necessary where the constituents differ significantly in character of properties and which may have a bearing on the quality of the material, e.g. the amount of secondary clay minerals may cause swelling on wetting.

Tabulated below is the summary of petrographic analysis that was carried out on the volcanic rock specimens of Samoa as reported in Kear and Wood (1959).

Table 1. Petrographic description of the different volcanic rock formations that occur in Upolu and Savai'i islands, Samoa.

Volcanic Formation	Rock Types	Petrography
Fagaloa Volcanics	The formation includes picrite to olivine basalt, feldspathic basalt, hornblende andesite and trachyte. Olivine basalt is the commonest rock in the Fagaloa Volcanics.	*Picrite basalt:* contains abundant phenocrystic olivine and micro-phenocrystic titaniferous augite in an intergranular mesostasis of ilmenite and magnetite, pyroxene and accessory apatite. Euhedral and anhedral crystals of olivine are present. *Olivine basalt:* Olivine is phenocrystic as large euhedral commonly replaced to some degree by iddingsite or small iron-ore granules. Pyroxene occurs as abundant micro-phenocrysts in the groundmass. Large laths of feldspar are rare. *Hornblende andesite:* has an even holocrystalline trachytic texture with phenocrysts of brown hornblende seated in well-formed small plagioclase laths.
Salani Volcanics	Contains a suite of picrite basalts, and olivine dolerite and basalts, most of which show to some degree the effects of zeolitization and other late-stage deuteric alterations. Olivine basalts form the dominant rock types of this formation.	*Picrite basalt:* contains phenocrystic olivine in euhedral and anhedral forms, commonly rimmed or pseudomorphed by iddingsite. Phenocrysts of pink pyroxene and occasional crystals of feldspar were observed in some specimens. Intergranular groundmass constituents are magnetite, ilmenite, apatite, titanaugite, occasional olivine and rare laths of labradorite. *Olivine basalt:* Phenocrystic olivine shows some degree of alteration to iddingsite. Zoned pink titanaugite is the commonest of other phenocrysts and is often found as micro-phenocrysts in the groundmass. Feldspar laths, zoned and twinned, range from basic to acid labradorite. Traces of zeolite development are observed in most of the rocks of the Salani formation.
Mulifanua Volcanics	Consists of olivine basalts, and dolerite to analcite basalts.	There is strong petrologic similarity between the rocks of the Mulifanua formation and those already described from the Salani Volcanics. Not only are the types are exactly the same, but the detailed petrographic descriptions are also the same.
Lefaga Volcanics	Composed of picrite basalts and dolerites.	*Picrite basalt:* contains euhedral and anhedral olivine phenocrysts. The pyroxenes of these rocks appear to be titaniferous and are confined to the groundmass along with sub-equal quantities of iron-ore. Plagioclase feldspars are accessory. *Dolerite:* contains phenocrystic olivine which has been strongly resorbed and carries heavy marginal zones of iddingsites. Some pyroxene crystals are titaniferous and are subophitic to the labradorite feldspar.
Puapua Volcanics	Largely consists of picrite basalts, olivine basalts and vitric tuff.	*Picrite basalt:* phenocrystic olivine and some peridotitic fragments are seated in the groundmass consisting of intergranular pyroxene, iron ores, rare olivine and zoned plagioclase laths. Occasional small patches of glass appear in one of the specimens. *Olivine basalt:* large crystals of olivine, which are partly resorbed, and labradorite feldspar were observed. Pyroxenes are confined to the groundmass along with ilmenite and feldspar. A specimen consists of approximately 60 % basaltic glass with embedded phenocrysts of pyroxene, labradorite and olivine. *Vitric tuff:* shows no sign of conversion to palagonite since the refractive index of the clear brown glass shards is always high. Crystal fragments of olivine and pyroxene are present in small quantities but there is a notable absence of accidental rock fragments other than older vitric tuff.
Aopo Volcanics	Composed of ropy, vesicular, porphyritic (feldspar and olivine) basalts.	No thin section specimen was prepared for the rocks of this formation.

1.2 Origin of Aggregate

Natural occurring sand and gravel originate from both terrestrial and marine sources. Rock fragments that derive from terrestrial environments are being dislodged from their natural sources commonly by gravity, weathering, tectonic and seismic activities. They tend to accumulate in low-lying areas such as valleys and rivers by natural transportation processes such as landslides, erosion, and the carrying capacity of wind and river water. This material is normally deposited, either temporarily or permanently, downstream from their sources. In Samoa, volcanic rocks are major sources of aggregate and are available in in-situ hard rock form, river gravel deposits and may also occur in finer-grained sand and gravel along coastal zones.

The aggregate material that occurs in the lagoon areas is a combination of terrestrially-derived sand and gravel, and material that are produced within the marine environment. In the tropics one of the major sources of sand and gravel are coral reefs. In addition, marine organisms that thrive on shallow marine environments such as *foraminifera*, *halimeda*, and shells are also significant contributors to the sand resources. They normally occur in sediment deposits as fragments of dead material of these organisms.

The relative abundance of different components is influenced by various factors like the amount of corals and organisms that dwell in and around the area, the proximity of river / creek mouth from the site, and the current regimes that aid sediment transportation in the offshore environment. For example, an extraction area close to a river mouth is expected to yield significant amount of terrestrially-derived material. On the other hand, a sediment deposit close to an area near coral reefs and where abundant marine organisms thrive is expected to have high marine-derived material.

2. BACKGROUND

Three previous studies were carried out in the shallow lagoon areas in selected parts of Upolu and Savai'i islands. The first was conducted by the New Zealand Oceanographic Institute (NZOI) under contract to SOPAC in December 1988 to: i) identify nearshore sand and gravel resources for construction purposes; and ii) capture baseline information for inshore areas for coastal zone management (Lewis et al. 1989).

The second survey was conducted by SOPAC in 1995 in Vaiusu Bay at the request of the government of Samoa (Smith, 1995). The objectives of this survey were to: i) identify and map alternative sand and aggregate resources in Vaiusu Bay, and ii) estimate potential volumes of resources within the identified area. During this survey 60 jet-probe holes were drilled into the lagoon floor to ascertain sediment thickness, obtain samples for grain size analysis, and determine sediment distribution and composition.

The most recent study relating to aggregate assessment was funded and carried out by the Korean Institute of Geology, Mining and Materials (KIGAM) at the request of the Government of Samoa through SOPAC. One of the objectives of the KIGAM study was the identification of potential areas for future aggregate assessment (Kim and Lee, 1999). The study area was focussed along the coastal strip between Puapua and Salelologa villages, the most populous part of Savai'i.

Offshore dredging operations in Vaiusu Bay has been ongoing for nearly thirty years (Tawake, 2004). In the early days of dredging, backhoe excavators and draglines were used to extract sand and gravel at this site at some social and environmental costs.

Figure 2. *Various stages of dredging in Vaiusu Bay, northwest of Apia.*

As Smith (1995) reported, these were some of the impacts of offshore dredging at Vaiusu:

- high water turbidity at the site;
- creation of excavation pits in the seabed;
- pollution related to operations;
- shoreline erosion;
- poor flushing of semi-enclosed bodies of water due to the construction of causeways; and
- aesthetically displeasing remains of old working and rusting equipment.

The company involved acquired a suction pump dredge system in 2001, which has been in operation since. As witnessed in 2004, this extraction process was not the best practice as a leaking pipe (Figure 2a) and the process of sediment discharge near the shoreline (2b) were significantly contributing to elevated water turbidity. Sediment stockpiling (Figure 2c) and removal (Figure 2d) from the shoreline also contributed to the elevated turbidity level and the interference with sediment supply and transport (the "draw-down effect") of sediments along the coast.

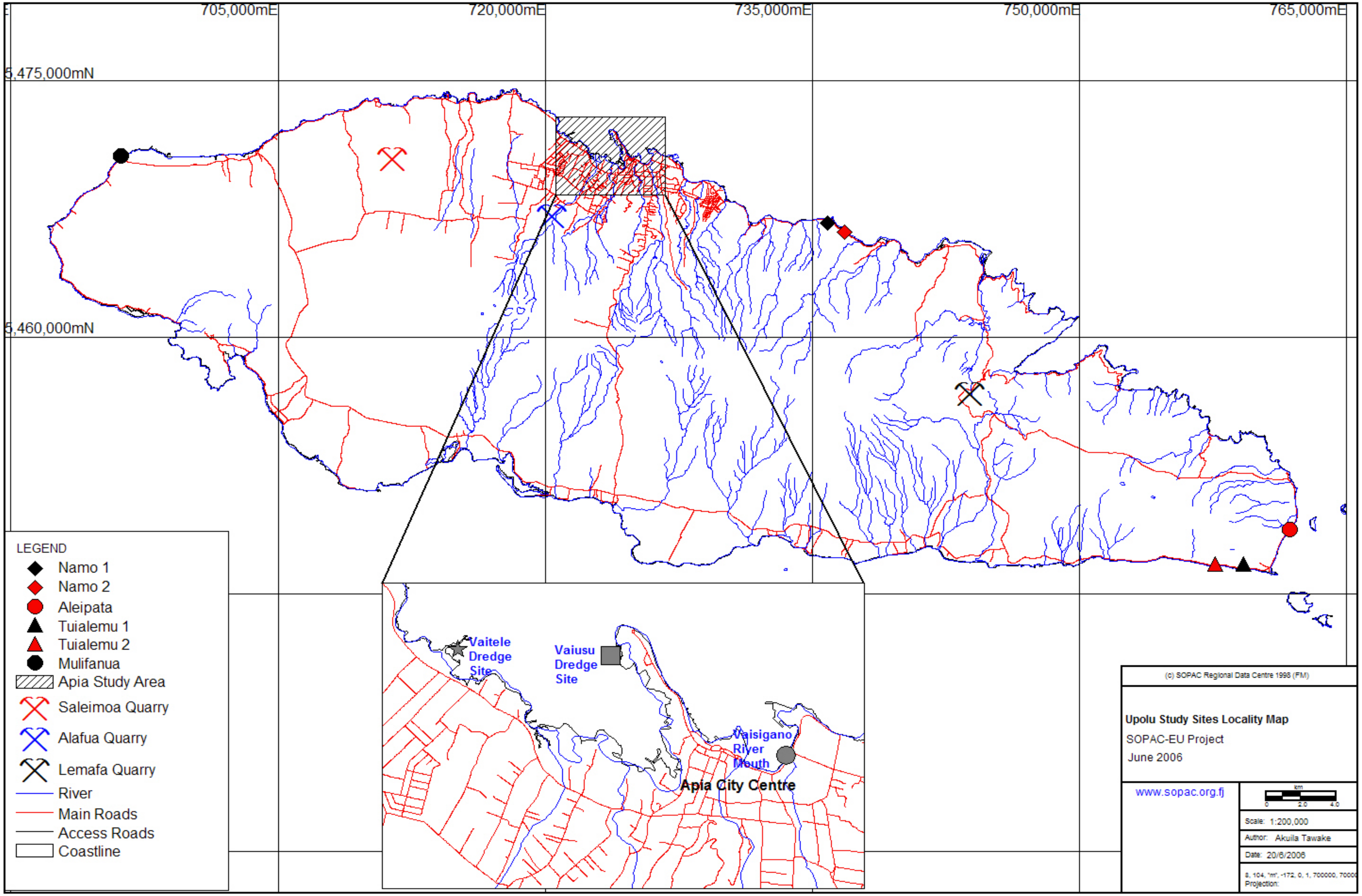

***Figure 3.** Upolu study sites locality map.*

During the site visit in October 2005, it was discovered that another dredge company by the name of Strickland Brothers has been extracting aggregate on the landward side of Vaiusu Bay. This extraction operation employs a tug-barge-backhoe excavator combination. The tug-boat tows the barge to the extraction site and the backhoe excavator on the barge does the extraction. Once the barge is filled up, it is towed back to shore by the tug-boat and off-loaded.

Lewis et al. (1989) reported dredging of the boat channel linking the wharf with the deeper part of the lagoon at Aleipata in late 1988 using a backhoe excavator.

2.1 SOPAC-EU Project Intervention

Under the SOPAC-EU Reducing Vulnerability Project, one of the three key focal areas is the identification and assessment of potential aggregate sources that can be used for construction purposes. This component of the Project also deals with issues pertaining to planning, development and management of sand and gravel resources in the PICs. It was decided based on in-country stakeholder consultations that the Project would concentrate on selected intervention areas on the two principal islands of Upolu and Savai'i.

At the initial inception of the Project, two multi-stakeholder consultation Meetings were held in Apia in 2003. The first one was held in April to introduce the Project to stakeholders and to discuss proposed activities for Samoa. The second meeting was held in December where relevant issues were identified and tasks were subsequently formulated. Aggregate-related activities requested included assessment of selected sites nation-wide with the short-term interest being in identifying potential extraction sites.

The identified tasks were refined in consultation with relevant stakeholders and subsequently implemented during the 2004 and 2005 field surveys covered in this report.

2.2 Survey Sites

The preliminary aggregate assessment work in Samoa was carried out in two phases – the first in March 2004 and the second in October 2005. The 2004 assessment was confined to the island of Upolu where the Alafua and Saleimoa quarries (Figure 3) were inspected and hard rock samples were collected. In addition, a number of dredged sediment samples from three offshore dredge sites, namely Vaiusu, Vaitele and Mulifanua (Figure 3) were also collected for further scientific analyses. Samples were sent to Fiji via the SOPAC survey boat that was conducting oceanographic surveys around Samoa at the time.

Further preliminary assessments were conducted in October 2005 in an endeavour to assess potential terrestrial and marine aggregate sources. On Upolu, additional samples were collected from Mulifanua, together with sediment samples from Aleipata and at the mouth of the Vaisigano River (Figure 3) that discharges into the Apia Harbour.

Hard rock sources at Namo, Lemafa and Tuialemu (Figure 3) were inspected and tested. On the island of Savai'i, preliminary assessments were carried out at Salelologa Harbour, the old and new Puapua quarries, the Saleaula Lava field, Fagaloa Volcanics and the Vaisala Quarry (Figure 4).

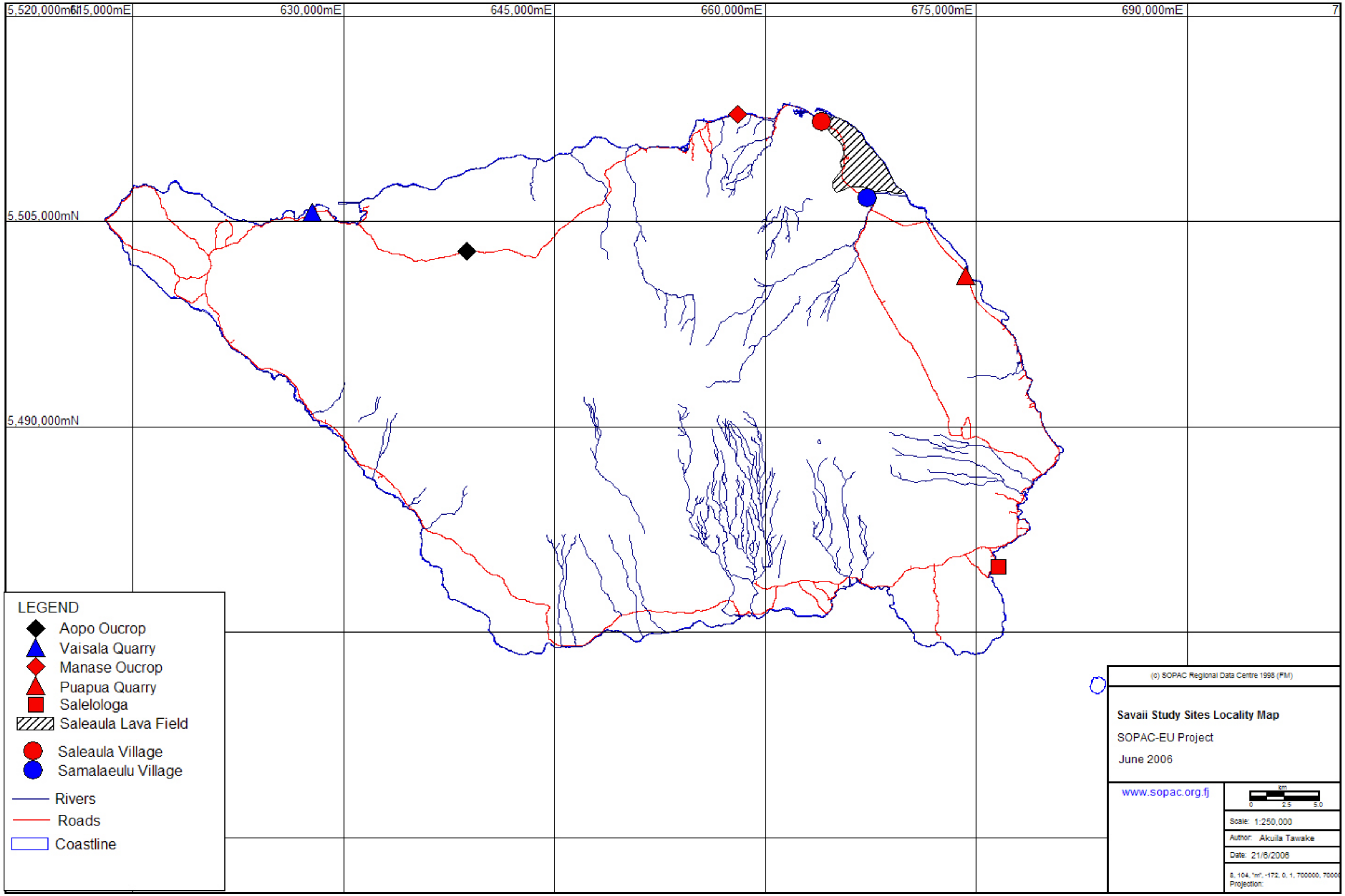

Figure 4. *Savai'i study sites locality map.*

2.3 Environmental Considerations

The environmental considerations for the Mulifanua dredge site and the potential sites of Aleipata and Salelologa are highlighted in Tawake (2005a). The proposal by Samoa Ports Authority (SPA) to dredge the vicinity of the Salelologa Wharf to allow bigger ships to use the wharf warrants an environmental impact assessment. These three sites are considered environmentally sensitive as discussed in Tawake (2005a).

3. METHODS

The assessment of aggregate sources involves site inspection, mapping, sample collection and analyses, and data compilation and interpretation. For sediment samples that were collected from the offshore areas, grain size and composition analyses were performed on each sample to determine the relative abundance of each grain size class and various constituents of the sediment material.

The details of all sample analyses and tests are highlighted in Appendix 1.

3.1 Marine Sediment Sampling

A total of eighteen marine sediment samples were collected from three different dredge areas in Samoa in March 2004. All these samples were hand-dug from the dredged sediment stockpile at each of the three active dredge sites at the time. Six samples (Vaiusu #1 – Vaiusu #6) were collected from Vaiusu, another six from Vaitele (Vaitele #1 – Vaitele #6), and an additional six samples from Mulifanua (Mulifanua #2 – Mulifanua #7).

In 2005, an additional twenty-five marine sediment samples were collected from four different locations, three in Upolu and one in Savai'i. Six samples were collected from Mulifanua (MF05 #1 – MF05 #3, MF05 #5 – MF05 #7) around the vicinity of the current dredge site. Eight samples were collected from Aleipata (AP05 #1 – AP05 #8), two from the mouth of the Vaisigano River (VR05 #1 and VR05 #2), and nine samples were collected from Salelologa (SL05 #1 – SL05 #9) in Savai'i. All these samples were hand-dug from the surface of the seabed at various locations at each site and a tape measure was used to record the water depth at each sample location.

Additionally, a hand-held GPS was used to record the coordinates of each sampling point. The coordinates that were recorded for each sample location in the three main sites of Mulifanua, Aleipata and Salelologa are given in Appendix 2. These coordinates are used to plot the sampling points at each site as shown in Figures 5, 6 and 7.

3.1.1 Mulifanua

This area is described as a shallow lagoon environment with discontinuous fringing reefs. SPA is currently dredging the boat channel at the wharf and its vicinity. Sediment samples were collected from different points at the site as shown in Figure 5. Significant amount of seagrass and *halimeda* were observed on the seafloor.

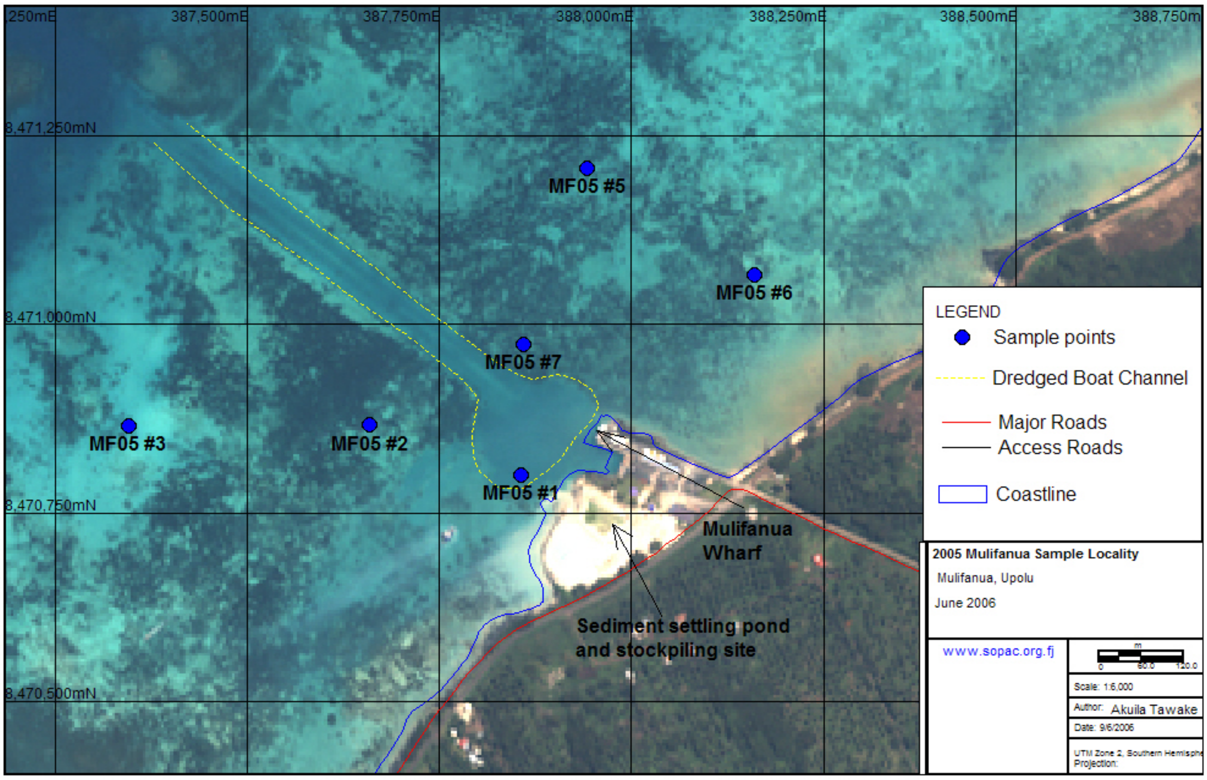

Figure 5. *The 2005 Mulifanua samples locality map.*

3.1.2 Aleipata

This is a shallow lagoon environment enclosed by fringing reefs with isolated coral heads inside the lagoon. Sediment samples were collected from different points around the wharf as shown in Figure 6.

