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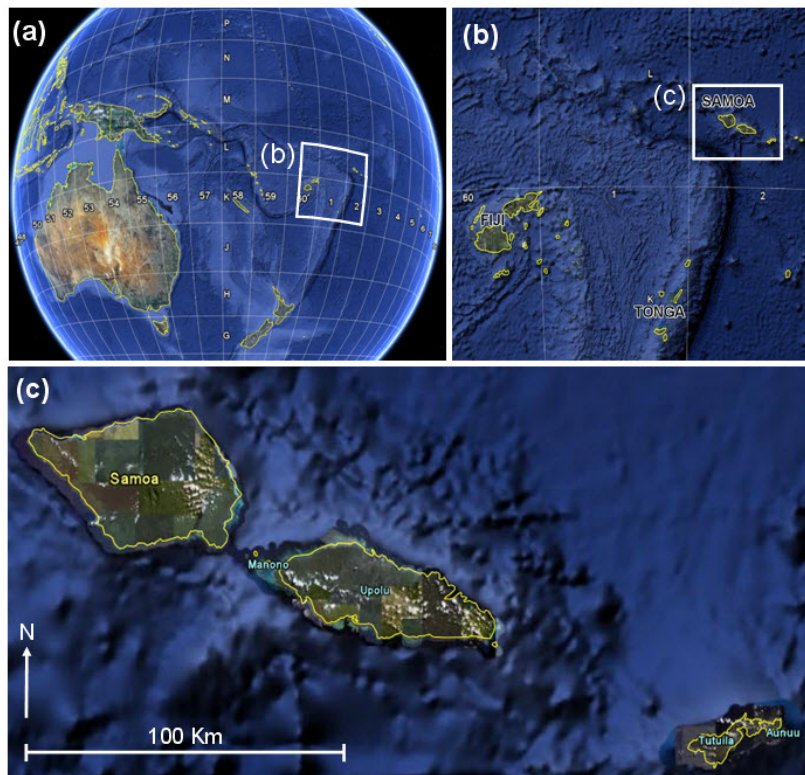
Australian Tsunami Research  
Centre  
School of Biological, Earth and  
Environmental Sciences

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## UNESCO-IOC International Tsunami Survey Team Samoa (ITST Samoa)

### Interim Report of Field Survey 14<sup>th</sup> – 21<sup>st</sup> October 2009

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(Source: Google Earth, 2009)

Report presented to the Government of Samoa  
Monday 26<sup>th</sup> October 2009



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**Interim Report of Field Survey  
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**Australian Tsunami Research Centre Miscellaneous Report No. 2:  
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- Australian Tsunami Research Centre
- Central Research Institute of Electric Power Industry, Japan
- Disaster Management Office, Government of Samoa
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- Engineering Consultants (Adam Jowitt), Samoa
- GNS Science, New Zealand
- Istituto Nazionale di Geofisica e Vulcanologia, Italy
- Japan Society of Civil Engineers
- Ministry of Agriculture, Forests and Fisheries, Government of Samoa
- Ministry of Education, Sports and Culture (Avele College), Samoa
- Ministry of Health, Government of Samoa
- Ministry of Natural Resources and Environment, Government of Samoa
- Ministry of Women, Community and Social Development, Government of Samoa
- Ministry of Works, Transport and Infrastructure, Government of Samoa
- National Defense Academy, Japan
- National Institute of Water & Atmospheric Research, New Zealand
- National University of Samoa
- Paradigm Documentaries, Samoa
- Port and Airport Research Institute, Japan
- Samoa Red Cross Society
- Scientific Research Organisation of Samoa
- South Pacific Applied Geoscience Commission, Fiji
- United States Geological Survey
- University of Bologna, Italy
- University of French Polynesia, Tahiti
- University of Hawaii at Hilo, Hawaii, USA
- University of the South Pacific, Fiji and Samoa
- West Coast/Alaska Tsunami Warning Centre, USA



## **DISCLAIMER**

This is an Interim Report. It represents a very rapid compilation of data collected and our initial discussion and preliminary recommendations.

It should be considered as preliminary since we have had insufficient time to ‘post-process’ collected data and correct it. For example, the measurements of tsunami run-up are ‘uncorrected’ for the position of the tide at