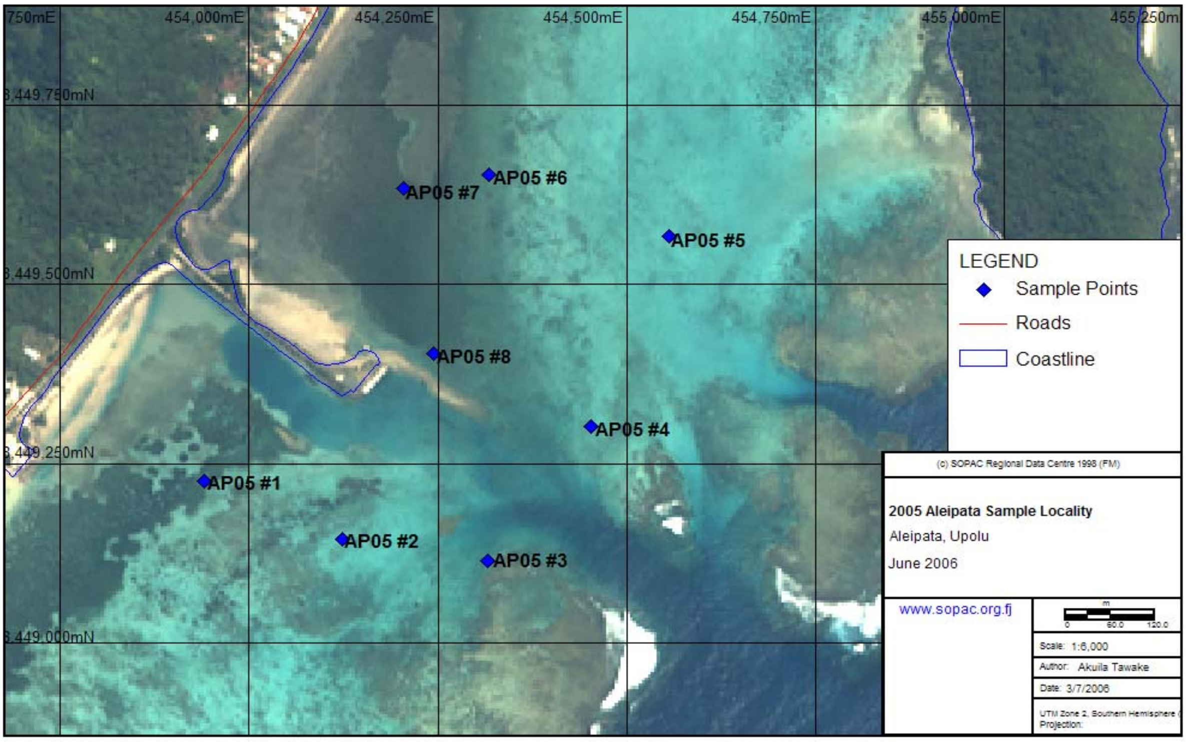

Figure 6. *The 2005 Aleipata samples locality map.*

3.1.3 Salelologa

Like Mulifanua, Salelologa Harbour is an important port that has the docking facilities for the transportation of passengers and cargo to and from Savai'i. The harbour is generally shallow with a relatively deeper natural boat channel that links the wharf and the open ocean. Sediment samples were collected from different points in the lagoon as shown in Figure 7.

The details of the marine sediment analyses are shown in Appendices 8 and 9.

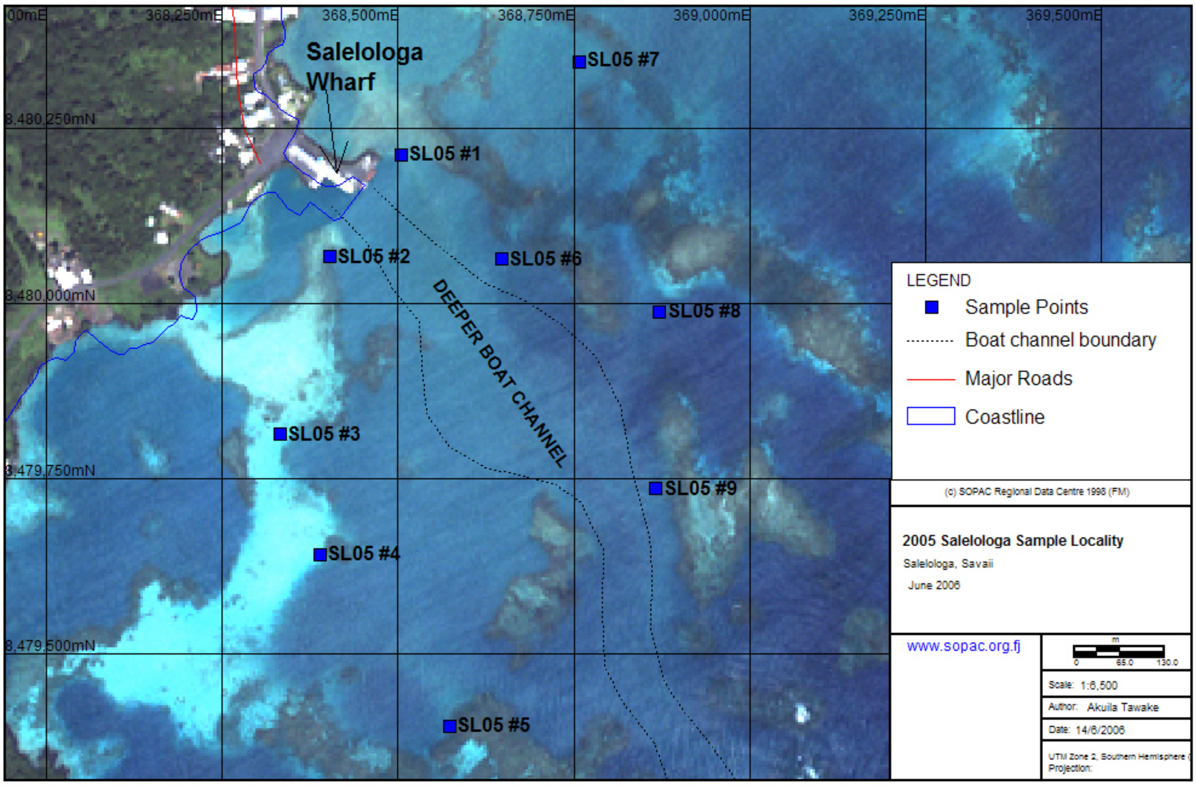

Figure 7. *The 2005 Salelologa samples locality map.*

3.2 Terrestrial rock sampling and testing

Three rock samples in the form of boulders were collected from Alafua Quarry and two from Saleimoa Quarry in 2004 and they were sent to Fiji for geo-technical tests. These rock samples were cut into appropriate sizes and strength tested using the Schmidt Classification Hammer and the Point Load Tester. In October 2005, potential aggregate sources on both Upolu and Savai'i islands were also inspected and tested for freshness, elasticity and strength using the Schmidt Hammer.

Sites that were assessed in Upolu are Namo, Lemafa and Tuialemu. Rocks of the Fagaloa and Salani Volcanic Formations were tested, which include volcanic breccias and basaltic lava flows. For the Namo and Tuialemu rock samples, tests were carried out on clasts and matrices of the Fagaloa and Salani breccia units, respectively. Due to the weak and weathered nature of the matrices of these two formations, the hammer had either recorded very low readings or no values at all. Only the tests that were performed on fresh clasts within each breccia units yielded higher readings.

In Savai'i, rocks sources that occur near Puapua, Saleaula, Manase, Aopo and Vaisala Villages were assessed. These sites were chosen as potential sources of aggregate material for building construction and coastal defences in the local areas.

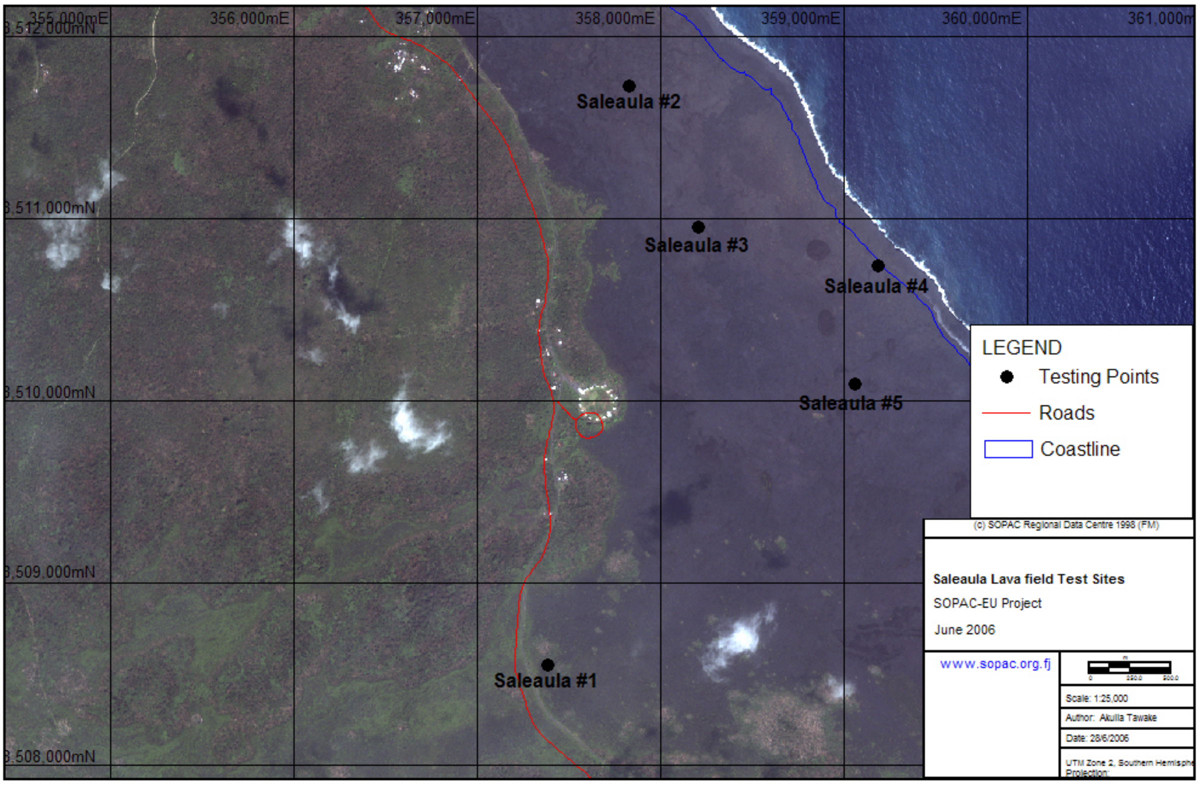

Figure 8. *The Saleaula lava field Schmidt Hammer strength test sites.*

The geology of the island reveals that each of the assessed sites occurs in different volcanic formations: Rocks at the Puapua Quarry are part of the Puapua Volcanics; Saleaula and Aopo lavas constitute the Aopo Volcanics; the Manase outcrop is part of the older Fagaloa Volcanics, and the Vaisala Quarry is within the Mulifanua Volcanics. Due to the vastness and accessibility of the Saleaula lava, more tests were conducted at different locations within the lava field. The test sites are shown in Figure 8.

3.2.1 Other Tests

The rock cubes that were used for the non-destructive Schmidt Hammer test were also used to measure water content and density of each sample. Each cube was oven dried at 110°C for 48 hours and weighed. The cube samples were then soaked in water for 72 hours before the weight of each cube was measured. These are essential for the determination of the water content, and the dry and wet densities of each sample.

4. RESULTS

4.1 Marine Sediment Analyses

Given below are the summary of grain size and compositional analyses with the corresponding histograms for all the marine sediment samples collected from various sites in 2004 and 2005.

4.1.1 Grain Size Analysis

The results of the grading analyses are shown in Table 2. In order to classify each sample according to the relative abundance of gravel, sand and mud/silt, this table is vital for data verification. The Sand:Gravel Ratio column is necessary as the basis for the use of descriptive labels such as 'gravely sand' and 'sandy gravel' to classify sediment samples. This is indicative of the type of sediments that occur at the site where the samples were collected.

Table 2. *Grading results in percentage composition for all the samples collected from Samoa in 2004 and 2005.*

Sample ID	Gravel %	Sand %					Mud/Silt %	Sand : Gravel Ratio
		Very Coarse	Coarse	Medium	Fine	Very Fine		
Vaiusu #1	33.07	13.94	18.12	14.30	16.75	3.37	0.44	2.01
Vaiusu #2	27.84	14.01	20.73	17.82	16.14	3.12	0.34	2.58
Vaiusu #3	35.89	13.97	19.73	14.66	12.39	2.86	0.49	1.77
Vaiusu #4	27.99	14.02	20.63	17.20	15.36	3.95	0.84	2.54
Vaiusu #5	31.95	14.61	19.76	14.38	13.70	4.68	0.93	2.10
Vaiusu #6	18.40	12.96	16.13	16.48	23.37	10.28	2.37	4.31
Vaitele #1	52.99	16.34	11.51	9.20	8.28	1.57	0.12	0.89
Vaitele #2	48.40	18.34	15.62	8.17	6.32	2.34	0.79	1.05
Vaitele #3	43.11	16.00	15.04	9.96	10.06	4.28	1.56	1.28
Vaitele #4	34.84	18.36	18.28	11.41	10.77	4.54	1.80	1.82
Vaitele #5	37.77	18.21	18.23	11.03	10.24	3.93	1.60	1.63
Vaitele #6	31.73	17.62	18.68	12.09	12.60	5.11	2.18	2.08
Mulifanua #2	41.89	13.44	14.91	11.43	11.69	4.27	2.36	1.33
Mulifanua #3	55.14	9.81	11.45	8.11	7.63	4.26	3.60	0.75
Mulifanua #4	53.00	9.92	11.84	8.36	8.54	4.37	3.95	0.81
Mulifanua #5	51.93	10.50	11.37	8.53	9.65	4.37	3.66	0.86
Mulifanua #6	11.64	15.68	11.44	7.89	11.69	23.36	18.28	6.02
Mulifanua #7	51.89	11.05	12.63	9.40	9.53	3.55	1.95	0.89
MF05 #1	35.17	13.35	17.62	13.88	13.61	4.33	1.96	1.79
MF05 #2	26.63	19.10	26.52	15.27	10.50	1.47	0.45	2.74
MF05 #3	9.07	17.96	26.10	18.88	20.52	6.87	0.67	9.96
MF05 #5	24.37	20.39	21.95	17.70	11.75	2.83	1.12	3.06
MF05 #6	13.81	35.66	34.10	12.18	3.92	0.28	0.11	6.24
MF05 #7	3.92	17.30	28.32	21.84	22.13	5.11	1.35	24.22
AP05 #1	4.29	10.80	16.88	15.28	30.10	13.69	8.64	20.22
AP05 #2	5.39	12.68	23.74	23.72	24.42	8.32	1.64	17.23

AP05 #3	16.47	28.73	32.61	13.60	5.29	2.16	0.90	5.00
AP05 #4	12.38	13.83	32.83	22.36	16.72	1.55	0.25	7.05
AP05 #5	5.73	19.51	39.20	24.88	8.82	1.36	0.41	16.36
AP05 #6	5.99	19.36	34.01	20.33	14.44	3.89	1.75	15.36
AP05 #7	1.63	18.49	35.20	24.28	15.82	4.09	0.43	60.05
AP05 #8	2.80	13.35	24.89	22.55	20.64	9.08	6.30	32.33
VR05 #1	1.10	3.88	4.29	6.08	42.15	41.40	1.10	88.91
VR05 #2	33.01	22.49	19.74	13.79	9.16	1.61	0.20	2.02
SL05 #1	35.17	13.35	17.62	13.88	13.61	4.33	1.96	1.79
SL05 #2	26.63	19.10	26.52	15.27	10.50	1.47	0.45	2.74
SL05 #3	9.07	17.96	26.10	18.88	20.52	6.87	0.67	9.96
SL05 #4	18.86	20.52	24.39	18.45	14.32	3.12	0.43	4.28
SL05 #5	24.37	20.39	21.95	17.70	11.75	2.83	1.12	3.06
SL05 #6	13.81	35.66	34.10	12.18	3.92	0.28	0.11	6.24
SL05 #7	3.92	17.30	28.32	21.84	22.13	5.11	1.35	24.16
SL05 #8	21.48	28.25	26.10	14.21	7.70	1.62	0.57	3.63
SL05 #9	19.47	18.84	23.19	19.27	15.44	3.56	0.46	4.12

4.1.1.1 Vaiusu

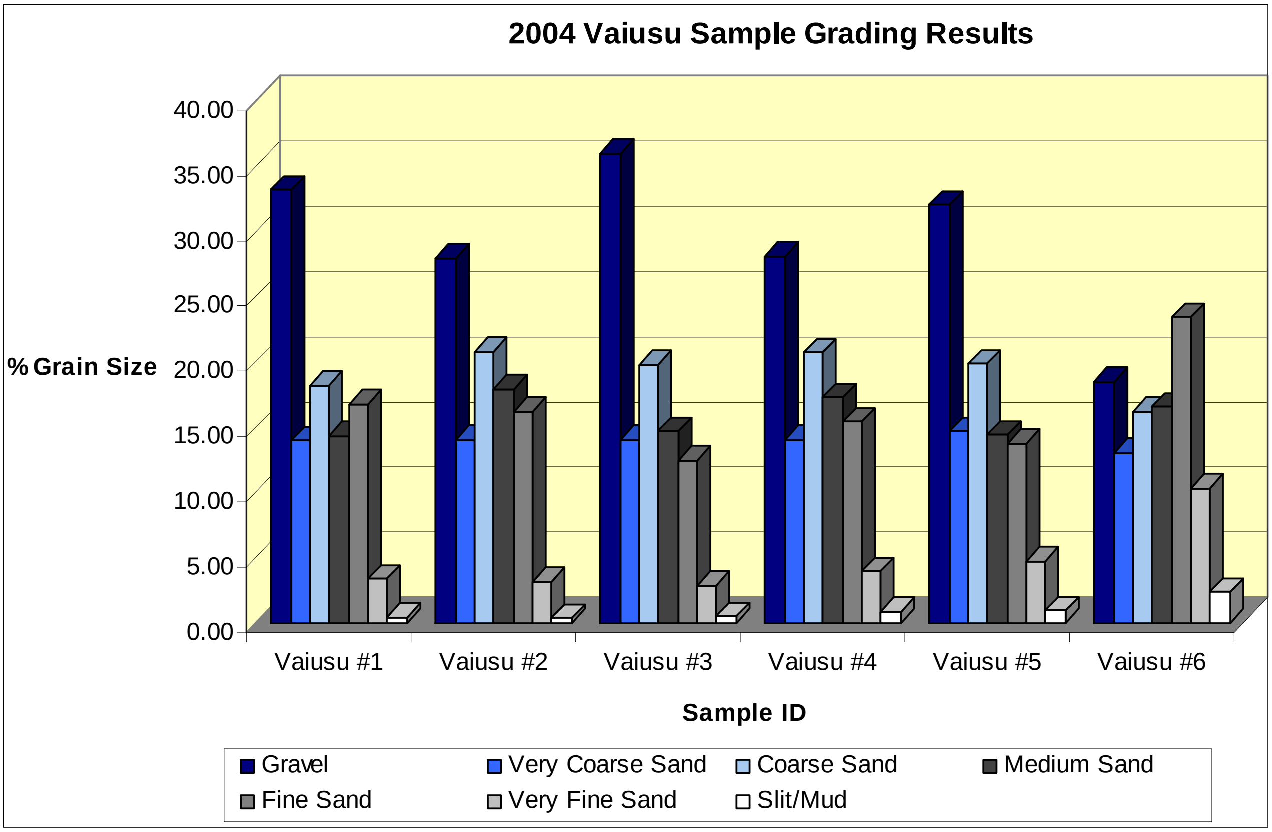

Figure 9. *The histogram for the grading analysis results of the Vaiusu samples.*

4.1.1.2 Vaitele

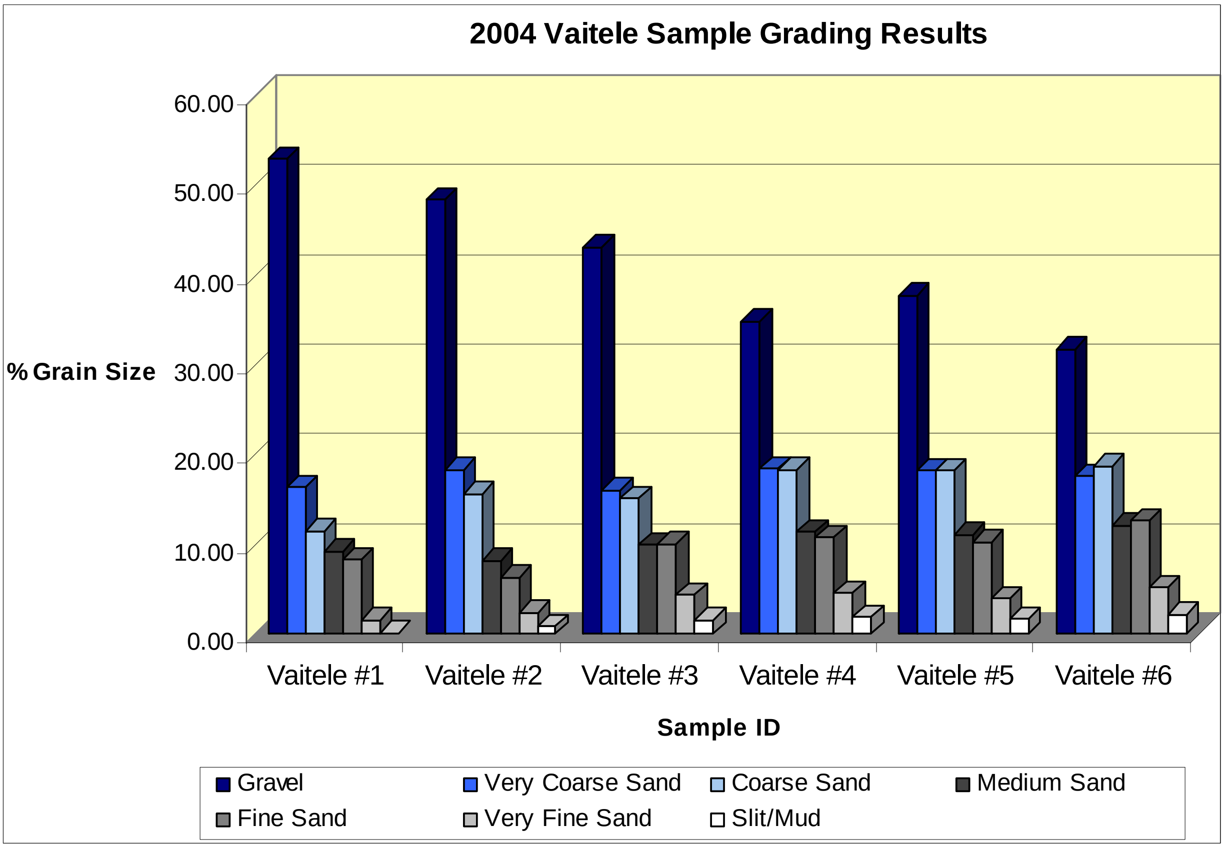

Figure 10. *The histogram for the grading analysis results of the Vaitele samples.*

4.1.1.3 Mulifanua

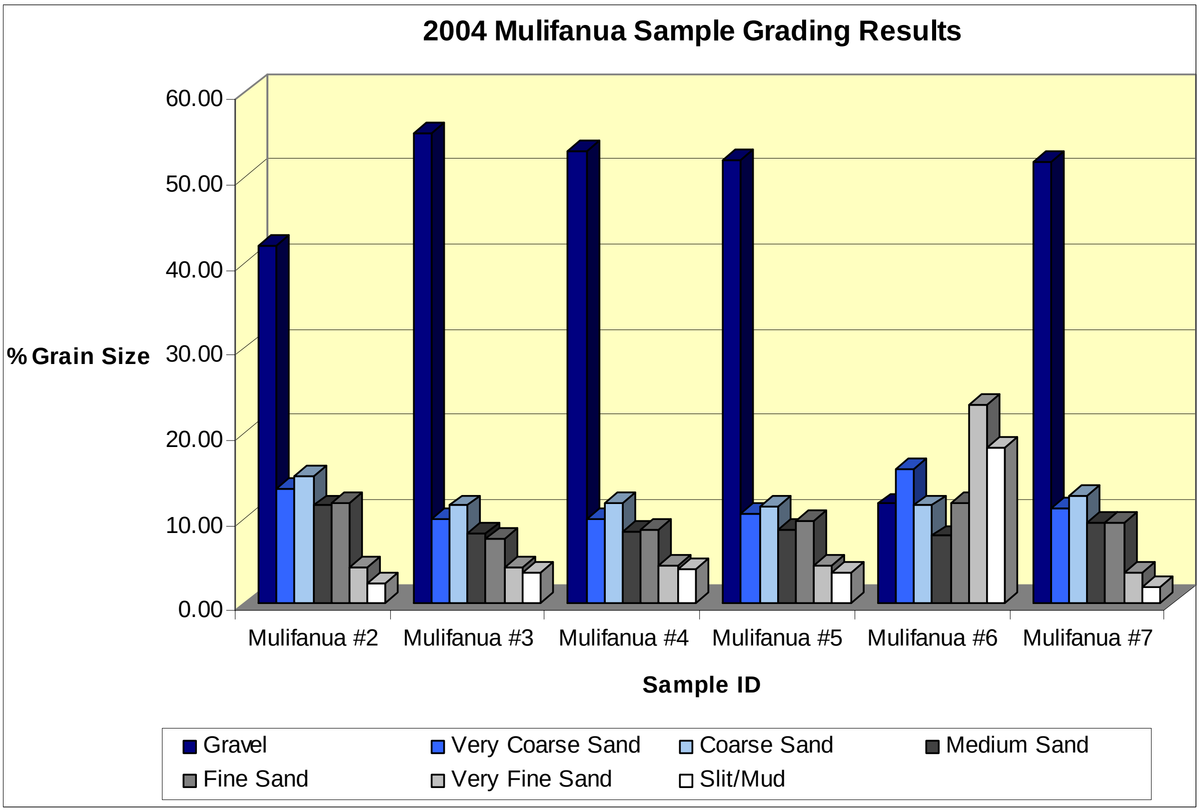

Figure 11. *The histogram for the grading analysis results of the 2004 Mulifanua samples.*

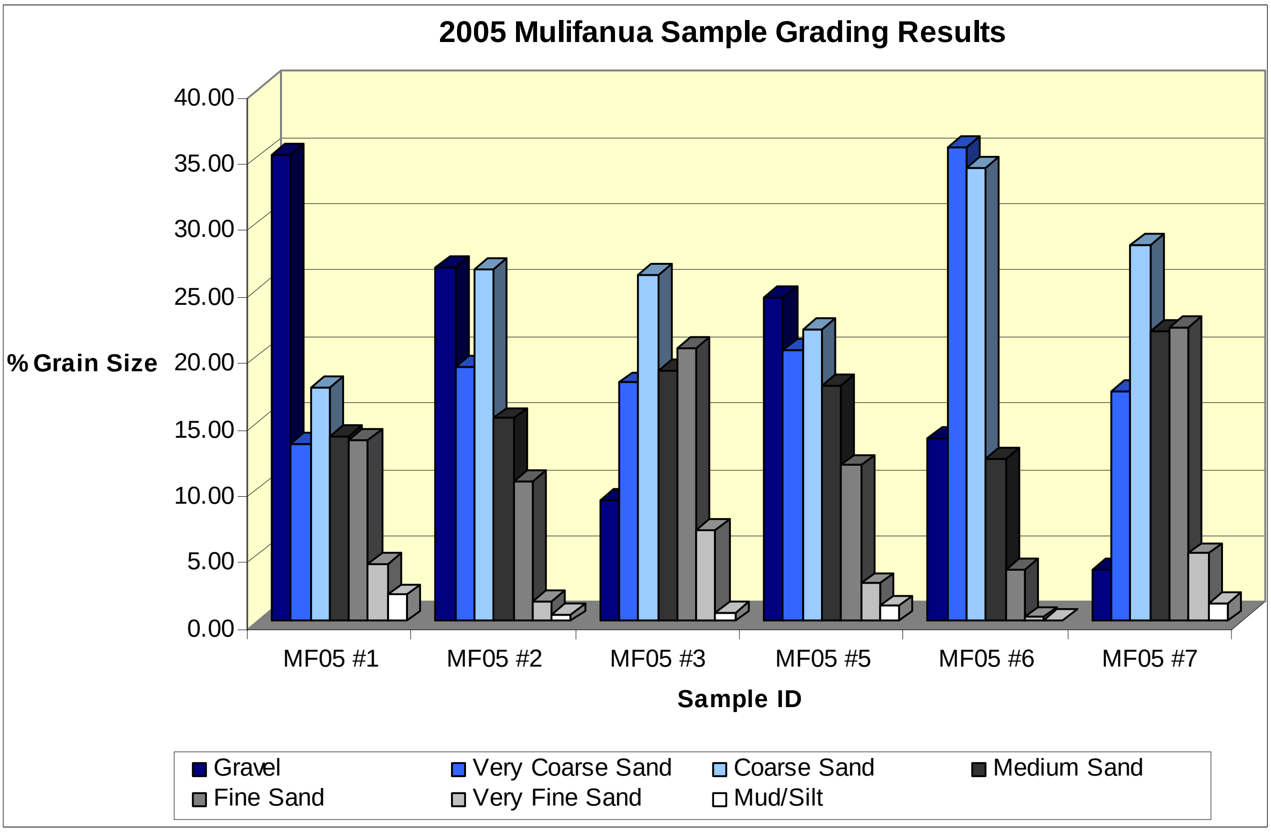

Figure 12. *The histogram for the grading analysis results of the 2005 Mulifanua samples.*

4.1.1.4 Aleipata

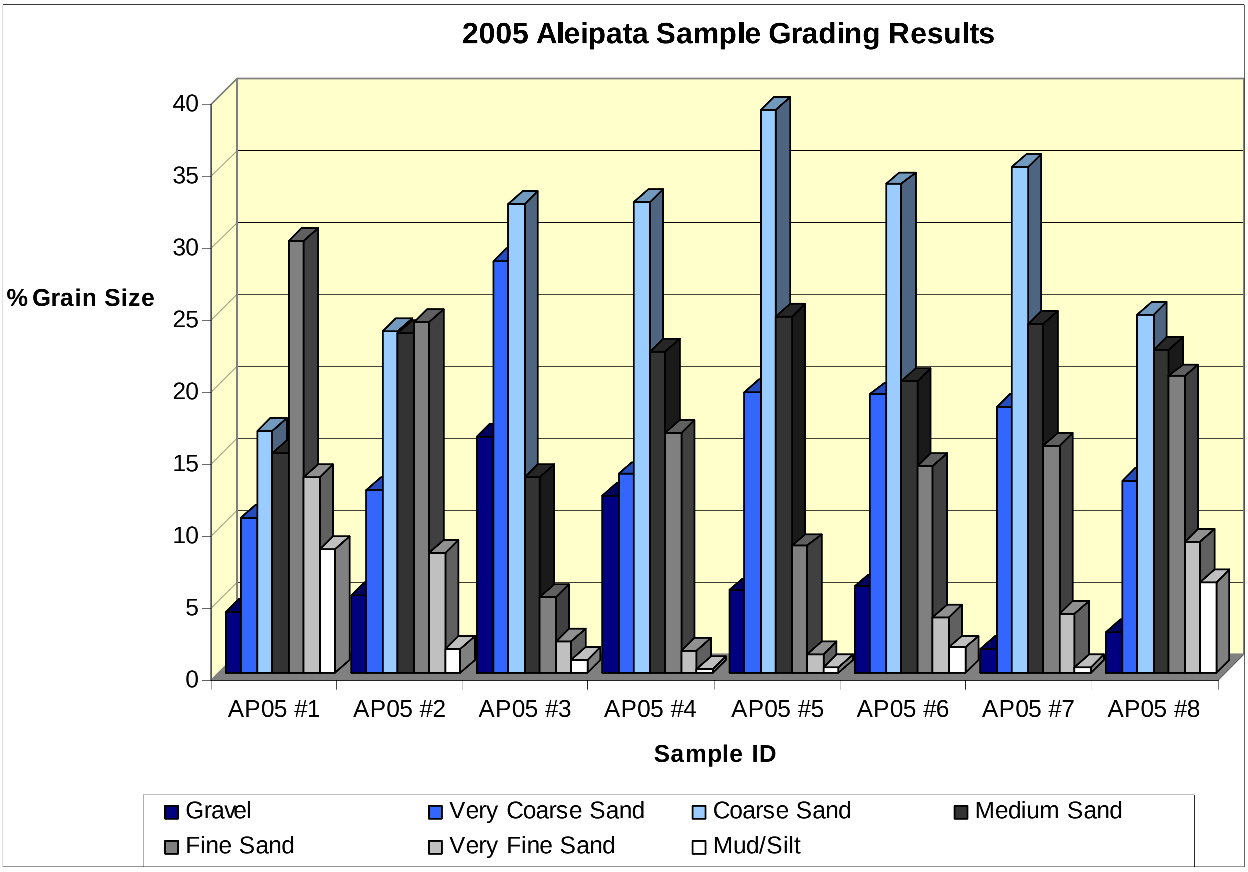

Figure 13. *The histogram for the grading analysis results of the Aleipata samples.*

4.1.1.5 Vaisigano River mouth

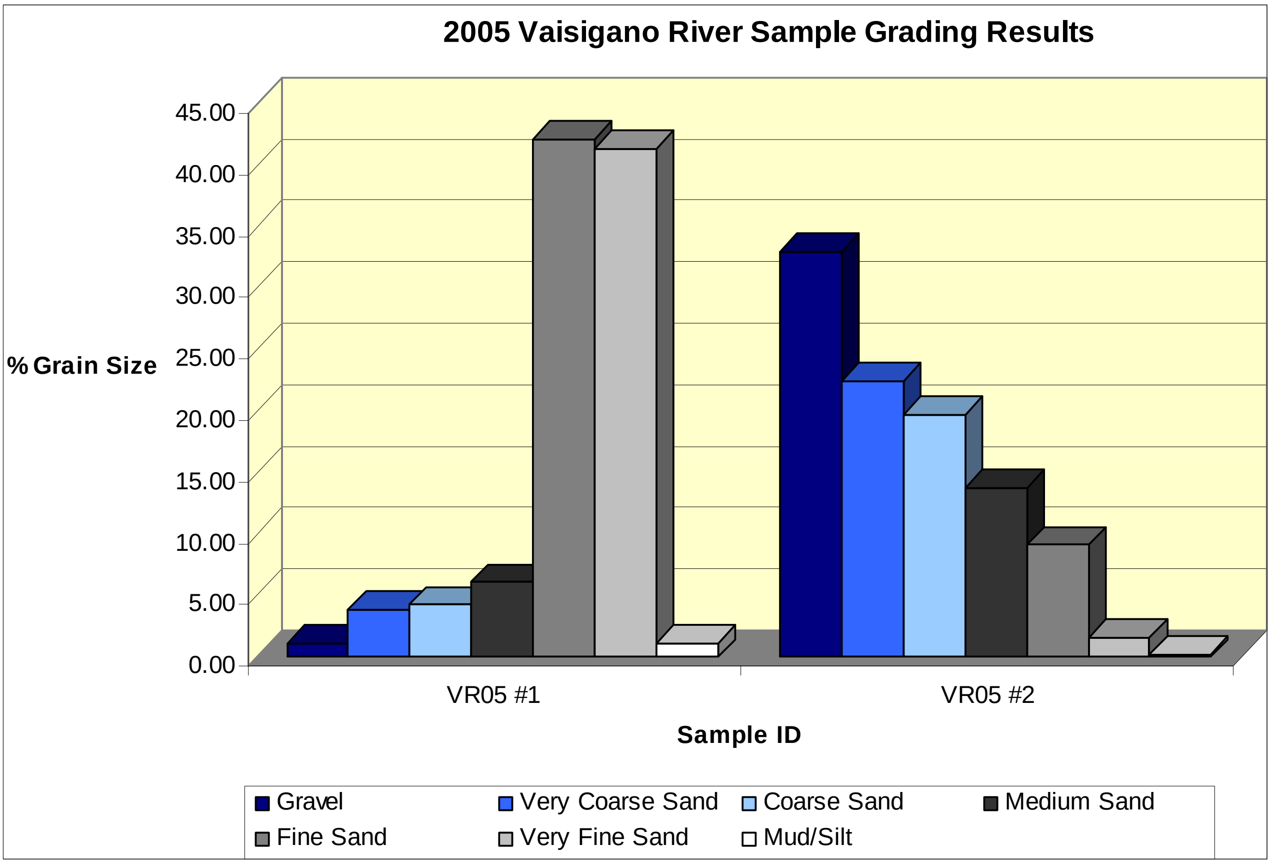

Figure 14. *The histogram for the grading analysis results of the Vaisigano River mouth samples.*

4.1.1.6 Salelologa

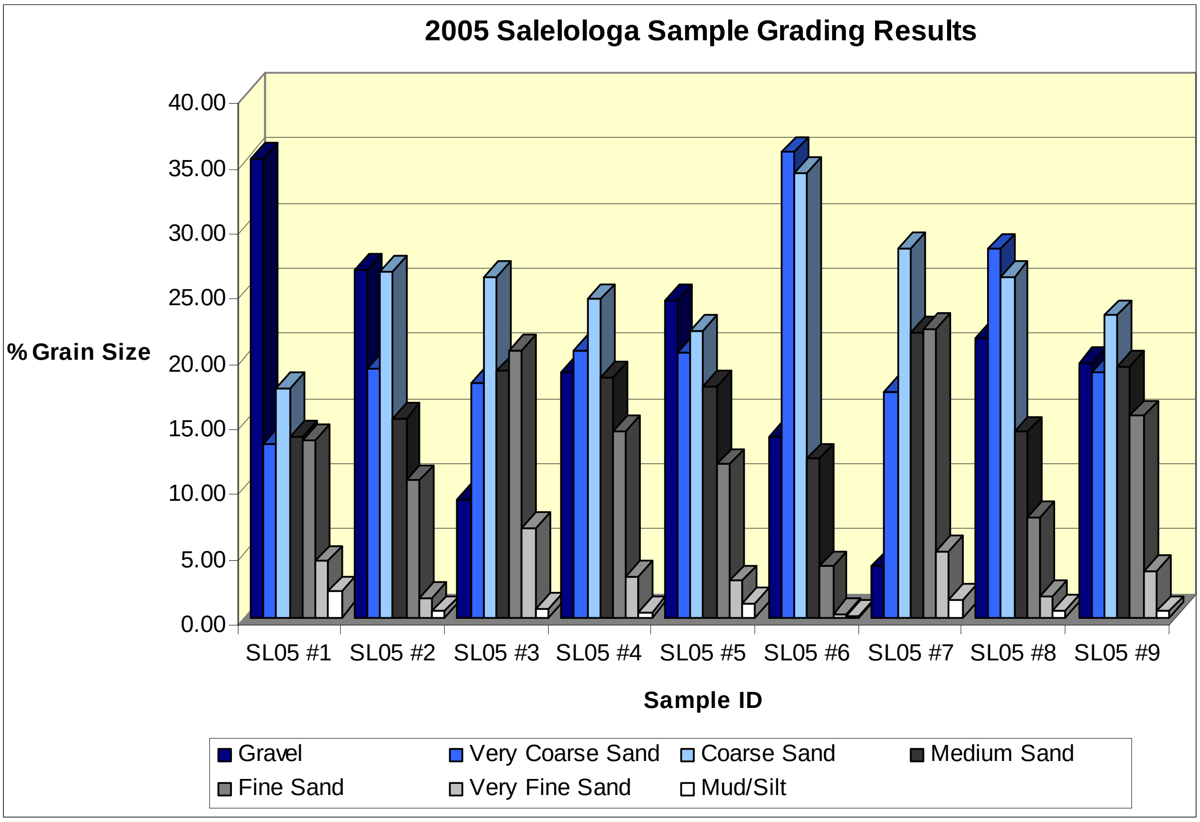

Figure 15. *The histogram for the grading analysis results of the Salelologa samples.*

4.1.2 Composition Analysis

4.1.2.1 Vaiusu

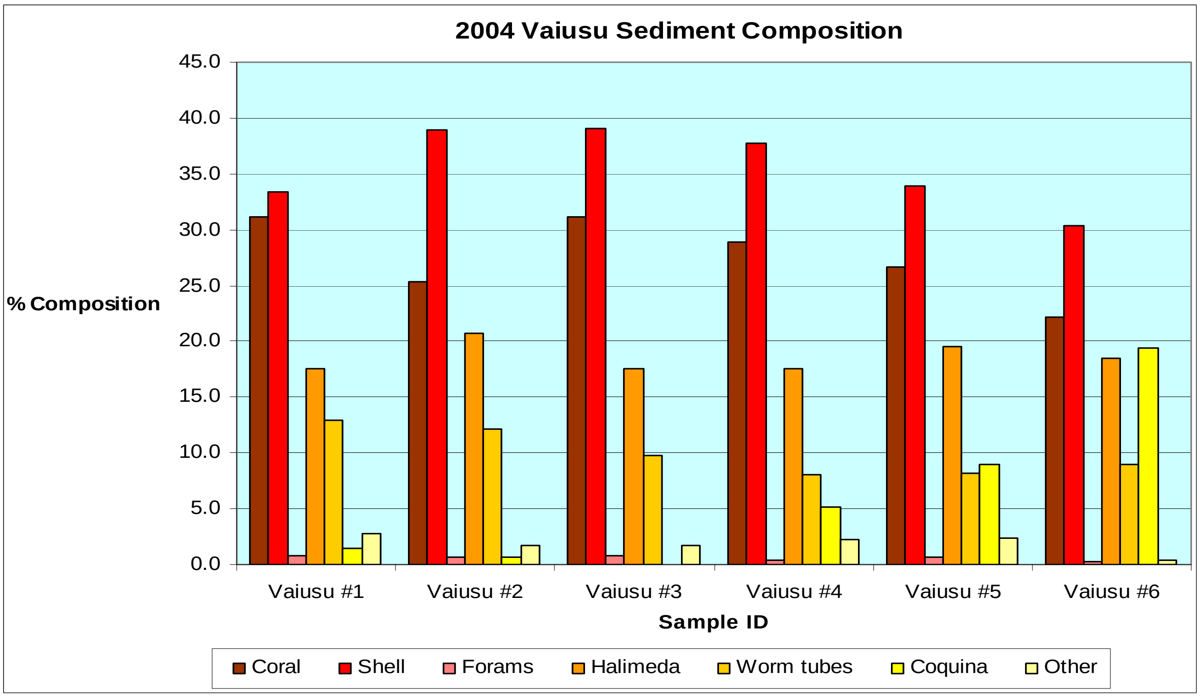

Figure 16. The histogram of the relative percentage composition of the Vaiusu samples.

4.1.2.2 Vaitele

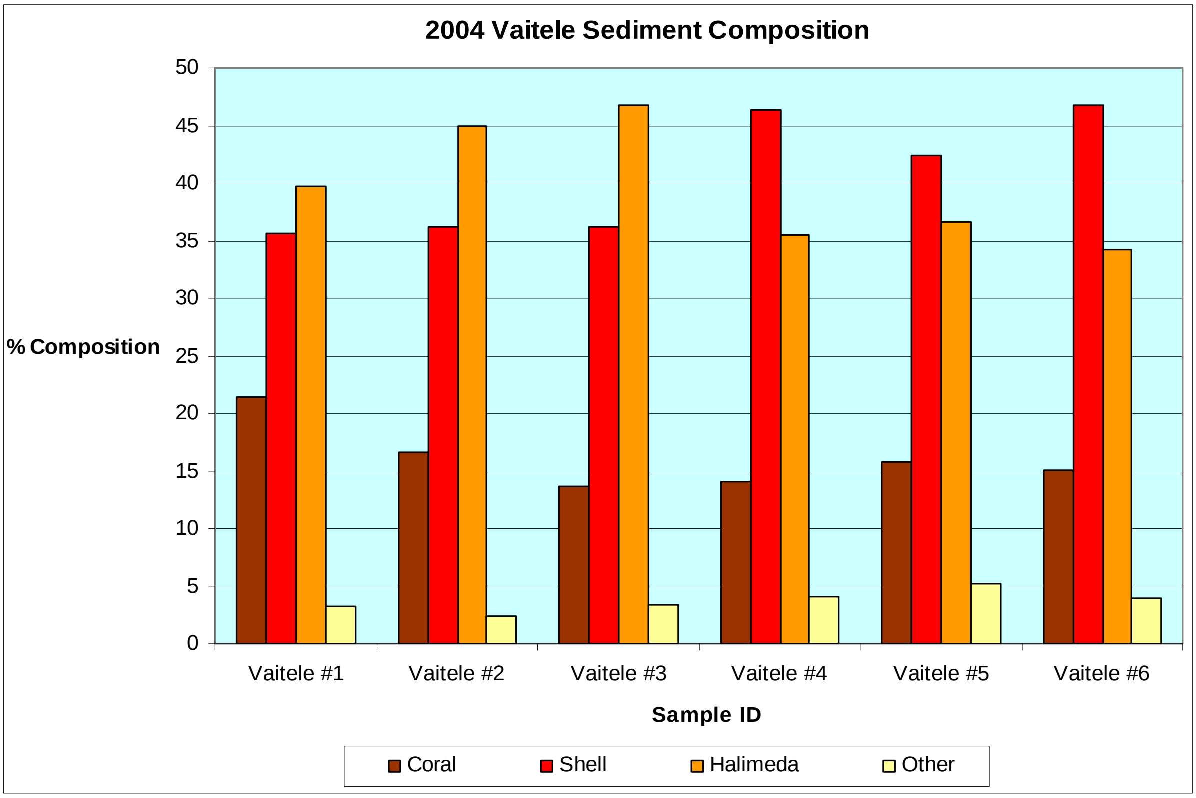

Figure 17. The histogram of relative percentage composition of the Vaitele samples.

4.1.2.3 Mulifanua

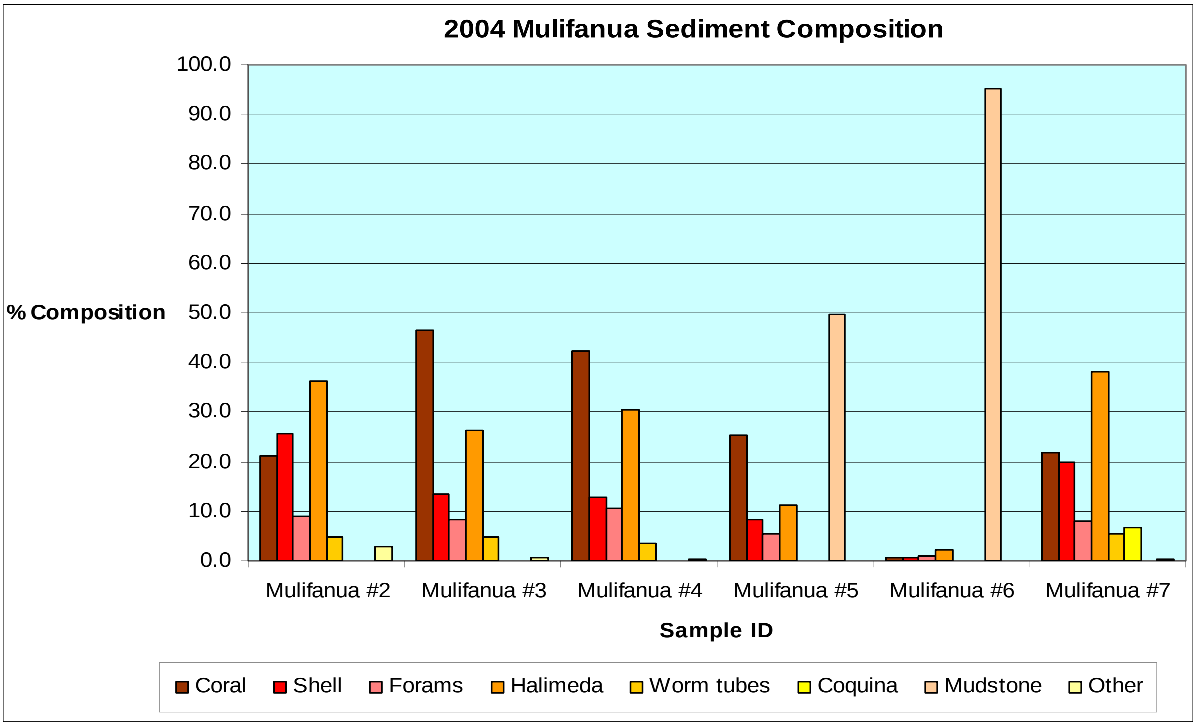

Figure 18. The histogram of the relative percentage composition of the 2004 Mulifanua samples.

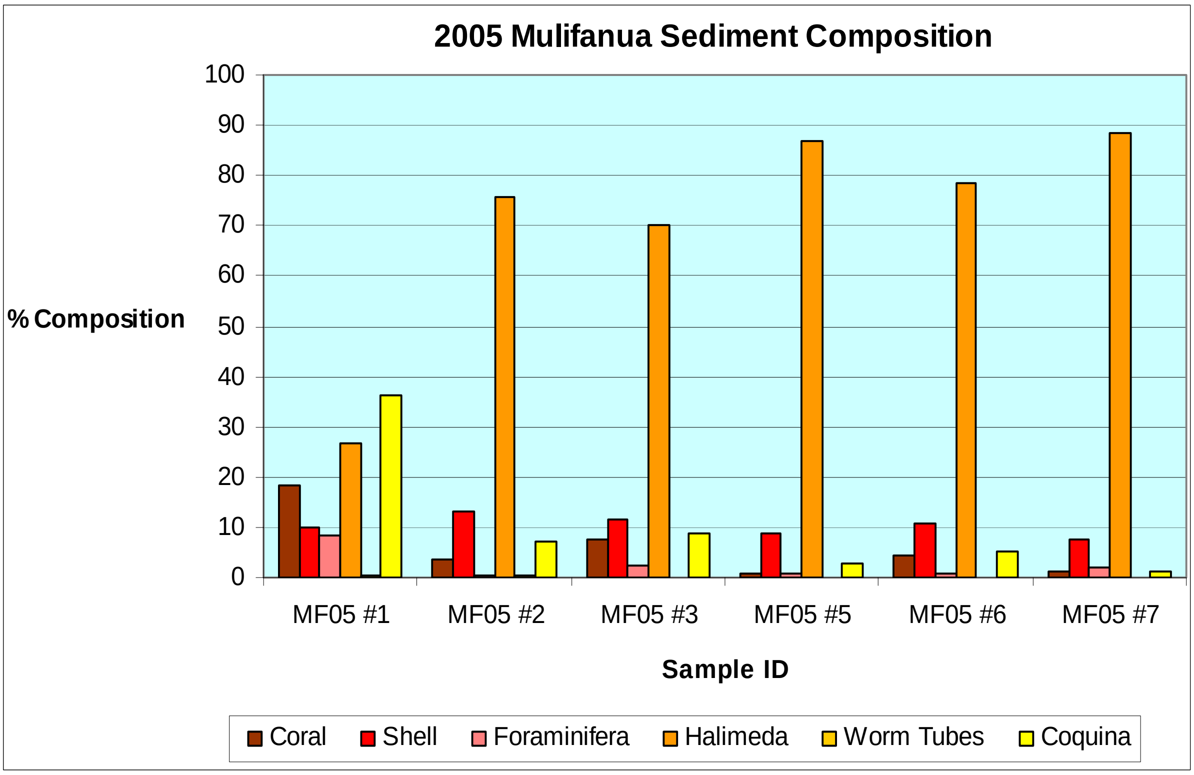

Figure 19. The histogram of the relative percentage composition of the 2005 Mulifanua samples.

4.1.2.4 Aleipata

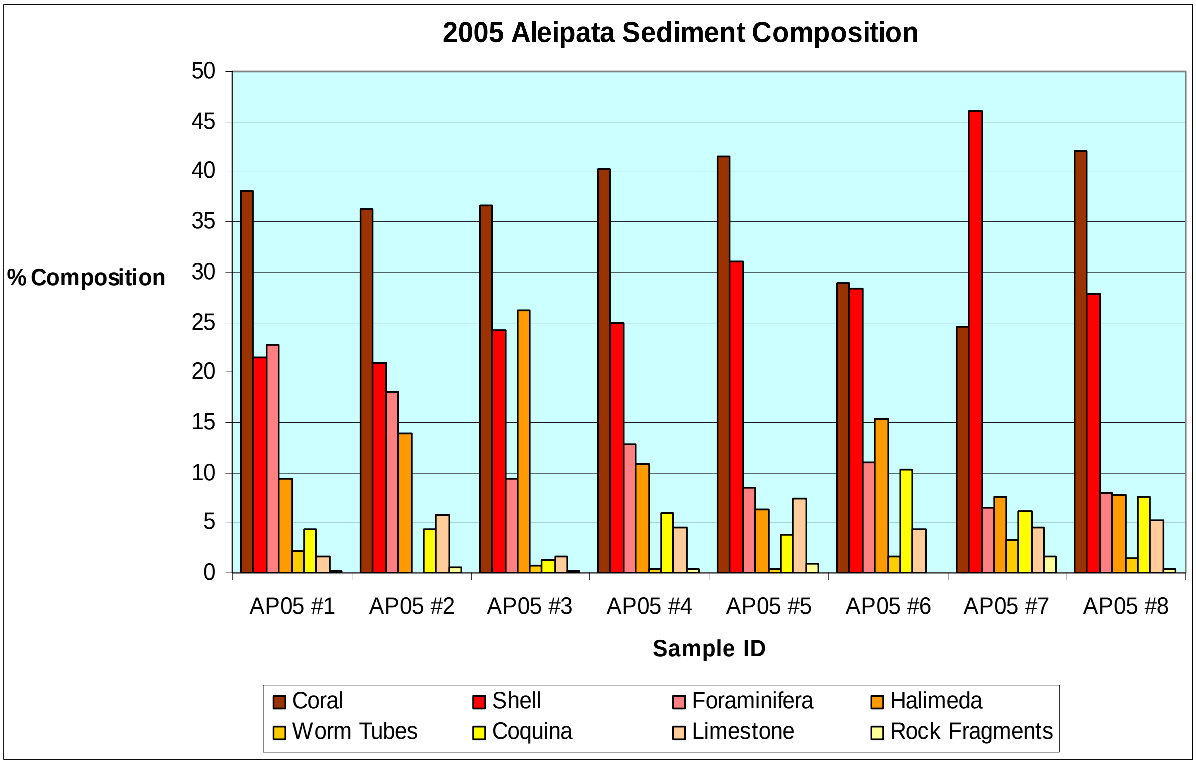

Figure 20. The histogram of the relative percentage composition of the Aleipata samples.

4.1.2.5 Vaisigano River

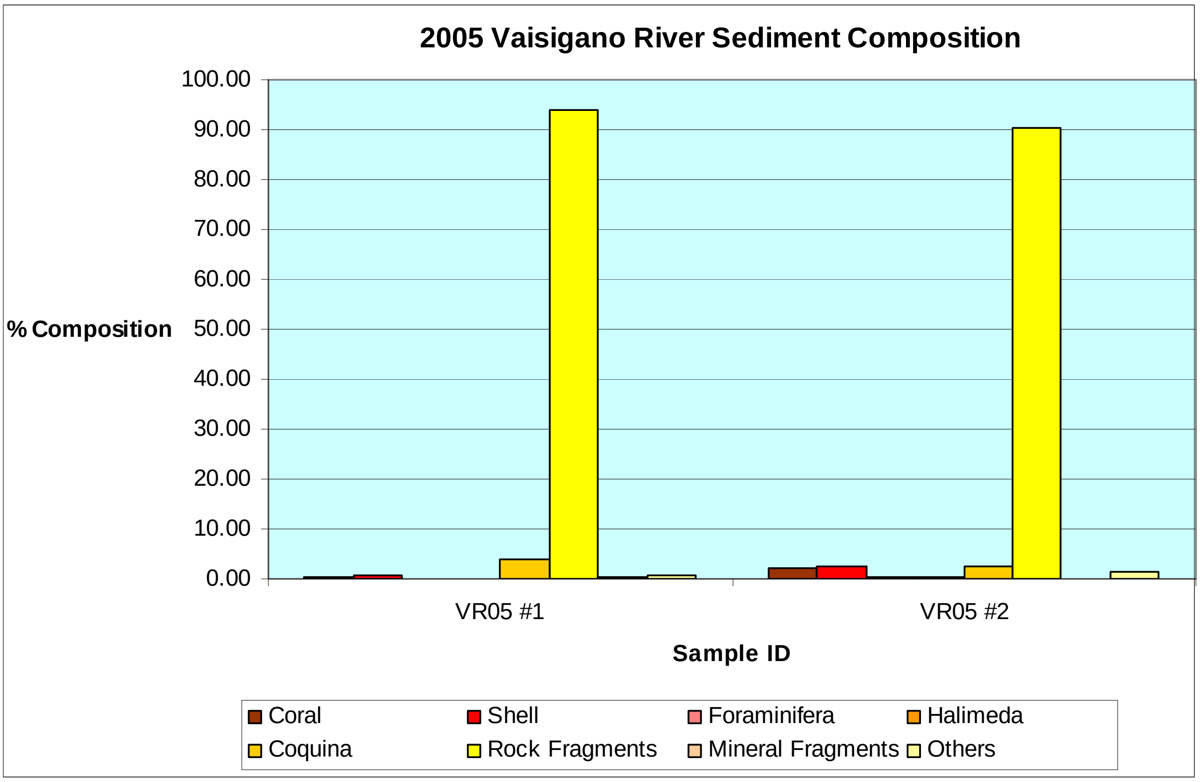

Figure 21. The histogram of the relative percentage composition of the Vaisigano River samples.

4.1.2.6 Salelologa

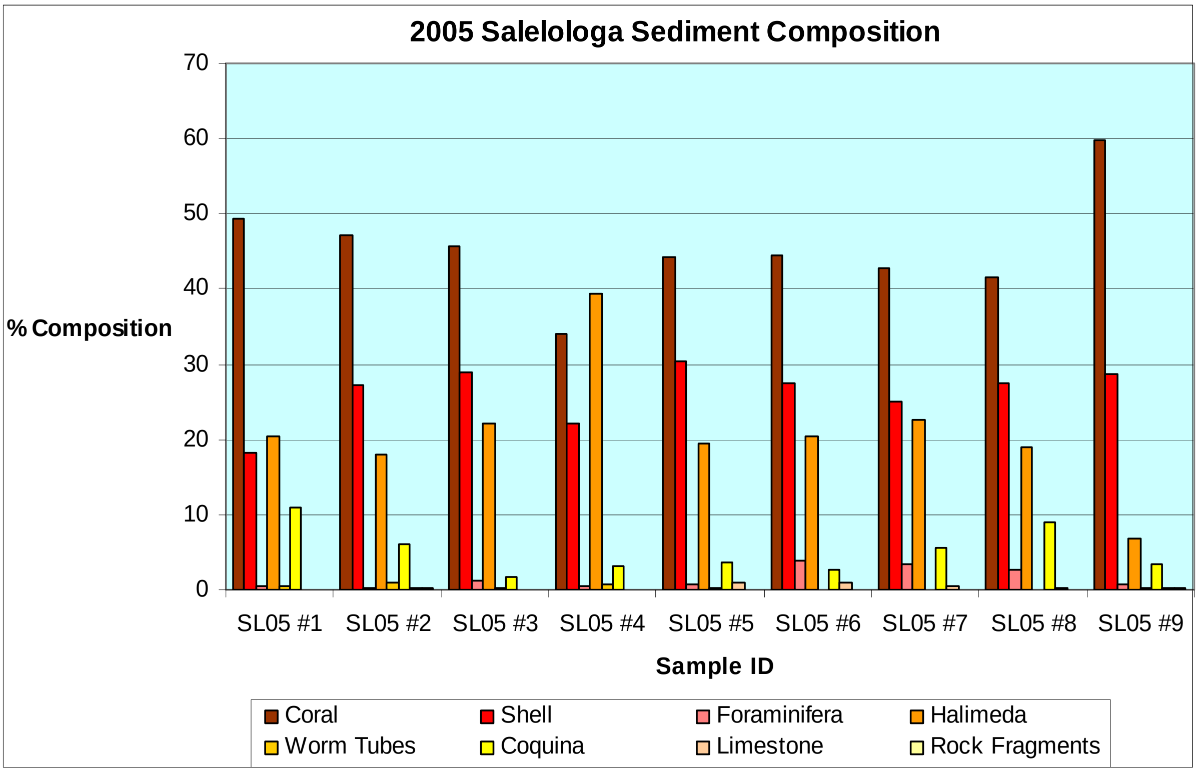

Figure 22. The histogram of the relative percentage composition of the Salelologa samples.

The relative percentage compositions of individual samples are given in Tables A – G in Appendix 3.

4.2 Terrestrial Aggregate Sources Assessment Results

The results of tests that were conducted on the 2004 rock samples and on selected rock sources in 2005 will be presented in this section.

4.2.1 2004 Geotechnical Analyses

Basic geotechnical tests conducted on rock samples collected from Alafua and Saleimoa Quarries were strength test, porosity and specific gravity. In addition, the physical appearance of each specimen is described in Table 3.

Table 3. *Description of hand specimens of the rock samples collected from the Alafua and Saleimoa Quarries.*

Sample ID	Description
Alafua #1	Fresh, compact fine-grained basalt. Vesicles and fractures are filled with carbonate. Pyrite and chlorite are largely fracture controlled.
Alafua #2	Fresh, vesicular basalt. Partially brecciated with carbonate-filled vesicles and minor carbonate stockwork.
Alafua #3	Fresh amygdaloidal pyroxene (generally 1 – <1 mm pyroxene crystals) basalt. Carbonate/quartz-filled vesicles. Irregular and cross-cutting micro-veins are common.
Saleimoa #1	Fresh, fine-grained and vesicular (1 – <1 mm in diameter) basalt. Porphyritic with 5-10 % plagioclase.
Saleimoa #2	Fresh and fine-grained basalt. Highly vesicular (~10 %) with variable sizes which can be as big as 2 cm in diameter. Porphyritic in texture.

4.2.2 Schmidt Hammer Test

The results of the Schmidt Hammer tests that were carried out in 2004 and 2005 are shown below.

4.2.2.1 Alafua and Saleimoa Samples

The histogram displaying the Schmidt Hammer test results for the Alafua and Saleimoa rock samples is in Figure 23. The readings obtained from the upper most curve (i.e. $\alpha = -90$) of Figure D of Appendix 1 are provided in Appendix 4, Part A.

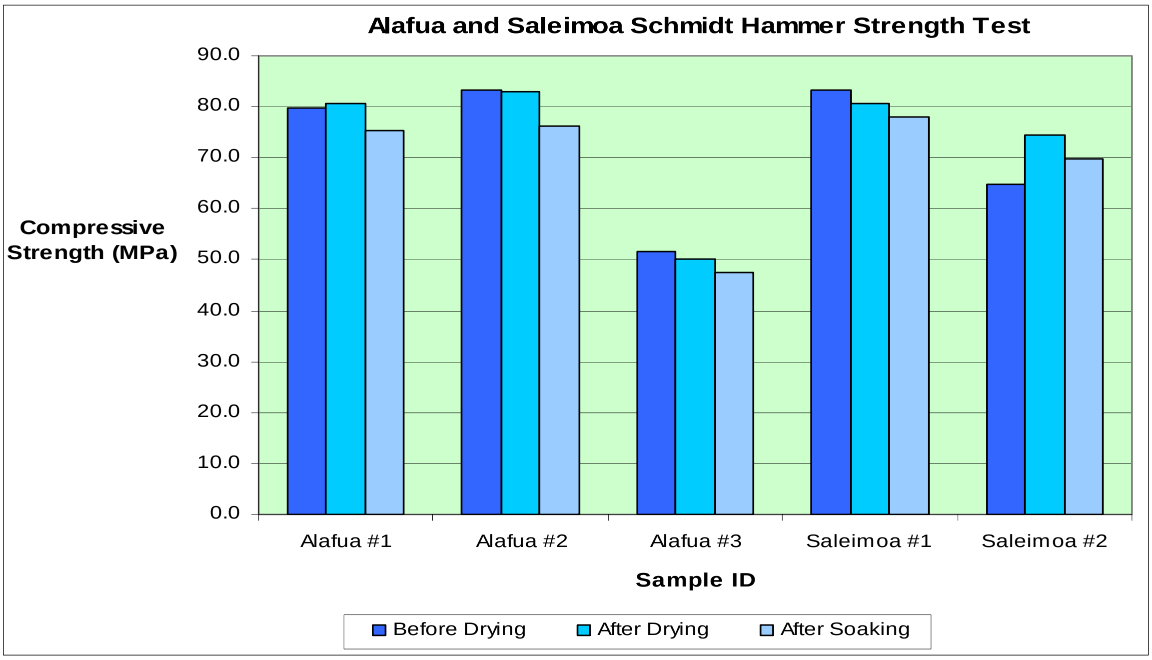

Figure 23. Histogram showing the comparison of rock strengths before drying, after drying and after soaking using the Schmidt Hammer.

4.2.3 Point Load Test

The point load strengths and strength designation of the 2004 Alafua and Saleimoa rock samples using a Point Load Tester are shown in Table 4 and Figure 24. Note that the unit used for the point load strength (MN/m^2) is equivalent to MPa.

Table 4. *Point load strength of individual Alafua and Saleimoa samples.*

Sample ID	P (MN)	De^2 (m^2)	Is (MN/m^2)	Strength Designation
Alafua 1a	0.0194	0.003	6.45	Very high
Alafua 1b	0.0118	0.0036	3.24	Very high
Alafua 1c	0.0209	0.0036	5.87	Very high
Alafua 2a	0.0221	0.0024	9.19	Very high
Alafua 2b	0.0180	0.0015	12.27	Extremely high
Alafua 2c	0.0143	0.0017	8.65	Very high
Alafua 3a	0.0056	0.0021	2.71	High
Alafua 3b	0.0050	0.002	2.46	High
Alafua 3c	0.0059	0.0015	3.96	Very high
Saleimoa 1a	0.0307	0.0033	9.3	Very high
Saleimoa 1b	0.0321	0.003	10.79	Extremely high
Saleimoa 1c	0.0362	0.0038	9.49	Very high
Saleimoa 2a	0.0272	0.0023	12.08	Extremely high
Saleimoa 2b	0.0245	0.0026	9.59	Very high
Saleimoa 2c	0.0288	0.0018	16.15	Extremely high

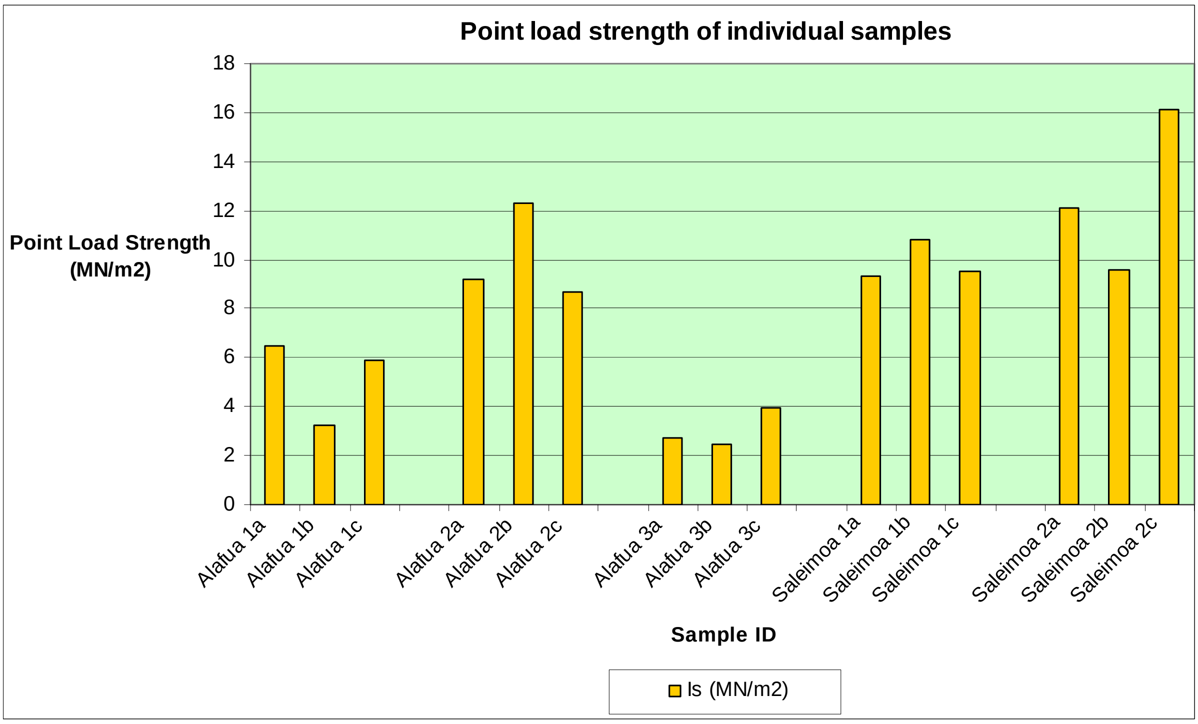

Figure 24. Histogram showing the point load strength of individual samples.

Generally, the point load test results show strong variations among individual samples and lower strength for all the samples compared to the compressive strengths recorded by the Schmidt Hammer test. The dimension of rock cubes used for the point load test and the load readings of individual samples are given in Appendix 5.

The point load strength is then used to compute the strength designation of each sample using the nomogram displayed in Appendix 7.

4.2.4 Water Content and Density

Table 5. *Percentage water contents and densities of Alafua and Saleimoa samples.*

Sample ID	% Water Content	Density (g/cm^3)	
		Dry	Wet
Alafua #1	0.63	2.86	2.88
Alafua #2	0.63	2.66	2.73
Alafua #3	2.59	3.11	3.13
Saleimoa #1	0.61	2.98	3.00
Saleimoa #2	1.10	2.85	2.88

The details of sample weight, volume, densities and water contents are shown in Appendix 6.

4.2.5 2005 Schmidt Hammer Test

The results of the 2005 Schmidt Hammer strength tests on in-situ rock sources at selected locations of Upolu and Savai'i islands are given in Figures 25 to 27. More details are provided in Appendix 4, Parts B – D.

4.2.5.1 Upolu Rocks

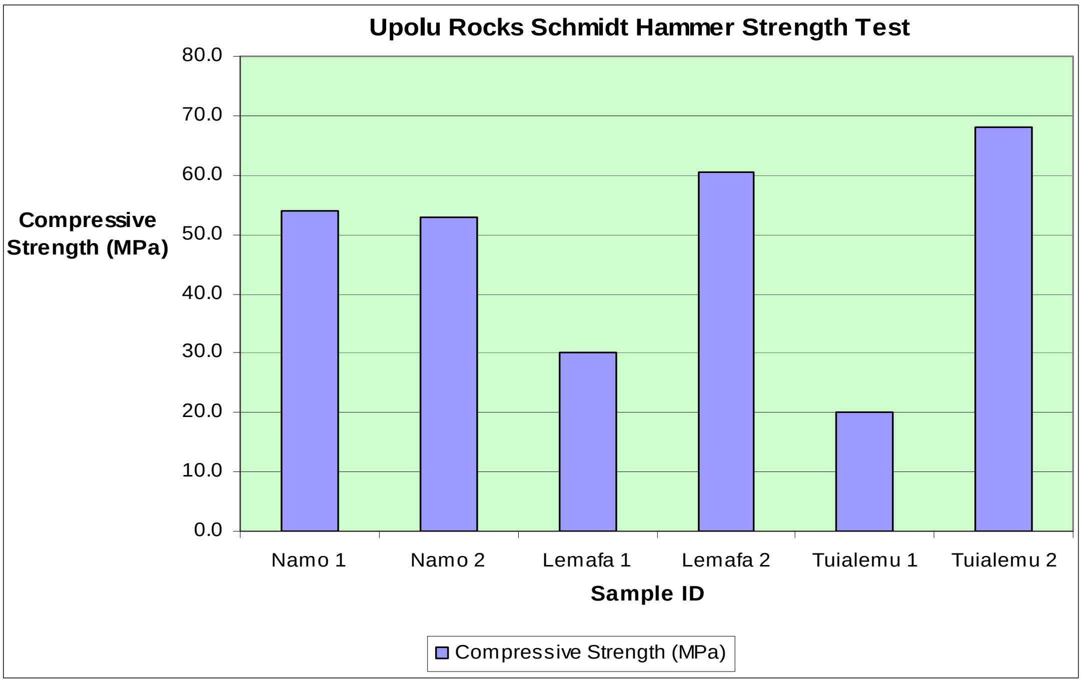

Figure 25. *Histogram showing the relative compressive strengths of selected aggregate sources on Upolu using the Schmidt Hammer.*

4.2.5.2 Savai'i Rocks

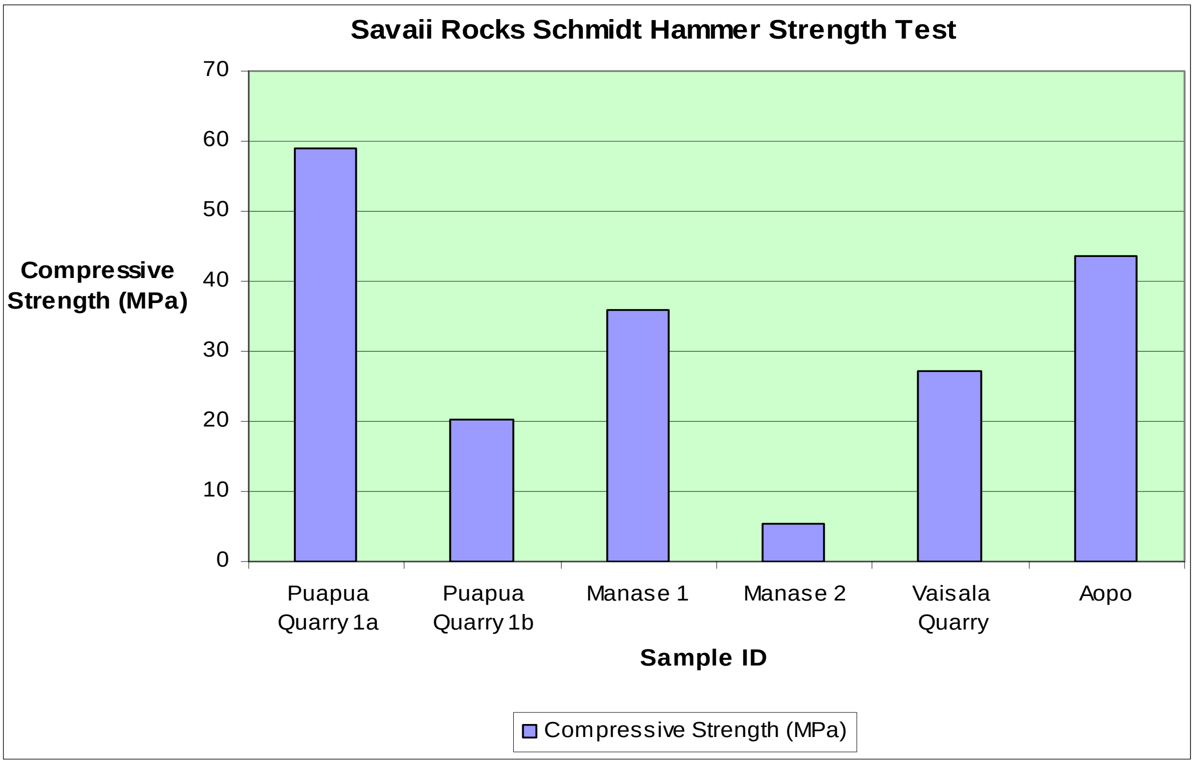

Figure 26. *Histogram showing the relative compressive strengths of selected aggregate sources on Savai'i using the Schmidt Hammer.*

4.2.5.3 Saleaula lava field rocks

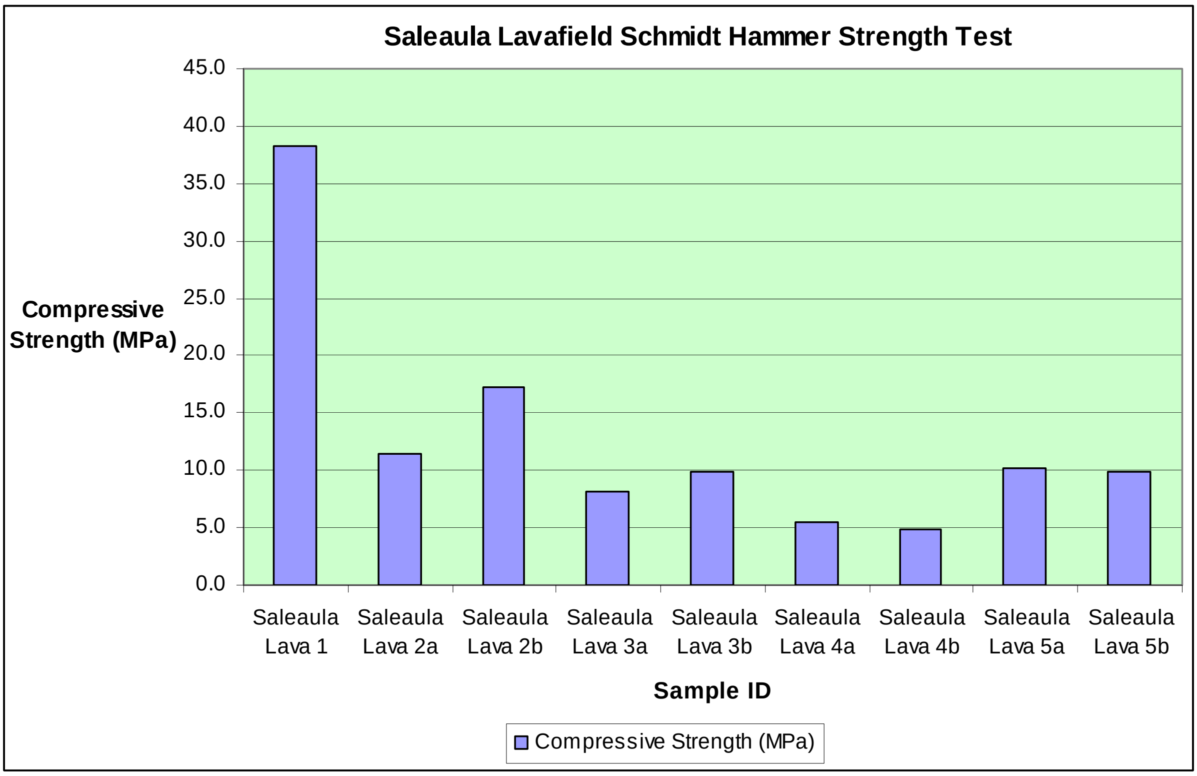

Figure 27. *Histogram showing the relative compressive strengths of rocks at different locations within the Saleaula lava field using the Schmidt Hammer.*

5. DISCUSSION

5.1 Marine Aggregate

The results of all the marine sediment analysis and the subsequent interpretations will be discussed here.

5.1.1 Vaiusu

The grain-size analysis for the Vaiusu Bay sediments reveals high gravel and sand contents. However, the sand category (i.e. very coarse to fine sand) dominates the sediment composition in all samples. The relative grain-size abundance indicates that the Vaiusu sediments can be classified as sandy gravel. This is also revealed in Table 2 where the average sand-to-gravel ratio is below 3. The mud/silt contents of all Vaiusu samples are insignificant.

The dredged sediments from Vaiusu are generally greyish in colour and mainly composed of coral rubble and shell detritus as shown in Figure 16. Generally coral and shell make up an average of more than 60 % of the sediment. Halimeda is considered a minor component that represents less than 17 to 20 % of the total sediments. The insignificant fines content of the sediment coupled with its relative constituent abundance are indicative of the occurrence of relatively good quality aggregate at Vaiusu.

5.1.2 Vaitele

The grain size histogram has consistently displayed high gravel content for all the Vaitele samples ranging, in terms of percentage composition, between 30 and 50 %. Significant amount of very coarse and coarse sand is exhibited in each sample with lesser amount of medium and fine sand in all the samples. Very fine sand and mud/silt generally have a combined abundance of less than 5 %. The sand-to-gravel ratio is between 1 and 2 and hence the Vaitele sediment can be referred to as sandy gravel.

The sediment material is composed largely of shells and *halimeda* fragments as displayed in Figure 17. They have a combined abundance of about 80 % with *halimeda* comprising approximately half of that amount. Coral rubble is minor and it represents an average of about 16 % of the entire dredged material.

The high abundance of the weak and friable *halimeda* in the Vaitele sediments has degraded the quality of the sediments, thus they can be regarded as poor construction material. The Vaitele sediment can be better utilised for landfill and reclamation purposes. Alternatively, the sediment can be screened in order to isolate and then utilise the coral and shell components of the gravel.

5.1.3 Mulifanua

In terms of grain-size distribution, there is a significant difference between the 2004 dredged samples and the seabed samples that were collected in 2005. The 2004 samples consistently displayed high gravel composition with relatively low but consistent individual sand category (e.g. medium-grained sand). The silt and mud content in the 2004 samples are generally low but still higher than that of the 2005 samples. The unusual high silt and mud content in Mulifanua #6 supports the assumption that the *halimeda* material had been broken into finer particles during the sediment pumping and stockpiling processes. The 2005 samples reveal variable abundance but consistently indicate higher percentage of sand with minor amount of gravel.

The composition of the 2004 samples exhibits significant abundance of coral rubble and *halimeda* with minor amounts of shell detritus and forams. However, the high abundance of the so called mudstone component in samples Mulifanua #5 and Mulifanua #6 may give a false impression of the occurrence of consolidated mudstone in the offshore areas of Mulifanua. In fact the term mudstone has been used to classify cemented aggregation of very fine particles of various marine-derived material that cannot be identified under the microscope. Due to the friable nature of *halimeda* together with the colour and the texture of the clayey material, it can be deduced that these muddy material are predominantly made up of very fine halimeda fragments.

On the other hand, the 2005 samples demonstrate a more representative reflection of the material that occurs in the offshore areas of Mulifanua. *Halimeda* is the only major component making up more than 80 % of the total composition. The high percentage of coquina in sample MF05 #1 can be attributed to the close proximity of the sample point to the point of discharge from the sediment-settling pond hence the finer material that have accumulated around that area were being sampled. Coral, shell and coquina are present in much lesser proportion.

As witnessed in the Mulifanua sediment stockpile, the high silt and mud contents can be attributed to the disintegration of halimeda fragments. Abundant silt and mud in sand is not recommended for use as construction material. Like the Vaitele sediment, they can be better utilised for land fill and reclamation.

5.1.4 Aleipata

Generally, the Aleipata sediment predominantly consists of coarse- to medium-grained sand with minor amounts of very coarse and fine-grained sand. Gravel is relatively insignificant. Very fine sand and mud/silt occur in minor amounts in sample #1 (AP05 #1) and sample #8 (AP05 #2) but insignificant in the rest of the samples. In total, sand represents 80 to 90 % of the sediment at Aleipata, hence it is classified as sand.

Coral rubble and shell detritus are the major constituents of the sediment with a combined average percentage composition of about 65 %. Forams and *halimeda* occur in variable but lesser amounts. *Halimeda* represents an average of less than 15 % of the total sediment. Coquina records an average of 6 % while worm tubes; limestone and rock fragments are insignificant.

The dominance of stronger and relatively durable material such as coral and shell fragments in the sediment has made the Aleipata sediment a suitable commodity for construction. The lesser amount of *halimeda* coupled with the insignificant amount of silt and mud content have rendered the quality of the sediment as suitable for construction.

5.1.5 Vaisigano River

The two Vaisigano River mouth samples exhibit differing grain-size characteristics. VR05 #1 is predominantly composed of fine to very fine-grained sand consisting of more than 80 % of the total sediment and the other grain-size ranges constitute less than 20 % of the total sand. On the other hand, VR05 #2 largely consists of gravel and very coarse to medium-grained sand. Sand makes up about 60 % of the sample. Silt and mud represent an insignificant amount in both samples.

Unlike the sediment composition of the other sites, the Vaisigano River mouth is composed almost entirely of basaltic rock fragments that make up more than 90 % of both samples. The other components such as minerals and marine-derived sediments form the remaining less than 10 % of the total composition. This is mainly due to terrestrially-derived material that is being continuously discharged into the marine environment and deposited around the vicinity of the river mouth. The huge amount of volcanic rock boulders that are used for coastal defences along the Apia Habour foreshore may have also contributed to this aggregate deposit due to wave action and weathering.

These volcanic rock fragments are stronger and more durable than any marine-derived material, hence are excellent sources of sand and gravel for construction. However, any large-scale extraction operation at the river mouth and along the river is considered not feasible due to the limited extent of the resource. Additionally, excessive removal of this limited resource can cause riverbank erosion and sediment draw down that may affect the stability of nearby infrastructure.

5.1.6 Salelologa

There is a significant degree of variability when comparing the percentage grain size of individual samples as shown in Figure 15. Generally, the samples are predominantly composed of gravel to coarse-grained sand. Medium and fine-grained sand also occur in significant amounts. The Salelologa sand can be referred to as gravely sand. Mud/silt is consistently low in every sample.

The sediment is composed largely of coral rubble with significant contributions from shell fragments and *halimeda*. Fragments of coral must have derived from the nearby fringing reefs and the coral heads that occur in Salelologa Harbour. Coral and shell fragments have a combined average composition of more than 70 %. *Halimeda* makes up about 20 % and other constituents share the remaining less than 10 % as shown in Figure 22.

Both the grain size and the composition are indicative of relatively good quality sand and gravel. With the higher percentage composition of coral and shell constituents the sediment can be used for most construction purposes except applications that require high strength and durability. The 20 % of *halimeda* in the sediment are most likely to contribute significantly to the increasing amount of silt and mud during any dredging process as they tend to disintegrate easily.

5.2 Terrestrial Aggregate

5.2.1 Alafua

The test results indicate slight variation in compressive strength of the samples using the Schmidt Hammer test. However, the point load test results display significant point load strength variations. Generally Alafua #1 and #2 exhibit relatively superior strength compared to Alafua #3.

The strength variations between samples from the same site are indicative of strength variability within the same aggregate source. Rock samples that were collected from three different places at the rock face of Alafua Quarry responded differently to all the tests carried out due to differing rock properties of each sample. For example, the low to moderate strength of Alafua #3 can be attributed to high porosity, minerals present, degree of cohesion and the microvein fractures.

The results generally indicate that Alafua Quarry possesses good aggregate sources suitable for building and road construction, as exhibited by samples Alafua #1 and #2. In contrast, the quarry also contains weak to moderately strong material that are not recommended for high-stress applications such as road-sealing chips.

5.2.2 Saleimoa

Both the Saleimoa samples exhibit high compressive and point-load strengths. The Schmidt Hammer test recorded slightly higher values for sample Saleimoa #1 compared to Saleimoa #2.

With the fresh, homogenous nature of the samples being tested, the slightly lower compressive strength of Saleimoa #2 can be attributed to the porosity of the rock.

On the other hand, the higher degree of variation of the point-load strength of individual samples is indicative of the rock strength variability within the rocks of the Saleimoa Quarry. The histogram (Figure 24) shows strength variations among individual cube samples that were cut from the same sample (e.g. Saleimoa 2a – 2c from sample Saleimoa #2).

Furthermore, the point-load strength of the Saleimoa samples are higher than that of the Alafua samples, which indicate that the Saleimoa Quarry rocks are generally stronger than the rocks of Alafua. The strength designation of the Saleimoa samples is either very high or extremely high.

5.2.3 Upolu Rock Sources

Apart from the site inspection and the Schmidt Hammer tests that were carried out at each of the Upolu site (Namo, Lemafa and Tuialemu) in 2005, there are additional factors that need to be considered. The test results indicate variable but generally good compressive strength of the individual samples. The outcome of the tests on rock clasts at Namo and Tuialemu have confirmed that they can be used as sources of good quality aggregate provided that the weak, clayey matrix material are removed by screening.

The Namo and Tuialemu rock sources are just adjacent to the main highway. This close proximity of the Namo site to the main highway is a major obstacle to the development of this resource. It would be costly to re-align the road in order to develop the rock sources that are exposed along the northeastern part of the island; hence it is therefore not a feasible option.

The mixed results of the Tuialemu rock tests could be attributed to the degree of weathering of the clasts being tested. Unlike rock outcrops along Namo, the rock sources in both the Tuialemu quarries are at about 50 metres from the main highway. As long as explosives are not used to break the rocks, these sites could potentially supply aggregate to nearby villages and resorts for building construction and coastal defence purposes.

The Lemafa Quarry face is predominantly composed of basaltic lava flow with minor breccia component. While other geotechnical tests are essential to ascertain the physical, mechanical and chemical characteristics of the Lemafa rocks, the Schmidt Hammer test results and the visual inspection of the source have confirmed that the rocks are strong, compact and fresh. The strength variability could be attributed to the slight weathering of the rock surface and the visible fractures that exist within the rock body.

Due to the presence of massive lava flow at Lemafa, this site could be developed as one of the best quarry sites on the island. Similar lava flows that may occur in other parts of Upolu could also be identified and assessed.

5.2.4 Savai'i Rock Sources

The results of the Schmidt Hammer test on selected in-situ rock sources on Savai'i are quite variable with 58 MPa being the highest reading and the lowest strength value recorded at 5 MPa. As previously discussed, the variability in the compressive strength values may not necessarily be a true reflection of the strength of the rock being tested but are often lowered by the degree of weathering and existing plane of weakness (fractures and shears). With the exception of the Saleaula lava field, the rest of the assessed aggregate sources on Savai'i are pretty small in terms of resource volume, hence they cannot sustain medium-to-large quarry operations.

The outcrop at Puapua Quarry consists of a relatively small, moderately- to highly-weathered basalt lava band. The relatively fresh inner part of the lava was tested using the Schmidt

Hammer. The compressive strength values indicated that the fresh part of lava can be developed to supply good quality aggregate. In contrast, the weathered material are weak, friable and will contribute to increasing amounts of dust and mud if crushed.

The Fagaloa Volcanics that crops out between Manase and Safotu villages possesses moderate to low compressive strengths. This 110 m by 18 m rock face is adjacent to the main highway. The occurrence of this Manase outcrop adjacent to the main highway has diminished the value of the rock as a potential aggregate source. Similarly, the fresh part of the rocks at Vaisala Quarry exhibited moderate strength. It is therefore proposed that the fresh portion of this volcanic unit should be used for building construction and coastal defences. Further tests would be required if this quarry is to be used as a source for road tarsealing chips.

A relatively fresh and compact outcrop of the Aopo Volcanics that occurs to the west of Aopo Village was tested. The compressive strength result reveals a stronger aggregate source. However, the occurrence of this formation in scattered, small quantities coupled with the moderately to highly weathered state of most outcrops, the Aopo Volcanics is not considered a reliable source of sand and gravel.

5.2.5 Saleaula Lava Field

The Saleaula lava field is largely made up of highly vesicular pahoehoe lava with far lesser aa lava being observed on the fringes of the deposit. The 100-year lava deposit is generally highly to moderately weathered. With the exception of the Saleaula Lava 1, all the other test sites exhibited low compressive strengths. This can be attributed to the generally moderate state of weathering coupled with the highly vesicular nature of the lava.

As demonstrated by the high compressive strength of the Saleaula Lava 1, the bigger, fresh and relatively compact lava blocks at this site (site Saleaula #1 of Figure 8) are recommended as potential sources of sand and gravel. This site is located to the west of Samalaeulu Village and on the seaward side of the main highway.

6. CONCLUSIONS

The percentage composition of each constituent in the samples reflect their actual abundance in the shallow lagoon areas where they were extracted. Based on the grain size and relative composition, the sand and gravel material at Vaiusu, Aleipata, Vaisigano and Salelologa are preferred sources of construction material. In contrast, due to the high content of *halimeda* at Vaitele and Mulifanua, the material extracted from them are relatively poor material for construction purposes.

The rocks at Alafua Quarry can be considered as good sources of aggregate but selective extraction is necessary for quality material that are normally required for higher performance applications. While the Saleimoa rocks are comparable to the ones at Alafua, the consistently higher strengths and durability of the Saleimoa rocks make them a more superior source of sand and gravel.

In addition, the Lemafa Quarry on Upolu and the southeastern part of the Saleaula lava field on Savai'i are accessible and they possess reasonable quality and quantity to support medium-scale quarry operations. The rest of the terrestrial aggregate sources that were inspected and tested on Upolu and Savai'i are not considered suitable for any commercial operation but can supply the sand and gravel for the local area.

7. RECOMMENDATIONS

- The Ministry of Natural Resource, Environment and Meteorology (MNREM) should consider adopting a management regime that strongly emphasises the importance of conducting aggregate source assessment and operation feasibility studies prior to development at any new site to improve on the current ad hoc extraction practices.

- A *"Framework for Sustainable Aggregate Development and Management"* would need to address the following to ensure the proper development and management of any aggregate resource:–

    - Aggregate Prospecting and Assessment.
    - Stakeholder Consultation.
    - Feasibility Study.
    - Aggregate Development Licensing Process.
    - Resource Development.
    - Environmental Management / Monitoring.
    - Institutionalising Aggregate Management.

- Such an institutionalised process would require the MNREM to build capacity to enable the implementation of the proposed strategy. Relevant policies need to be in place to support the strategy including people with relevant qualifications and experience to be responsible for its implementation, and the acquisition of the necessary technical equipment and tools.

- Aggregate that are being extracted from Mulifanua and Vaitele can be screened to remove the fine material (find sand, silt and mud) that are composed predominantly of very fine *halimeda* fragments and the gravel and coarser-grained sands retrieved and used for construction.

- Geotechnical tests such as the compressive strength test of concrete made from marine sediment samples must be conducted to further ascertain the suitability of the sand and gravel for construction especially for higher performance applications such as the construction of bridges and multi-storey buildings.

- The developer of Alafua Quarry should be selective in the type of material that are being supplied for road sealing. Material with significant amount of breccias matrix, pre-existing planes of weakness, and high porosity are bound to have lower strength and durability. Such material when subjected to high and constant pressure tend to disintegrate relatively easily.

- In cases where excellent quality aggregate are being sought, Lemafa Quarry should be further investigated due to the occurrence of fresh, compact and massive basalt lava in this area.

- Relevant authorities should place more emphasis on assessing and developing hard rock sources. There is huge potential for terrestrial resources development as opposed to the relatively average quality aggregate being sourced from the marine environment.

- It is recommended that the testing equipment from the Ministry of Works (MOW) laboratory and the equipment that had been donated by KIGAM to the Geoscience Section of the Meteorology Division be placed under the same roof. It would also be appropriate to acquire additional equipment such as the Schmidt Rock Classification Hammer, Point Load Tester, Los Angeles Abrasion Machine, Petrographic Microscope and a Thin Section Machine.

- The laboratory service should be promoted to potential users such as construction and aggregate extraction companies, educational institutions and government ministries. An appropriate cost should be charged for each test performed to generate revenue in order to maintain the equipment and keep the laboratory in operation.

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APPENDIX 1

Detailed description of sediment analysis and rock testing

1.1 Marine Sediment Analysis

1.1.1 Grain Size Analysis

All the marine aggregate samples were sent to Fiji for grain size and compositional analysis at the SOPAC Laboratory in Suva. The grain-size analysis involves placing about 500 cm^3 of each sample in a dish and all the filled dishes were placed in an oven. The oven temperature was set at 110ºC and left for 24 hours to dry the samples. Once the oven was switched off the samples were allowed to cool to room temperature. Each sample was sieved using a stack of sieves arranged in a reducing order of mesh sizes on a motorized sieve shaker (Figure A (i)).

A total of 14 different sieve sizes were used. The sieve shaker (Figure A (i)) utilised a horizontal and vertical motion during shaking to separate different grain-size ranges contained in each sample. This sediment sieving process shall take 20 to 25 minutes to complete depending on the amount of samples that need to be graded. At the end of the sieving process, the content of each sieve was then removed and placed in a plastic bag (Figure A (ii)) ready for microscopic analysis. The detailed sieving information is given in Appendices 8 and 9.

Figure A. The sieving process – i) the sieves being stacked on a sieve shaker; and ii) sediment samples being stored in different grain-size ranges in plastic bags.

The grain-size classification used in this report is given in Table A. This scale is based on powers of 2 mm, which yields a linear logarithmic scale via the phi-parameter (Φ) defined as:

$\Phi = -2 \log. d$ (Maharaj 1999)

Where: d is in mm

Table A. *Grain-size classification that is used in this report.*

Grain Size	Millimetres (mm)	Phi Values ( )
Gravel	64 – 2.0	– 6 to – 1
Very Coarse Sand	2.0 – 1.0	– 1 to 0
Coarse Sand	1.0 – 0.5	0 to +1
Medium Sand	0.5 – 0.25	+1 to +2
Fine Sand	0.25 – 0.13	+2 to +3
Very Fine Sand	0.13 – 0.06	+3 to +4
Silt/Mud	<0.06	> +4

As in Smith and Gatliff (1991), "sand" samples are those samples in which the sand to gravel ratio is greater than 19:1 and "gravelly sand' if the ratio is between 19:1 and 3:1. A ratio between 3:1 and 1:1 would be called "sandy gravel" and a ratio of less than 1:1 would be referred to as "gravel". Samples with fines (silt/mud) content between 10-20% would be called clayey and 20-40% fines as very clayey.

1.1.2 Compositional Analysis

The identity of the material that makes up a sample is determined by visual and microscopic examinations (Figure B (i)) of each graded sample (e.g. coarse sand). A portion of each graded sample, presumed to be an unbiased representative of the whole sample, is placed on a petri-dish and analysed. Normally, most of the grains should be identified through this microscopic work. Some may require further tests such as the use of 10 % HCl acid to confirm the identity of the unknown particles. An example of what is observed under the microscope is shown on Figure B (ii).

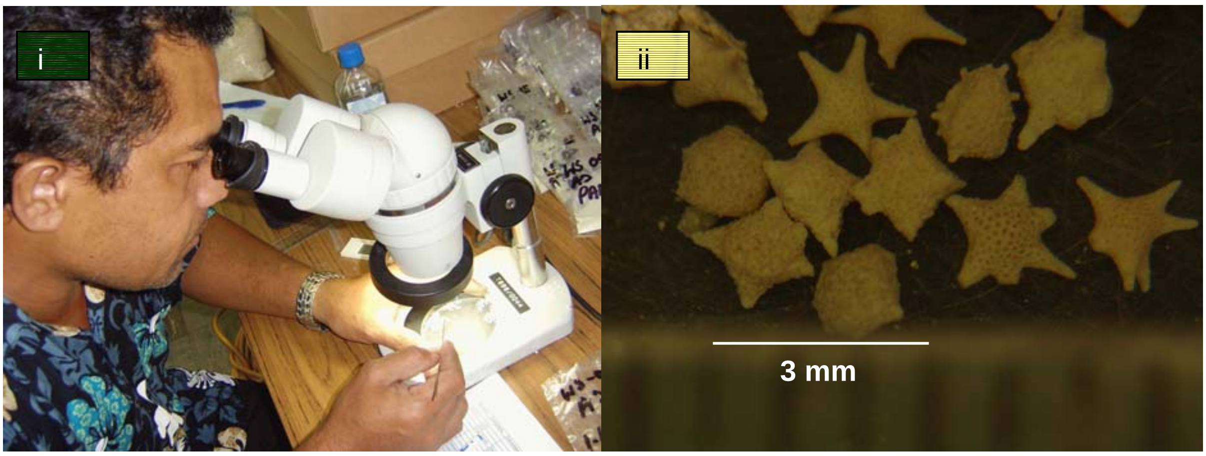


Figure B. Microscopic work that aids identification of different constituents – i) compositional analysis using a microscope; and ii) variety of foraminifera *species observed under the microscope.*

Once all the constituents are separated, the relative abundance of each constituent is conducted by weighing or counting the number of particles. The percentage composition of each constituent is then calculated and plotted on a histogram. The outcome of this analysis indicates the relative abundance of different constituents that make up the material that occurs at the location of aggregate extraction.

2.1 Terrestrial Rock Assessment

2.1.1 Schmidt Hammer Test

The rock classification Schmidt Hammer is an instrument, which is easy to use, for quick and approximate measurement of the resistance to pressure of rocks and manufactured concrete products. The principle on which it works are based on the rebound impact of a hammer on a piston which rests against the surface of the rock (or concrete sample: the greater the resistance of the sample, the greater the rebound impact (Tawake, 2005b). With the aid of the test hammer the quality of the concrete or of the rock can easily be determined.

Figure C. Strength test using a Schmidt Hammer – i) demonstration of how the hammer is being applied on a rock cube; and ii) use of the hammer in a horizontal position against a vertical rock wall.

The Schmidt Hammer is used by pressing the piston with increasing pressure against the surface of the rock. The device must always be perpendicular to the rock surface being tested. Once a rebound reading (H) has been recorded, the side button is pressed whilst the piston is held firmly against the rock. This device can be used to test rocks in both vertical downward (Figure C (i)) and upward positions, and also in slanting and horizontal (Figure C (ii)) positions.

The H values of rebound have been defined is such a way that they can be converted, by means of a diagram (Figure D), into terms of resistance to compression for test carried out on the cube. On the diagram (Figure D), 5 different curves are drawn which take into account the angle of the instrument. Individual curves on the diagram are used as follows:

- vertical downward, $\alpha = -90°$;
- vertical upward, $\alpha = 90°$;
- horizontal, $\alpha = 0°$;
- inclination of 45°, $\alpha = 45°$;
- declination of 45°, $\alpha = -45°$.

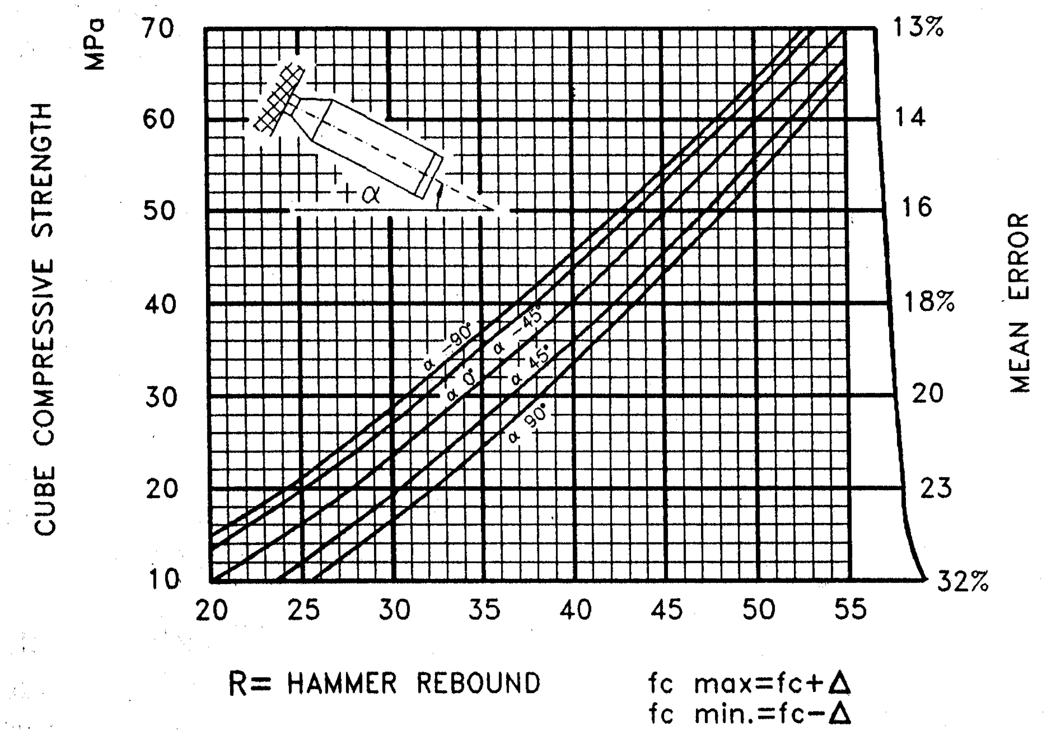


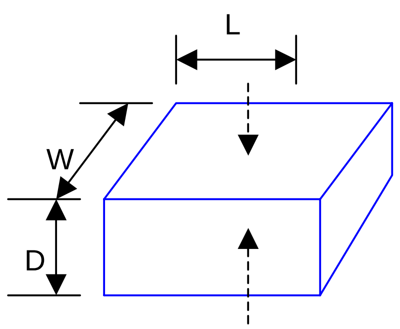
Figure D. The Cube Compressive Strength Diagram, used to determine the resistance to compression on a cube sample (from ASTM 2001).

2.1.2 Point Load Test

Three sample blocks were cut from each sample and the dimensions of each block were measured (Appendix 3) prior to being subjected to the point load test. The height of a block sample was taken as equivalent to the diameter (D) of a drill core sample.

The operating instructions were followed as specified in the Instruction Manual. The height of the sample was measured from the graduated diameter scale incorporated on the side of the load frame. In order to get a load reading (P), a force was steadily applied until the specimen failed. The maximum load pointer indicated the load used to break the rock block.

The average De^2 and P for each sample were calculated and used to determine the average, uncorrected point load strength value (I_s) of each sample using the formula $I_s = P/De^2$, where $De^2 = 4A/\pi$, and A = WD, the cross sectional of a plane through the platen contact points (Figure E).



It is important to note that samples with pre-existing fractures or those that have been subjected to weathering and/or alteration often produce lower than normal readings and are referred to as 'erroneous' results.

Figure E. The dimensions of a rock cube used for the block test.

APPENDIX 2

Sample Point coordinates and water depths for the 2005 Mulifanua, Aleipata and Salelologa sites

Sample ID	Longitude	Latitude	Water Depth (m)
Mulifanua # 1	W 172° 02' 15.5"	S 13° 49' 49.0"	0.8
Mulifanua # 2	W 172° 02' 22.1"	S 13° 49' 46.8"	2.5
Mulifanua # 3	W 172° 02' 32.5"	S 13° 49' 46.8"	2.7
Mulifanua # 4	W 172° 02' 25.8"	S 13° 49' 35.7"	3.4
Mulifanua # 5	W 172° 02' 12.6"	S 13° 49' 35.8"	3.0
Mulifanua # 6	W 172° 02' 05.4"	S 13° 49' 40.4"	2.8
Mulifanua # 7	W 172° 02' 15.4"	S 13° 49' 43.4"	3.7
Aleipata # 1	W 171° 25' 35.6"	S 14° 01' 37.9"	0.8
Aleipata # 2	W 171° 25' 29.5"	S 14° 01' 40.5"	1.6
Aleipata # 3	W 171° 25' 23.1"	S 14° 01' 41.5"	4.0
Aleipata # 4	W 171° 25' 18.5"	S 14° 01' 35.4"	1.8
Aleipata # 5	W 171° 25' 15.1"	S 14° 01' 26.8"	1.8
Aleipata # 6	W 171° 25' 23.0"	S 14° 01' 24.0"	1.6
Aleipata # 7	W 171° 25' 26.8"	S 14° 01' 24.6"	0.5
Aleipata # 8	W 171° 25' 25.5"	S 14° 01' 32.1"	1.3
Salelologa # 1	W 172° 12' 59.3"	S 13° 44' 40.7"	3.0
Salelologa # 2	W 172° 13' 01.9"	S 13° 44' 44.5"	2.7
Salelologa # 3	W 172° 13' 04.3"	S 13° 44' 52.7"	2.6
Salelologa # 4	W 172° 13' 02.4"	S 13° 44' 58.3"	2.8
Salelologa # 5	W 172° 12' 56.3"	S 13° 45' 06.3"	3.2
Salelologa # 6	W 172° 12' 53.7"	S 13° 44' 44.6"	4.3
Salelologa # 7	W 172° 12' 50.0"	S 13° 44' 35.5"	3.8
Salelologa # 8	W 172° 12' 46.3"	S 13° 44' 47.1"	3.1
Salelologa # 9	W 172° 12' 46.5"	S 13° 44' 55.3"	5.4

APPENDIX 3

Tables displaying percentage composition of marine sediment samples

Table A. Percentage composition of the Vaiusu samples.

	Vaiusu #1	Vaiusu #2	Vaiusu #3	Vaiusu #4	Vaiusu #5	Vaiusu #6
Forams	0.8	0.6	0.8	0.4	0.6	0.3
Halimeda	17.5	20.7	17.6	17.6	19.5	18.4
Coral	31.1	25.3	31.1	28.8	26.6	22.1
Shell	33.4	38.9	39.1	37.7	33.9	30.4
Worm tubes	13.0	12.1	9.7	8.1	8.1	8.9
Coquina	1.4	0.6	0.0	5.1	8.9	19.4
Other	2.8	1.7	1.8	2.3	2.3	0.5
Total	100	100	100	100	100	100

Table B. Percentage composition of the Vaitele samples.

	Vaitele #1	Vaitele #2	Vaitele #3	Vaitele #4	Vaitele #5	Vaitele #6
Halimeda	40	45	47	35	37	34
Coral	21	17	14	14	16	15
Shell	36	36	36	46	42	47
Other	3	2	3	4	5	4
Total	100	100	100	100	100	100

Table C. Percentage composition of the 2004 Mulifanua samples.

	Mulifanua #2	Mulifanua #3	Mulifanua #4	Mulifanua #5	Mulifanua #6	Mulifanua #7
Forams	9.1	8.4	10.5	5.5	1.1	7.9
Halimeda	36.3	26.2	30.5	11.3	2.2	38.2
Coral	21.2	46.6	42.2	25.2	0.7	21.7
Shell	25.6	13.5	12.9	8.2	0.7	19.9
Worm tubes	4.9	4.7	3.6	0.0	0.0	5.5
Coquina	0.0	0.0	0.0	0.0	0.0	6.6
Mud stone	0.0	0.0	0.0	49.7	95.3	0.0
Other	2.9	0.6	0.4	0.1	0.0	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table D. Percentage composition of the 2005 Mulifanua samples.

Sample ID	Coral	Shell	Foraminifera	Halimeda	Worm Tubes	Coquina	Total
MF05 #1	18.21	9.8	8.51	26.83	0.43	36.21	100
MF05 #2	3.4	12.96	0.31	75.62	0.46	7.25	100
MF05 #3	7.55	11.38	2.3	70.13	0	8.64	100
MF05 #5	0.74	8.78	0.87	87.02	0	2.6	100
MF05 #6	4.46	10.8	0.78	78.53	0.19	5.24	100
MF05 #7	1.16	7.38	1.87	88.36	0	1.24	100

Table E. Percentage composition of each Aleipata samples.

Sample ID	Coral	Shell	Forams	Halimeda	Worm Tubes	Coquina	Limestone	Rock Fragments	Total
AP05 #1	38.11	21.53	22.75	9.38	2.12	4.31	1.67	0.13	100
AP05 #2	36.36	20.91	17.99	13.96	0.06	4.29	5.85	0.58	100
AP05 #3	36.71	24.1	9.32	26.1	0.64	1.29	1.61	0.24	100
AP05 #4	40.3	24.95	12.87	10.79	0.3	6.04	4.45	0.3	100
AP05 #5	41.54	31.1	8.57	6.31	0.31	3.74	7.48	0.94	100
AP05 #6	28.95	28.31	11.07	15.43	1.63	10.25	4.26	0.09	100
AP05 #7	24.61	45.94	6.48	7.55	3.2	6.07	4.51	1.64	100
AP05 #8	42.04	27.85	7.96	7.74	1.4	7.53	5.16	0.32	100

Table F. Percentage composition of the Vaisigano River mouth samples.

Sample ID	Coral	Shell	Forams	Halimeda	Coquina	Rock Fragments	Mineral Fragments	Others	Total
VR05 #1	0.27	0.61	0.06	0.00	4.05	93.86	0.47	0.67	100
VR05 #2	2.21	2.56	0.35	0.35	2.49	90.40	0.14	1.52	100

Table G. Percentage composition of the Salelologa samples.

Sample ID	Coral	Shell	Forams	Halimeda	Worm Tubes	Coquina	Limestone	Rock Fragments	Total
SL05 #1	49.32	18.2	0.59	20.35	0.59	10.96	0	0	100
SL05 #2	47.15	27.12	0.17	17.96	1.04	6.04	0.35	0.17	100
SL05 #3	45.61	28.95	1.17	22.22	0.29	1.75	0	0	100
SL05 #4	33.95	22.09	0.58	39.36	0.69	3.22	0.12	0	100
SL05 #5	44.23	30.41	0.76	19.54	0.29	3.72	1.05	0	100
SL05 #6	44.55	27.5	3.86	20.45	0.11	2.61	0.91	0	100
SL05 #7	42.8	25.03	3.36	22.54	0.11	5.52	0.54	0.11	100
SL05 #8	41.48	27.49	2.7	19.06	0	8.94	0.34	0	100
SL05 #9	59.87	28.79	0.63	6.74	0.16	3.49	0.16	0.16	100

APPENDIX 4

Schmidt Hammer Strength Test Results

A. Schmidt Hammer Strength Test Results for the 2004 Alafua and Saleimoa rock samples

Sample ID	Average Rebound Values			Compressive Strength (MPa)		
	Before Drying	After Drying	After Soaking	Before Drying	After Drying	After Soaking
Alafua #1	57.0	57.4	55.0	79.7	80.6	75.2
Alafua #2	58.3	58.2	55.4	83.3	83.0	76.2
Alafua #3	43.2	42.7	41.1	51.7	50.2	47.5
Saleimoa #1	58.3	57.8	56.2	83.3	80.7	78.0
Saleimoa #2	50.1	54.8	52.5	64.7	74.6	69.7

B. 2005 Schmidt Hammer Strength Test Results for the in-situ rock sources from selected sites in Upolu Island

Locality	Rebound Values			Average Value	Compressive Strength (MPa)	Angle of the Instrument
	1st	2nd	3rd			
Namo 1	48.5	46.7	39.5	44.90	54.1	Horizontal position (a = 0°)
Namo 2	51.9	58.7	21.9	44.17	53.0	Horizontal position (a = 0°)
Lemafa 1	39.8	32.4	23.5	31.90	30.0	Horizontal position (a = 0°)
Lemafa 2	36.2	53.2	55.2	48.20	60.5	Horizontal position (a = 0°)
Tuialemu 1	26.8	17.9	27.7	24.13	20.0	Horizontal position (a = 0°)
Tuialemu 2	62.3	35.8	57.6	51.90	68.2	Horizontal position (a = 0°)

C. 2005 Schmidt Hammer Strength Test Results for the in-situ rock sources from selected sites on Savai'i Island

Locality	Rebound Values			Average Value	Compressive Strength (MPa)	Angle of the Instrument
	1st	2nd	3rd			
Puapua Quarry 1a	54.3	40.2	54	49.5	58.9	Horizontal position (a = 0°)
Puapua Quarry 1b	25.2	28.7	29.9	27.9	20.2	Horizontal position (a = 0°)
Manase 1	40.2	34	38.1	37.4	35.9	Horizontal position (a = 0°)
Manase 2	26.2	14	6.2	15.5	5.5	Horizontal position (a = 0°)
Vaisala Quarry	33.4	33.2	29.8	32.1	27.2	Horizontal position (a = 0°)
Aopo	28.7	41.2	46.5	38.8	43.6	Vertical downward position (a = –90°)

D. 2005 Schmidt Hammer Strength Test Results for the in-situ rock sources from various localities within the Saleaula lava field

Locality	Rebound Values			Average Values	Compressive Strength (MPa)	Angle of the Instrument
	1st	2nd	3rd			
Saleaula Lava 1	43.3	39.8	24.4	35.8	38.3	Vertical downward position (a = –90°)
Saleaula Lava 2a	15.7	11.5	23.2	16.8	11.5	Vertical downward position (a = –90°)
Saleaula Lava 2b	13.5	21.9	30.4	21.9	17.3	Vertical downward position (a = –90°)
Saleaula Lava 3a	6.7	18.3	16.2	13.7	8.2	Vertical downward position (a = –90°)
Saleaula Lava 3b	16.8	21.2	7.6	15.2	9.8	Vertical downward position (a = –90°)
Saleaula Lava 4a	11.9	7.6	13.2	10.9	5.5	Vertical downward position (a = –90°)
Saleaula Lava 4b	10.0	9.8	11.2	10.3	4.9	Vertical downward position (a = –90°)
Saleaula Lava 5a	20.1	19.9	7.6	15.9	10.2	Vertical downward position (a = –90°)
Saleaula Lava 5b	17.6	11.9	16.7	15.4	9.9	Vertical downward position (a = –90°)

APPENDIX 5

Rock cube dimension and test results for Point Load Testing

Rock Name	Sample No.	D (mm)	W (mm)	L (mm)	P (kN)	P (MN)
Alafua 1	a	40.00	59.00	75.00	19.40	0.0750
"	b	42.00	68.00	71.00	11.80	0.0710
"	c	43.00	65.00	70.00	20.90	0.0700
Alafua 2	a	32.00	59.00	79.00	22.10	0.0790
"	b	25.00	46.00	81.00	18.00	0.0810
"	c	22.00	59.00	82.00	14.30	0.0820
Alafua 3	a	28.00	58.00	70.00	5.60	0.0700
"	b	34.00	47.00	60.00	5.00	0.0600
"	c	26.00	45.00	70.00	5.90	0.0700
Saleimoa 1	a	36.00	72.00	76.00	30.70	0.0760
"	b	32.00	73.00	75.00	32.10	0.0750
"	c	41.00	73.00	84.00	36.20	0.0840
Saleimoa 2	a	31.00	57.00	64.00	27.20	0.0640
"	b	34.00	59.00	63.00	24.50	0.0630
"	c	35.00	40.00	69.00	28.80	0.0690

APPENDIX 6

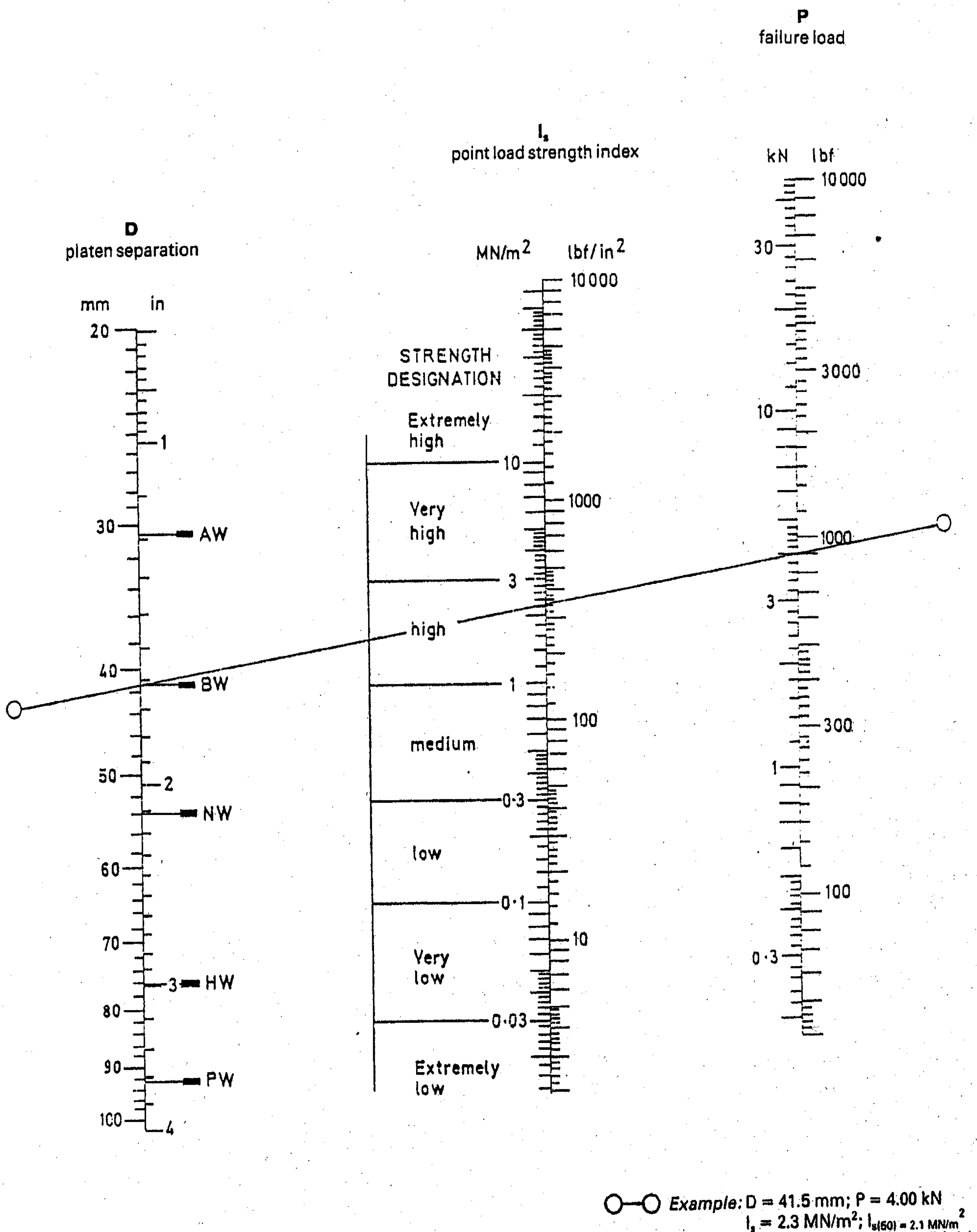
Water Content and Density of Alafua and Saleimoa Rock Samples

Sample ID	Weight (g)			Water content (g)	% Water Content
	Before Drying	After Drying	After Soaking		
Alafua #1	1338.20	1331.60	1340.10	8.50	0.63
Alafua #2	1356.10	1350.90	1359.40	8.50	0.63
Alafua #3	1264.30	1241.00	1274.00	33.00	2.59
Saleimoa #1	1432.90	1431.70	1440.50	8.80	0.61
Saleimoa #2	1278.30	1275.90	1290.10	14.20	1.10

Sample ID	Volume (cm^3)	Density (g/cm^3)		
		Before Heating	After Drying	After Soaking
Alafua #1	472.00	2.87	2.86	2.88
Alafua #2	466.00	2.71	2.66	2.73
Alafua #3	460.00	3.12	3.11	3.13
Saleimoa #1	480.00	2.99	2.98	3.00
Saleimoa #2	448.00	2.85	2.85	2.88

APPENDIX 7

Nomogram for computing point load strength designation (from ELE International, 2003)



Example: D = 41.5 mm; P = 4.00 kN
I_s = 2.3 MN/m²; $I_{s(50)}$ = 2.1 MN/m²
Strength designation = 'high'

APPENDIX 8

Particle Size Distribution Analysis Results for the 2004 Marine Sediment Samples

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Mulifanua				
Sample No:		# 2				
Amount in Grams	641.70	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	134.60	97.50	97.50	15.22	15.86
8.00	– 3.00	123.10	86.00	183.50	28.65	13.40
4.00	– 2.00	79.70	42.60	226.10	35.31	6.64
2.00	– 1.00	79.30	42.20	268.30	41.90	6.58
1.40	– 0.50	80.80	43.70	312.00	48.72	6.81
1.00	0.00	79.50	42.40	354.40	55.34	6.61
0.71	0.50	84.10	47.00	401.40	62.68	7.32
0.50	1.00	85.60	48.50	449.90	70.25	7.56
0.35	1.50	68.70	31.60	481.50	75.19	4.92
0.25	2.00	78.70	41.60	523.10	81.68	6.48
0.18	2.50	77.40	40.30	563.40	87.98	6.28
0.13	3.00	71.70	34.60	598.00	93.38	5.39
0.09	3.50	55.20	18.10	616.10	96.21	2.82
0.06	4.00	46.30	9.20	625.30	97.64	1.43
pan		52.20	15.10	640.40	100.00	2.35

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Mulifanua				
Sample No:		# 3				
Amount in Grams	612.70	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	191.10	154.00	154.00	25.17	25.13
8.00	– 3.00	133.10	96.00	250.00	40.86	15.67
4.00	– 2.00	86.60	49.50	299.50	48.95	8.08
2.00	– 1.00	75.00	37.90	337.40	55.15	6.19
1.40	– 0.50	68.00	30.90	368.30	60.20	5.04
1.00	0.00	66.20	29.10	397.40	64.96	4.75
0.71	0.50	71.40	34.30	431.70	70.56	5.60
0.50	1.00	72.80	35.70	467.40	76.40	5.83
0.35	1.50	58.80	21.70	489.10	79.94	3.54
0.25	2.00	65.00	27.90	517.00	84.50	4.55
0.18	2.50	60.40	23.30	540.30	88.31	3.80
0.13	3.00	60.50	23.40	563.70	92.14	3.82
0.09	3.50	52.30	15.20	578.90	94.62	2.48
0.06	4.00	48.00	10.90	589.80	96.40	1.78
pan		59.10	22.00	611.80	100.00	3.59

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Mulifanua				
Sample No:		# 4				
Amount in Grams	585.80	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	178.90	141.80	141.80	24.26	24.21
8.00	– 3.00	130.50	93.40	235.20	40.24	15.94
4.00	– 2.00	76.10	39.00	274.20	46.91	6.66
2.00	– 1.00	72.70	35.60	309.80	53.00	6.08
1.40	– 0.50	67.40	30.30	340.10	58.19	5.17
1.00	0.00	64.80	27.70	367.80	62.93	4.73
0.71	0.50	70.70	33.60	401.40	68.67	5.74
0.50	1.00	72.70	35.60	437.00	74.76	6.08
0.35	1.50	58.40	21.30	458.30	78.41	3.64
0.25	2.00	64.70	27.60	485.90	83.13	4.71
0.18	2.50	62.30	25.20	511.10	87.44	4.30
0.13	3.00	61.80	24.70	535.80	91.67	4.22
0.09	3.50	51.80	14.70	550.50	94.18	2.51
0.06	4.00	48.00	10.90	561.40	96.05	1.86
pan		60.20	23.10	584.50	100.00	3.94

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Mulifanua				
Sample No:		# 5				
Amount in Grams	497.70	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	103.00	65.90	65.90	13.31	13.24
8.00	– 3.00	116.40	79.30	145.20	29.33	15.93
4.00	– 2.00	99.40	62.30	207.50	41.91	12.52
2.00	– 1.00	86.70	49.60	257.10	51.93	9.97
1.40	– 0.50	64.70	27.60	284.70	57.50	5.55
1.00	0.00	61.50	24.40	309.10	62.43	4.90
0.71	0.50	66.00	28.90	338.00	68.27	5.81
0.50	1.00	64.50	27.40	365.40	73.80	5.51
0.35	1.50	55.50	18.40	383.80	77.52	3.70
0.25	2.00	60.90	23.80	407.60	82.33	4.78
0.18	2.50	63.00	25.90	433.50	87.56	5.20
0.13	3.00	59.00	21.90	455.40	91.98	4.40
0.09	3.50	50.20	13.10	468.50	94.63	2.63
0.06	4.00	45.60	8.50	477.00	96.34	1.71
pan		55.20	18.10	495.10	100.00	3.64

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Mulifanua				
Sample No:		# 6				
Amount in Grams	400.20	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	0.00	– 37.10	– 37.10	– 9.29	– 9.27
8.00	– 3.00	0.00	– 37.10	– 74.20	– 18.58	– 9.27
4.00	– 2.00	41.10	4.00	4.00	1.00	1.00
2.00	– 1.00	79.60	42.50	46.50	11.65	10.62
1.40	– 0.50	72.30	35.20	81.70	20.46	8.80
1.00	0.00	64.50	27.40	109.10	27.32	6.85
0.71	0.50	64.10	27.00	136.10	34.08	6.75
0.50	1.00	55.80	18.70	154.80	38.77	4.67
0.35	1.50	51.90	14.80	169.60	42.47	3.70
0.25	2.00	53.80	16.70	186.30	46.66	4.17
0.18	2.50	54.40	17.30	203.60	50.99	4.32
0.13	3.00	66.50	29.40	233.00	58.35	7.35
0.09	3.50	105.40	68.30	301.30	75.46	17.07
0.06	4.00	62.10	25.00	326.30	81.72	6.25
pan		110.10	73.00	399.30	100.00	18.24

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Mulifanua				
Sample No:		# 7				
Amount in Grams	564.40	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	218.70	181.60	181.60	32.22	32.18
8.00	– 3.00	84.70	47.60	229.20	40.67	8.43
4.00	– 2.00	70.00	32.90	262.10	46.50	5.83
2.00	– 1.00	67.40	30.30	292.40	51.88	5.37
1.40	– 0.50	68.80	31.70	324.10	57.51	5.62
1.00	0.00	67.70	30.60	354.70	62.93	5.42
0.71	0.50	72.50	35.40	390.10	69.22	6.27
0.50	1.00	72.90	35.80	425.90	75.57	6.34
0.35	1.50	60.00	22.90	448.80	79.63	4.06
0.25	2.00	67.20	30.10	478.90	84.97	5.33
0.18	2.50	65.00	27.90	506.80	89.92	4.94
0.13	3.00	62.90	25.80	532.60	94.50	4.57
0.09	3.50	50.00	12.90	545.50	96.79	2.29
0.06	4.00	44.20	7.10	552.60	98.05	1.26
pan		48.10	11.00	563.60	100.00	1.95

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaitele				
Sample No:		# 1				
Amount in Grams	491.80	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	49.50	12.40	12.40	2.53	2.52
8.00	– 3.00	113.20	76.10	88.50	18.03	15.47
4.00	– 2.00	128.80	91.70	180.20	36.71	18.65
2.00	– 1.00	117.00	79.90	260.10	52.98	16.25
1.40	– 0.50	80.70	43.60	303.70	61.87	8.87
1.00	0.00	73.70	36.60	340.30	69.32	7.44
0.71	0.50	66.40	29.30	369.60	75.29	5.96
0.50	1.00	64.30	27.20	396.80	80.83	5.53
0.35	1.50	57.20	20.10	416.90	84.93	4.09
0.25	2.00	62.20	25.10	442.00	90.04	5.10
0.18	2.50	60.10	23.00	465.00	94.72	4.68
0.13	3.00	54.70	17.60	482.60	98.31	3.58
0.09	3.50	42.00	4.90	487.50	99.31	1.00
0.06	4.00	39.90	2.80	490.30	99.88	0.57
pan		37.70	0.60	490.90	100.00	0.12

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaitele				
Sample No:		# 2				
Amount in Grams	466.10	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	59.40	22.30	22.30	4.78	4.78
8.00	– 3.00	86.30	49.20	71.50	15.34	10.56
4.00	– 2.00	116.80	79.70	151.20	32.44	17.10
2.00	– 1.00	111.50	74.40	225.60	48.40	15.96
1.40	– 0.50	81.20	44.10	269.70	57.86	9.46
1.00	0.00	78.50	41.40	311.10	66.75	8.88
0.71	0.50	79.20	42.10	353.20	75.78	9.03
0.50	1.00	67.80	30.70	383.90	82.36	6.59
0.35	1.50	55.30	18.20	402.10	86.27	3.90
0.25	2.00	57.00	19.90	422.00	90.54	4.27
0.18	2.50	53.20	16.10	438.10	93.99	3.45
0.13	3.00	50.50	13.40	451.50	96.87	2.87
0.09	3.50	44.00	6.90	458.40	98.35	1.48
0.06	4.00	41.10	4.00	462.40	99.21	0.86
pan		40.80	3.70	466.10	100.00	0.79

Sample Description		SAND				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaitele				
Sample No:		# 3				
Amount in Grams	507.40	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	49.80	12.70	12.70	2.51	2.50
8.00	– 3.00	96.60	59.50	72.20	14.24	11.73
4.00	– 2.00	114.80	77.70	149.90	29.57	15.31
2.00	– 1.00	105.70	68.60	218.50	43.11	13.52
1.40	– 0.50	78.00	40.90	259.40	51.17	8.06
1.00	0.00	77.30	40.20	299.60	59.10	7.92
0.71	0.50	78.90	41.80	341.40	67.35	8.24
0.50	1.00	71.50	34.40	375.80	74.14	6.78
0.35	1.50	59.30	22.20	398.00	78.52	4.38
0.25	2.00	65.40	28.30	426.30	84.10	5.58
0.18	2.50	63.40	26.30	452.60	89.29	5.18
0.13	3.00	61.80	24.70	477.30	94.16	4.87
0.09	3.50	51.20	14.10	491.40	96.94	2.78
0.06	4.00	44.70	7.60	499.00	98.44	1.50
pan		45.00	7.90	506.90	100.00	1.56

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaitele				
Sample No:		# 4				
Amount in Grams	468.00	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	48.80	11.70	11.70	2.50	2.50
8.00	– 3.00	77.60	40.50	52.20	11.17	8.65
4.00	– 2.00	85.80	48.70	100.90	21.60	10.41
2.00	– 1.00	99.00	61.90	162.80	34.85	13.23
1.40	– 0.50	79.30	42.20	205.00	43.88	9.02
1.00	0.00	80.70	43.60	248.60	53.21	9.32
0.71	0.50	83.90	46.80	295.40	63.23	10.00
0.50	1.00	75.70	38.60	334.00	71.49	8.25
0.35	1.50	61.80	24.70	358.70	76.78	5.28
0.25	2.00	65.70	28.60	387.30	82.90	6.11
0.18	2.50	62.10	25.00	412.30	88.25	5.34
0.13	3.00	62.40	25.30	437.60	93.66	5.41
0.09	3.50	50.80	13.70	451.30	96.60	2.93
0.06	4.00	44.60	7.50	458.80	98.20	1.60
pan		45.50	8.40	467.20	100.00	1.79

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaitele				
Sample No:		# 5				
Amount in Grams	481.90	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	46.80	9.70	9.70	2.01	2.01
8.00	– 3.00	74.80	37.70	47.40	9.84	7.82
4.00	– 2.00	107.60	70.50	117.90	24.48	14.63
2.00	– 1.00	96.30	59.20	177.10	36.77	12.28
1.40	– 0.50	81.00	43.90	221.00	45.89	9.11
1.00	0.00	80.90	43.80	264.80	54.98	9.09
0.71	0.50	86.50	49.40	314.20	65.24	10.25
0.50	1.00	75.50	38.40	352.60	73.21	7.97
0.35	1.50	61.70	24.60	377.20	78.32	5.10
0.25	2.00	65.60	28.50	405.70	84.24	5.91
0.18	2.50	63.20	26.10	431.80	89.66	5.42
0.13	3.00	60.30	23.20	455.00	94.48	4.81
0.09	3.50	49.80	12.70	467.70	97.11	2.64
0.06	4.00	43.30	6.20	473.90	98.40	1.29
pan		44.80	7.70	481.60	100.00	1.60

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaitele				
Sample No:		# 6				
Amount in Grams	496.10	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	48.30	11.20	11.20	2.26	2.26
8.00	– 3.00	73.30	36.20	47.40	9.56	7.30
4.00	– 2.00	90.00	52.90	100.30	20.23	10.66
2.00	– 1.00	94.10	57.00	157.30	31.73	11.49
1.40	– 0.50	80.40	43.30	200.60	40.47	8.73
1.00	0.00	81.10	44.00	244.60	49.34	8.87
0.71	0.50	87.40	50.30	294.90	59.49	10.14
0.50	1.00	79.40	42.30	337.20	68.03	8.53
0.35	1.50	63.60	26.50	363.70	73.37	5.34
0.25	2.00	70.50	33.40	397.10	80.11	6.73
0.18	2.50	68.10	31.00	428.10	86.36	6.25
0.13	3.00	68.60	31.50	459.60	92.72	6.35
0.09	3.50	53.20	16.10	475.70	95.97	3.25
0.06	4.00	46.30	9.20	484.90	97.82	1.85
pan		47.90	10.80	495.70	100.00	2.18

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaiusu				
Sample No:		# 1				
Amount in Grams	611.50	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	88.90	51.80	51.80	8.48	8.47
8.00	– 3.00	118.80	81.70	133.50	21.86	13.36
4.00	– 2.00	82.50	45.40	178.90	29.29	7.42
2.00	– 1.00	60.20	23.10	202.00	33.08	3.78
1.40	– 0.50	73.30	36.20	238.20	39.00	5.92
1.00	0.00	86.00	48.90	287.10	47.01	8.00
0.71	0.50	94.40	57.30	344.40	56.39	9.37
0.50	1.00	90.50	53.40	397.80	65.14	8.73
0.35	1.50	73.00	35.90	433.70	71.02	5.87
0.25	2.00	88.50	51.40	485.10	79.43	8.41
0.18	2.50	91.50	54.40	539.50	88.34	8.90
0.13	3.00	85.00	47.90	587.40	96.18	7.83
0.09	3.50	52.20	15.10	602.50	98.66	2.47
0.06	4.00	42.60	5.50	608.00	99.56	0.90
pan		39.80	2.70	610.70	100.00	0.44

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaiusu				
Sample No:		# 2				
Amount in Grams	583.80	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	102.50	65.40	65.40	11.21	11.20
8.00	– 3.00	85.90	48.80	114.20	19.58	8.36
4.00	– 2.00	64.40	27.30	141.50	24.26	4.68
2.00	– 1.00	58.00	20.90	162.40	27.85	3.58
1.40	– 0.50	71.10	34.00	196.40	33.68	5.82
1.00	0.00	84.80	47.70	244.10	41.86	8.17
0.71	0.50	98.90	61.80	305.90	52.45	10.59
0.50	1.00	96.20	59.10	365.00	62.59	10.12
0.35	1.50	82.10	45.00	410.00	70.30	7.71
0.25	2.00	96.00	58.90	468.90	80.40	10.09
0.18	2.50	90.40	53.30	522.20	89.54	9.13
0.13	3.00	77.90	40.80	563.00	96.54	6.99
0.09	3.50	51.50	14.40	577.40	99.01	2.47
0.06	4.00	40.90	3.80	581.20	99.66	0.65
pan		39.10	2.00	583.20	100.00	0.34

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaiusu				
Sample No:		# 3				
Amount in Grams	607.80	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	136.00	98.90	98.90	16.27	16.27
8.00	– 3.00	89.00	51.90	150.80	24.81	8.54
4.00	– 2.00	80.40	43.30	194.10	31.94	7.12
2.00	– 1.00	61.10	24.00	218.10	35.89	3.95
1.40	– 0.50	73.50	36.40	254.50	41.88	5.99
1.00	0.00	85.60	48.50	303.00	49.86	7.98
0.71	0.50	100.10	63.00	366.00	60.23	10.37
0.50	1.00	94.00	56.90	422.90	69.59	9.36
0.35	1.50	76.30	39.20	462.10	76.04	6.45
0.25	2.00	87.00	49.90	512.00	84.25	8.21
0.18	2.50	80.50	43.40	555.40	91.39	7.14
0.13	3.00	69.00	31.90	587.30	96.64	5.25
0.09	3.50	50.30	13.20	600.50	98.82	2.17
0.06	4.00	41.30	4.20	604.70	99.51	0.69
pan		40.10	3.00	607.70	100.00	0.49

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaiusu				
Sample No:		# 4				
Amount in Grams	559.80	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	97.50	60.40	60.40	10.79	10.79
8.00	– 3.00	85.70	48.60	109.00	19.47	8.68
4.00	– 2.00	63.30	26.20	135.20	24.15	4.68
2.00	– 1.00	58.60	21.50	156.70	27.99	3.84
1.40	– 0.50	69.90	32.80	189.50	33.85	5.86
1.00	0.00	82.80	45.70	235.20	42.02	8.16
0.71	0.50	96.80	59.70	294.90	52.68	10.66
0.50	1.00	92.90	55.80	350.70	62.65	9.97
0.35	1.50	79.60	42.50	393.20	70.24	7.59
0.25	2.00	90.90	53.80	447.00	79.85	9.61
0.18	2.50	85.30	48.20	495.20	88.46	8.61
0.13	3.00	74.90	37.80	533.00	95.21	6.75
0.09	3.50	53.20	16.10	549.10	98.09	2.88
0.06	4.00	43.10	6.00	555.10	99.16	1.07
pan		41.80	4.70	559.80	100.00	0.84

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaiusu				
Sample No:		# 5				
Amount in Grams	582.50	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	112.30	75.20	75.20	12.92	12.91
8.00	– 3.00	94.40	57.30	132.50	22.77	9.84
4.00	– 2.00	63.70	26.60	159.10	27.34	4.57
2.00	– 1.00	63.90	26.80	185.90	31.95	4.60
1.40	– 0.50	73.10	36.00	221.90	38.13	6.18
1.00	0.00	86.10	49.00	270.90	46.55	8.41
0.71	0.50	99.50	62.40	333.30	57.28	10.71
0.50	1.00	89.70	52.60	385.90	66.32	9.03
0.35	1.50	75.50	38.40	424.30	72.92	6.59
0.25	2.00	82.40	45.30	469.60	80.70	7.78
0.18	2.50	78.10	41.00	510.60	87.75	7.04
0.13	3.00	75.80	38.70	549.30	94.40	6.64
0.09	3.50	56.10	19.00	568.30	97.66	3.26
0.06	4.00	45.30	8.20	576.50	99.07	1.41
pan		42.50	5.40	581.90	100.00	0.93

Sample Description		Sand				
Survey/Cruise		WS – 04				
Test Date						
Test Number						
Sample Position		Vaiusu				
Sample No:		# 6				
Amount in Grams	504.90	Water depth:		Surface		
Aperture	Ph Value	Weight	Wt retained	cum wt ret	cum %	indiv %
16.00	– 4.00	0.00		0.00	0.00	0.00
8.00	– 3.00	77.70	40.60	40.60	8.06	8.04
4.00	– 2.00	60.20	23.10	63.70	12.64	4.58
2.00	– 1.00	57.70	20.60	84.30	16.73	4.08
1.40	– 0.50	64.60	27.50	111.80	22.19	5.45
1.00	0.00	71.40	34.30	146.10	28.99	6.79
0.71	0.50	78.50	41.40	187.50	37.21	8.20
0.50	1.00	77.40	40.30	227.80	45.21	7.98
0.35	1.50	69.50	32.40	260.20	51.64	6.42
0.25	2.00	87.50	50.40	310.60	61.64	9.98
0.18	2.50	94.00	56.90	367.50	72.93	11.27
0.13	3.00	103.70	66.60	434.10	86.15	13.19
0.09	3.50	76.40	39.30	473.40	93.95	7.78
0.06	4.00	54.40	17.30	490.70	97.38	3.43
pan		50.30	13.20	503.90	100.00	2.61

APPENDIX 9

Particle Size Distribution Analysis Results for the 2005 Marine Sediment Samples

Amount (grams)		531		Water Depth (m)	0.8	
Sample Description		White calcareous sand		Test Date	11th October 2005	
Sample Number		MF05 #1		Test Number		
Survey Cruise				Sample position	13°49'49.0"S, 172°02'15.5"W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	52	14.9	14.9	2.82	2.81
8 mm	– 3	60.5	23.4	38.3	7.25	4.41
4 mm	– 2	76.5	39.4	77.7	14.70	7.42
2 mm	– 1	115.9	78.8	156.5	29.61	14.84
1.4 mm	– 0.5	103.4	66.3	222.8	42.16	12.49
1.0 mm	0	91.8	54.7	277.5	52.51	10.30
0.71 mm	0.5	86.3	49.2	326.7	61.82	9.27
0.5 mm	1	72.3	35.2	361.9	68.48	6.63
0.35 mm	1.5	58.6	21.5	383.4	72.54	4.05
0.25 mm	2	59.1	22	405.4	76.71	4.14
0.18 mm	2.5	55.2	18.1	423.5	80.13	3.41
0.125 mm	3	54.8	17.7	441.2	83.48	3.33
0.09 mm	3.5	54.4	17.3	458.5	86.75	3.26
0.063 mm	4	62.9	25.8	484.3	91.64	4.86
PAN		81.3	44.2	528.5	100.00	8.32

Amount (grams)		443.5		Water Depth (m)	2.5	
Sample Description		White calcareous sand		Test Date	11th October 2005	
Sample Number		MF05 #2		Test Number		
Survey Cruise				Sample position	13°49"46.8"S, 172°02'22.1"W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	40.2	3.1	3.1	0.70	0.70
4 mm	– 2	52.2	15.1	18.2	4.11	3.40
2 mm	– 1	99	61.9	80.1	18.07	13.96
1.4 mm	– 0.5	113.2	76.1	156.2	35.24	17.16
1.0 mm	0	106.1	69	225.2	50.80	15.56
0.71 mm	0.5	99.9	62.8	288	64.97	14.16
0.5 mm	1	89.9	52.8	340.8	76.88	11.91
0.35 mm	1.5	67.2	30.1	370.9	83.67	6.79
0.25 mm	2	65.7	28.6	399.5	90.12	6.45
0.18 mm	2.5	55.1	18	417.5	94.18	4.06
0.125 mm	3	49.4	12.3	429.8	96.95	2.77
0.09 mm	3.5	42.5	5.4	435.2	98.17	1.22
0.063 mm	4	39.9	2.8	438	98.80	0.63
PAN		42.4	5.3	443.3	100.00	1.20

Amount (grams)		469.3		Water Depth (m)	2.7	
Sample Description		White calcareous sand		Test Date	11th October 2005	
Sample Number		MF05 #3		Test Number		
Survey Cruise				Sample position	13° 49' 46.8" S, 172° 02' 32.5" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	0	0	0	0.00	0.00
4 mm	– 2	37.9	0.8	0.8	0.17	0.17
2 mm	– 1	50.9	13.8	14.6	3.11	2.94
1.4 mm	– 0.5	51.8	14.7	29.3	6.25	3.13
1.0 mm	0	66.8	29.7	59	12.58	6.33
0.71 mm	0.5	108.6	71.5	130.5	27.83	15.24
0.5 mm	1	142.7	105.6	236.1	50.35	22.50
0.35 mm	1.5	118.6	81.5	317.6	67.73	17.37
0.25 mm	2	112	74.9	392.5	83.71	15.96
0.18 mm	2.5	78.2	41.1	433.6	92.47	8.76
0.125 mm	3	58.8	21.7	455.3	97.10	4.62
0.09 mm	3.5	44.1	7	462.3	98.59	1.49
0.063 mm	4	39.7	2.6	464.9	99.15	0.55
PAN		41.1	4	468.9	100.00	0.85

Amount (grams)		309.5		Water Depth (m)	3	
Sample Description		White calcareous sand		Test Date	11th October 2005	
Sample Number		MF05 #5		Test Number		
Survey Cruise				Sample position	13° 49' 35.8" S, 172° 02' 12.6" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	37.4	0.30	0.30	0.10	0.10
4 mm	– 2	39.6	2.5	2.8	0.91	0.81
2 mm	– 1	118.8	81.7	84.5	27.35	26.40
1.4 mm	– 0.5	74	36.9	121.4	39.29	11.92
1.0 mm	0	65.9	28.8	150.2	48.61	9.31
0.71 mm	0.5	63.9	26.8	177	57.28	8.66
0.5 mm	1	64.6	27.5	204.5	66.18	8.89
0.35 mm	1.5	63.6	26.5	231	74.76	8.56
0.25 mm	2	72.8	35.7	266.7	86.31	11.53
0.18 mm	2.5	56.2	19.1	285.8	92.49	6.17
0.125 mm	3	46.7	9.6	295.4	95.60	3.10
0.09 mm	3.5	42.9	5.8	301.2	97.48	1.87
0.063 mm	4	40.7	3.6	304.8	98.64	1.16
PAN		41.3	4.2	309	100.00	1.36

Amount (grams)		402.4		Water Depth (m)	2.8	
Sample Description		White calcareous sand		Test Date	11th October 2005	
Sample Number		MF05 #6		Test Number		
Survey Cruise				Sample position	13° 49' 40.4" S, 172° 02' 05.4" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	42.5	5.4	5.4	1.34	1.34
8 mm	– 3	39.3	2.2	7.6	1.89	0.55
4 mm	– 2	41.9	4.8	12.4	3.08	1.19
2 mm	– 1	87.2	50.1	62.5	15.52	12.45
1.4 mm	– 0.5	78.8	41.7	104.2	25.88	10.36
1.0 mm	0	77.3	40.2	144.4	35.86	9.99
0.71 mm	0.5	76.5	39.4	183.8	45.64	9.79
0.5 mm	1	76.8	39.7	223.5	55.50	9.87
0.35 mm	1.5	68.7	31.6	255.1	63.35	7.85
0.25 mm	2	81.7	44.6	299.7	74.42	11.08
0.18 mm	2.5	82.4	45.3	345	85.67	11.26
0.125 mm	3	71.8	34.7	379.7	94.29	8.62
0.09 mm	3.5	49.4	12.3	392	97.34	3.06
0.063 mm	4	42.2	5.1	397.1	98.61	1.27
PAN		42.7	5.6	402.7	100.00	1.39

Amount (grams)		296.4		Water Depth (m)	3.7	
Sample Description		White calcareous sand		Test Date	11th October 2005	
Sample Number		MF05 #7		Test Number		
Survey Cruise				Sample position	13° 49' 43.4" S, 172° 02' 15.4" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	48	10.9	10.9	3.67	3.68
4 mm	– 2	44.5	7.4	18.3	6.17	2.50
2 mm	– 1	109	71.9	90.2	30.39	24.26
1.4 mm	– 0.5	79.9	42.8	133	44.81	14.44
1.0 mm	0	69.4	32.3	165.3	55.69	10.90
0.71 mm	0.5	67.2	30.1	195.4	65.84	10.16
0.5 mm	1	70.3	33.2	228.6	77.02	11.20
0.35 mm	1.5	58.5	21.4	250	84.23	7.22
0.25 mm	2	55.4	18.3	268.3	90.40	6.17
0.18 mm	2.5	49	11.9	280.2	94.41	4.01
0.125 mm	3	46.2	9.1	289.3	97.47	3.07
0.09 mm	3.5	40.6	3.5	292.8	98.65	1.18
0.063 mm	4	38.6	1.5	294.3	99.16	0.51
PAN		39.6	2.5	296.8	100.00	0.84

Amount (grams)		524.3		Water Depth (m)	0.8	
Sample Description		White calcareous sand		Test Date	12th October 2005	
Sample Number		AP05 #1		Test Number		
Survey Cruise				Sample position	14 01' 37.9" S, 171 25' 35.6" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	0	0	0	0.00	0.00
4 mm	– 2	38.7	1.6	1.6	0.31	0.31
2 mm	– 1	58	20.9	22.5	4.31	3.99
1.4 mm	– 0.5	60.5	23.4	45.9	8.78	4.46
1.0 mm	0	70.3	33.2	79.1	15.14	6.33
0.71 mm	0.5	83.5	46.4	125.5	24.01	8.85
0.5 mm	1	79.2	42.1	167.6	32.07	8.03
0.35 mm	1.5	69.6	32.5	200.1	38.29	6.20
0.25 mm	2	84.7	47.6	247.7	47.40	9.08
0.18 mm	2.5	106.2	69.1	316.8	60.62	13.18
0.125 mm	3	125.8	88.7	405.5	77.59	16.92
0.09 mm	3.5	82.1	45	450.5	86.20	8.58
0.063 mm	4	63.9	26.8	477.3	91.33	5.11
PAN		82.4	45.3	522.6	100.00	8.64

Amount (grams)		486.5		Water Depth (m)	1.6	
Sample Description		White calcareous sand		Test Date	12th October 2005	
Sample Number		AP05 #2		Test Number		
Survey Cruise				Sample position	14° 01' 40.5" S, 171° 25' 29.5" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	0	0	0	0.00	0.00
4 mm	– 2	39.3	2.2	2.2	0.45	0.45
2 mm	– 1	61.1	24	26.2	5.39	4.93
1.4 mm	– 0.5	62.5	25.4	51.6	10.62	5.22
1.0 mm	0	73.4	36.3	87.9	18.08	7.46
0.71 mm	0.5	93.1	56	143.9	29.60	11.51
0.5 mm	1	96.6	59.5	203.4	41.84	12.23
0.35 mm	1.5	85.1	48	251.4	51.72	9.87
0.25 mm	2	104.5	67.4	318.8	65.58	13.85
0.18 mm	2.5	98	60.9	379.7	78.11	12.52
0.125 mm	3	95	57.9	437.6	90.02	11.90
0.09 mm	3.5	65.3	28.2	465.8	95.82	5.80
0.063 mm	4	49.4	12.3	478.1	98.35	2.53
PAN		45.1	8	486.1	100.00	1.64

Amount (grams)		389.1		Water Depth (m)	4	
Sample Description		White calcareous sand		Test Date	12th October 2005	
Sample Number		AP05 #3		Test Number		
Survey Cruise				Sample position	14° 01' 41.5" S, 171° 25' 23.1" W	
Aperture	**Phi Value**	**Sample & Container**	**Individual Weight Retained**	**Cumulative Weight Retained**	**Cumulative % Retained**	**Individual %**
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	0	0	0	0.00	0.00
4 mm	– 2	47.4	10.3	10.3	2.65	2.65
2 mm	– 1	90.9	53.8	64.1	16.51	13.83
1.4 mm	– 0.5	90.5	53.4	117.5	30.27	13.72
1.0 mm	0	95.5	58.4	175.9	45.31	15.01
0.71 mm	0.5	106.3	69.2	245.1	63.14	17.78
0.5 mm	1	94.8	57.7	302.8	78.00	14.83
0.35 mm	1.5	68.5	31.4	334.2	86.09	8.07
0.25 mm	2	58.6	21.5	355.7	91.63	5.53
0.18 mm	2.5	48.1	11	366.7	94.46	2.83
0.125 mm	3	46.7	9.6	376.3	96.93	2.47
0.09 mm	3.5	42.9	5.8	382.1	98.43	1.49
0.063 mm	4	39.7	2.6	384.7	99.10	0.67
PAN		40.6	3.5	388.2	100.00	0.90

Amount (grams)		516.9		Water Depth (m)	1.8	
Sample Description		White calcareous sand		Test Date	12th October 2005	
Sample Number		AP05 #4		Test Number		
Survey Cruise				Sample position	14° 01' 35.4" S, 171° 25' 18.5" W	
Aperture	**Phi Value**	**Sample & Container**	**Individual Weight Retained**	**Cumulative Weight Retained**	**Cumulative % Retained**	**Individual %**
16 mm	– 4	64.9	27.8	27.8	5.38	5.38
8 mm	– 3	46.3	9.2	37	7.16	1.78
4 mm	– 2	43.6	6.5	43.5	8.42	1.26
2 mm	– 1	57.6	20.5	64	12.39	3.97
1.4 mm	– 0.5	60.4	23.3	87.3	16.90	4.51
1.0 mm	0	85.3	48.2	135.5	26.23	9.32
0.71 mm	0.5	124	86.9	222.4	43.06	16.81
0.5 mm	1	119.9	82.8	305.2	59.09	16.02
0.35 mm	1.5	89.6	52.5	357.7	69.25	10.16
0.25 mm	2	100.2	63.1	420.8	81.47	12.21
0.18 mm	2.5	91.3	54.2	475	91.97	10.49
0.125 mm	3	69.3	32.2	507.2	98.20	6.23
0.09 mm	3.5	43.7	6.6	513.8	99.48	1.28
0.063 mm	4	38.5	1.4	515.2	99.75	0.27
PAN		38.4	1.3	516.5	100.00	0.25

Amount (grams)		536.2		Water Depth (m)	1.8	
Sample Description		White calcareous sand		Test Date	12th October 2005	
Sample Number		AP05 #5		Test Number		
Survey Cruise				Sample position	14° 01' 26.8" S, 171° 25' 15.1" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	45.4	8.3	8.3	1.55	1.55
4 mm	– 2	41.9	4.8	13.1	2.45	0.90
2 mm	– 1	54.7	17.6	30.7	5.73	3.28
1.4 mm	– 0.5	69.9	32.8	63.5	11.85	6.12
1.0 mm	0	108.9	71.8	135.3	25.26	13.39
0.71 mm	0.5	147.1	110	245.3	45.79	20.51
0.5 mm	1	137.3	100.2	345.5	64.50	18.69
0.35 mm	1.5	104	66.9	412.4	76.98	12.48
0.25 mm	2	103.6	66.5	478.9	89.40	12.40
0.18 mm	2.5	70.2	33.1	512	95.58	6.17
0.125 mm	3	51.3	14.2	526.2	98.23	2.65
0.09 mm	3.5	42.2	5.1	531.3	99.18	0.95
0.063 mm	4	39.3	2.2	533.5	99.59	0.41
PAN		39.3	2.2	535.7	100.00	0.41

Amount (grams)		486		Water Depth (m)	1.6	
Sample Description		White calcareous sand		Test Date	12th October 2005	
Sample Number		AP05 #6		Test Number		
Survey Cruise				Sample position	14° 01' 24.0" S, 171° 25' 23.0" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	0	0	0	0.00	0.00
4 mm	– 2	45.2	8.1	8.1	1.67	1.67
2 mm	– 1	58.1	21	29.1	6.00	4.32
1.4 mm	– 0.5	67	29.9	59	12.17	6.15
1.0 mm	0	101.3	64.2	123.2	25.41	13.21
0.71 mm	0.5	128	90.9	214.1	44.15	18.70
0.5 mm	1	111.5	74.4	288.5	59.50	15.31
0.35 mm	1.5	84.3	47.2	335.7	69.23	9.71
0.25 mm	2	88.7	51.6	387.3	79.87	10.62
0.18 mm	2.5	78.4	41.3	428.6	88.39	8.50
0.125 mm	3	66	28.9	457.5	94.35	5.95
0.09 mm	3.5	49.6	12.5	470	96.93	2.57
0.063 mm	4	43.5	6.4	476.4	98.25	1.32
PAN		45.6	8.5	484.9	100.00	1.75

Amount (grams)		484.7		Water Depth (m)	0.5	
Sample Description		White calcareous sand		Test Date	12th October 2005	
Sample Number		AP05 #7		Test Number		
Survey Cruise				Sample position	14° 01' 32.1" S, 171° 25' 25.5" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	38	0.9	0.9	0.19	0.19
4 mm	– 2	37.8	0.7	1.6	0.33	0.14
2 mm	– 1	43.4	6.3	7.9	1.63	1.30
1.4 mm	– 0.5	62.9	25.8	33.7	6.96	5.32
1.0 mm	0	100.9	63.8	97.5	20.13	13.16
0.71 mm	0.5	128.3	91.2	188.7	38.96	18.82
0.5 mm	1	116.5	79.4	268.1	55.35	16.38
0.35 mm	1.5	92.9	55.8	323.9	66.87	11.51
0.25 mm	2	99	61.9	385.8	79.64	12.77
0.18 mm	2.5	76.2	39.1	424.9	87.72	8.07
0.125 mm	3	74.7	37.6	462.5	95.48	7.76
0.09 mm	3.5	52.9	15.8	478.3	98.74	3.26
0.063 mm	4	41.1	4	482.3	99.57	0.83
PAN		39.2	2.1	484.4	100.00	0.43

Amount (grams)		517.5		Water Depth (m)	1.3	
Sample Description		White calcareous sand		Test Date	12th October 2005	
Sample Number		AP05 #8		Test Number		
Survey Cruise				Sample position	14° 01' 40.5" S, 171° 25' 35.6" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	0	0	0	0.00	0.00
4 mm	– 2	38.2	1.1	1.1	0.21	0.21
2 mm	– 1	50.5	13.4	14.5	2.81	2.59
1.4 mm	– 0.5	64	26.9	41.4	8.03	5.20
1.0 mm	0	79.3	42.2	83.6	16.22	8.15
0.71 mm	0.5	98.7	61.6	145.2	28.17	11.90
0.5 mm	1	104.3	67.2	212.4	41.20	12.99
0.35 mm	1.5	91.2	54.1	266.5	51.70	10.45
0.25 mm	2	99.7	62.6	329.1	63.84	12.10
0.18 mm	2.5	89.2	52.1	381.2	73.95	10.07
0.125 mm	3	91.8	54.7	435.9	84.56	10.57
0.09 mm	3.5	65.2	28.1	464	90.01	5.43
0.063 mm	4	56	18.9	482.9	93.68	3.65
PAN		69.7	32.6	515.5	100.00	6.30

Amount (grams)		445.5		Water Depth (m)	1.3	
Sample Description		Volcanic rock fragments		Test Date	14th October 2005	
Sample Number		VR05 #1		Test Number		
Survey Cruise				Sample position	Apia Harbour	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	0	0	0	0.00	0.00
4 mm	– 2	37.3	0.2	0.2	0.04	0.04
2 mm	– 1	42.9	5.8	6	1.10	1.30
1.4 mm	– 0.5	47.6	10.5	16.5	3.03	2.36
1.0 mm	0	47.7	10.6	27.1	4.98	2.38
0.71 mm	0.5	49.1	12	39.1	7.18	2.69
0.5 mm	1	48.5	11.4	50.5	9.27	2.56
0.35 mm	1.5	47.5	10.4	60.9	11.18	2.33
0.25 mm	2	59.8	22.7	83.6	15.35	5.10
0.18 mm	2.5	91.1	54	137.6	25.26	12.12
0.125 mm	3	212.7	175.6	313.2	57.50	39.42
0.09 mm	3.5	218.6	181.5	494.7	90.82	40.74
0.063 mm	4	81.1	44	538.7	98.90	9.88
PAN		43.1	6	544.7	100.00	1.35

Amount (grams)		669.2		Water Depth (m)	1.4	
Sample Description		Volcanic rock fragments		Test Date	14th October 2005	
Sample Number		VR05 #2		Test Number		
Survey Cruise				Sample position	Apia Harbour	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	73.1	0	0	0.00	0.00
8 mm	– 3	55.4	0	0	0.00	0.00
4 mm	– 2	116.3	79.2	79.2	12.89	11.84
2 mm	– 1	160.7	123.6	202.8	33.01	18.47
1.4 mm	– 0.5	111.9	74.8	277.6	45.18	11.18
1.0 mm	0	100.5	63.4	341	55.50	9.47
0.71 mm	0.5	102.4	65.3	406.3	66.13	9.76
0.5 mm	1	93.1	56	462.3	75.24	8.37
0.35 mm	1.5	76.8	39.7	502	81.71	5.93
0.25 mm	2	82.1	45	547	89.03	6.72
0.18 mm	2.5	70.1	33	580	94.40	4.93
0.125 mm	3	60.4	23.3	603.3	98.19	3.48
0.09 mm	3.5	44.9	7.8	611.1	99.46	1.17
0.063 mm	4	39.2	2.1	613.2	99.80	0.31
PAN		38.3	1.2	614.4	100.00	0.18

Amount (grams)		478.5		Water Depth (m)	3	
Sample Description		White calcareous sand		Test Date	05th October 2005	
Sample Number		SL05 #1		Test Number		
Survey Cruise				Sample position	13° 44' 40.7" S, 172° 12' 59.3" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	83.4	46.3	46.3	9.68	9.68
8 mm	– 3	68.8	31.7	78	16.31	6.62
4 mm	– 2	71.3	34.2	112.2	23.47	7.15
2 mm	– 1	93.2	56.1	168.3	35.20	11.72
1.4 mm	– 0.5	66.5	29.4	197.7	41.35	6.14
1.0 mm	0	71.6	34.5	232.2	48.57	7.21
0.71 mm	0.5	79.6	42.5	274.7	57.46	8.88
0.5 mm	1	78.9	41.8	316.5	66.20	8.74
0.35 mm	1.5	67.2	30.1	346.6	72.50	6.29
0.25 mm	2	73.4	36.3	382.9	80.09	7.59
0.18 mm	2.5	70.4	33.3	416.2	87.05	6.96
0.125 mm	3	68.9	31.8	448	93.70	6.65
0.09 mm	3.5	51.5	14.4	462.4	96.72	3.01
0.063 mm	4	43.4	6.3	468.7	98.03	1.32
PAN		46.5	9.4	478.1	100.00	1.96

Amount (grams)		490.5		Water Depth (m)	2.7	
Sample Description		White calcareous sand		Test Date	05th October 2005	
Sample Number		SL05 #2		Test Number		
Survey Cruise				Sample position	13° 44' 44.5" S, 172° 13' 01.9" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	98.4	61.3	61.3	12.51	12.50
8 mm	– 3	69.8	32.7	94	19.18	6.67
4 mm	– 2	47.7	10.6	104.6	21.34	2.16
2 mm	– 1	63.1	26	130.6	26.64	5.30
1.4 mm	– 0.5	72.4	35.3	165.9	33.84	7.20
1.0 mm	0	95.5	58.4	224.3	45.76	11.91
0.71 mm	0.5	109.8	72.7	297	60.59	14.82
0.5 mm	1	94.5	57.4	354.4	72.30	11.70
0.35 mm	1.5	72.4	35.3	389.7	79.50	7.20
0.25 mm	2	76.7	39.6	429.3	87.58	8.07
0.18 mm	2.5	67.6	30.5	459.8	93.80	6.22
0.125 mm	3	58.1	21	480.8	98.08	4.28
0.09 mm	3.5	42.6	5.5	486.3	99.20	1.12
0.063 mm	4	38.8	1.7	488	99.55	0.35
PAN		39.3	2.2	490.2	100.00	0.45

Amount (grams)		489.3		Water Depth (m)	2.6	
Sample Description		White calcareous sand		Test Date	05th October 2005	
Sample Number		SL05 #3		Test Number		
Survey Cruise				Sample position	13° 44' 52.7" S, 172° 13' 04.3" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	0	0	0	0.00	0.00
4 mm	– 2	38.9	1.8	1.8	0.37	0.37
2 mm	– 1	79.7	42.6	44.4	9.07	8.71
1.4 mm	– 0.5	76.4	39.3	83.7	17.09	8.03
1.0 mm	0	85.7	48.6	132.3	27.02	9.93
0.71 mm	0.5	102.1	65	197.3	40.29	13.28
0.5 mm	1	99.8	62.7	260	53.09	12.81
0.35 mm	1.5	79.3	42.2	302.2	61.71	8.62
0.25 mm	2	87.3	50.2	352.4	71.96	10.26
0.18 mm	2.5	86.4	49.3	401.7	82.03	10.08
0.125 mm	3	88.2	51.1	452.8	92.46	10.44
0.09 mm	3.5	63	25.9	478.7	97.75	5.29
0.063 mm	4	44.8	7.7	486.4	99.33	1.57
PAN		40.4	3.3	489.7	100.00	0.67

Amount (grams)		464.5		Water Depth (m)	2.8	
Sample Description		White calcareous sand		Test Date	05th October 2005	
Sample Number		SL05 #4		Test Number		
Survey Cruise				Sample position	13° 44' 58.3" S, 172° 13' 02.4" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	53.5	16.4	16.4	3.53	3.53
8 mm	– 3	40.7	3.6	20	4.30	0.78
4 mm	– 2	45.2	8.1	28.1	6.04	1.74
2 mm	– 1	96.6	59.5	87.6	18.84	12.81
1.4 mm	– 0.5	85.1	48	135.6	29.17	10.33
1.0 mm	0	84.4	47.3	182.9	39.34	10.18
0.71 mm	0.5	95.7	58.6	241.5	51.95	12.62
0.5 mm	1	91.8	54.7	296.2	63.71	11.78
0.35 mm	1.5	76.2	39.1	335.3	72.12	8.42
0.25 mm	2	83.7	46.6	381.9	82.15	10.03
0.18 mm	2.5	74.6	37.5	419.4	90.21	8.07
0.125 mm	3	66.1	29	448.4	96.45	6.24
0.09 mm	3.5	48.7	11.6	460	98.95	2.50
0.063 mm	4	40	2.9	462.9	99.57	0.62
PAN		39.1	2	464.9	100.00	0.43

Amount (grams)		492		Water Depth (m)	3.2	
Sample Description		White calcareous sand		Test Date	05th October 2005	
Sample Number		SL05 #5		Test Number		
Survey Cruise				Sample position	13° 45' 06.3" S, 172° 12' 56.3" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	59.2	22.1	22.1	4.49	4.49
8 mm	– 3	38.8	1.7	23.8	4.83	0.35
4 mm	– 2	51.9	14.8	38.6	7.84	3.01
2 mm	– 1	118.4	81.3	119.9	24.35	16.52
1.4 mm	– 0.5	87.6	50.5	170.4	34.60	10.26
1.0 mm	0	86.9	49.8	220.2	44.71	10.12
0.71 mm	0.5	92.1	55	275.2	55.88	11.18
0.5 mm	1	90.1	53	328.2	66.64	10.77
0.35 mm	1.5	77.6	40.5	368.7	74.86	8.23
0.25 mm	2	83.7	46.6	415.3	84.32	9.47
0.18 mm	2.5	71.5	34.4	449.7	91.31	6.99
0.125 mm	3	60.5	23.4	473.1	96.06	4.76
0.09 mm	3.5	46.7	9.6	482.7	98.01	1.95
0.063 mm	4	41.4	4.3	487	98.88	0.87
PAN		42.6	5.5	492.5	100.00	1.12

Amount (grams)		466.3		Water Depth (m)	4.3	
Sample Description		White calcareous sand		Test Date	05th October 2005	
Sample Number		SL05 #6		Test Number		
Survey Cruise				Sample position	13° 44' 44.6" S, 172° 12' 53.7" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	0	0	0	0.00	0.00
4 mm	– 2	41.3	4.2	4.2	0.90	0.90
2 mm	– 1	97.3	60.2	64.4	13.80	12.91
1.4 mm	– 0.5	110.5	73.4	137.8	29.53	15.74
1.0 mm	0	130	92.9	230.7	49.44	19.92
0.71 mm	0.5	132.5	95.4	326.1	69.89	20.46
0.5 mm	1	100.7	63.6	389.7	83.52	13.64
0.35 mm	1.5	68.9	31.8	421.5	90.33	6.82
0.25 mm	2	62.1	25	446.5	95.69	5.36
0.18 mm	2.5	50	12.9	459.4	98.46	2.77
0.125 mm	3	42.5	5.4	464.8	99.61	1.16
0.09 mm	3.5	38.1	1	465.8	99.83	0.21
0.063 mm	4	37.4	0.3	466.1	99.89	0.06
PAN		37.6	0.5	466.6	100.00	0.11

Amount (grams)		481.6		Water Depth (m)	3.8	
Sample Description		White calcareous sand		Test Date	05th October 2005	
Sample Number		SL05 #7		Test Number		
Survey Cruise				Sample position	13° 44' 35.5" S, 172° 12' 50.0" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	41.9	4.8	4.8	1.00	1.00
4 mm	– 2	38.3	1.2	6	1.25	0.25
2 mm	– 1	50	12.9	18.9	3.93	2.68
1.4 mm	– 0.5	68.2	31.1	50	10.38	6.46
1.0 mm	0	89.3	52.2	102.2	21.23	10.84
0.71 mm	0.5	106.6	69.5	171.7	35.66	14.43
0.5 mm	1	104	66.9	238.6	49.55	13.89
0.35 mm	1.5	86.1	49	287.6	59.73	10.17
0.25 mm	2	93.3	56.2	343.8	71.40	11.67
0.18 mm	2.5	91	53.9	397.7	82.60	11.19
0.125 mm	3	89.8	52.7	450.4	93.54	10.94
0.09 mm	3.5	56.4	19.3	469.7	97.55	4.01
0.063 mm	4	42.4	5.3	475	98.65	1.10
PAN		43.6	6.5	481.5	100.00	1.35

Amount (grams)		470.1		Water Depth (m)	3.1	
Sample Description		White Calcareous sand		Test Date	05th October 2005	
Sample Number		SL05 #8		Test Number		
Survey Cruise				Sample position	13° 44' 47.1" S, 172° 12' 46.3" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	47.9	10.8	10.8	2.30	2.30
8 mm	– 3	39.7	2.6	13.4	2.85	0.55
4 mm	– 2	48.2	11.1	24.5	5.21	2.36
2 mm	– 1	113.6	76.5	101	21.50	16.27
1.4 mm	– 0.5	102.9	65.8	166.8	35.50	14.00
1.0 mm	0	104.1	67	233.8	49.77	14.25
0.71 mm	0.5	81.6	44.5	278.3	59.24	9.47
0.5 mm	1	115.3	78.2	356.5	75.88	16.63
0.35 mm	1.5	70.4	33.3	389.8	82.97	7.08
0.25 mm	2	70.6	33.5	423.3	90.10	7.13
0.18 mm	2.5	57.7	20.6	443.9	94.49	4.38
0.125 mm	3	52.7	15.6	459.5	97.81	3.32
0.09 mm	3.5	42.8	5.7	465.2	99.02	1.21
0.063 mm	4	39	1.9	467.1	99.43	0.40
PAN		39.8	2.7	469.8	100.00	0.57

Amount (grams)		538.7		Water Depth(m)	5.4	
Sample Description		White Calcareous sand		Test Date	05th October 2005	
Sample Number		SL05 #9		Test Number		
Survey Cruise				Sample position	13° 44' 55.3" S, 172° 12' 46.5" W	
Aperture	Phi Value	Sample & Container	Individual Weight Retained	Cumulative Weight Retained	Cumulative % Retained	Individual %
16 mm	– 4	0	0	0	0.00	0.00
8 mm	– 3	47.1	10	10	1.85	1.86
4 mm	– 2	63.5	26.4	36.4	6.74	4.90
2 mm	– 1	105.6	68.5	104.9	19.43	12.72
1.4 mm	– 0.5	86.1	49	153.9	28.50	9.10
1.0 mm	0	89.6	52.5	206.4	38.22	9.75
0.71 mm	0.5	98.6	61.5	267.9	49.61	11.42
0.5 mm	1	100.5	63.4	331.3	61.35	11.77
0.35 mm	1.5	85	47.9	379.2	70.22	8.89
0.25 mm	2	93	55.9	435.1	80.57	10.38
0.18 mm	2.5	82.9	45.8	480.9	89.06	8.50
0.125 mm	3	74.5	37.4	518.3	95.98	6.94
0.09 mm	3.5	52.5	15.4	533.7	98.83	2.86
0.063 mm	4	40.9	3.8	537.5	99.54	0.71
PAN		39.6	2.5	540	100.00	0.46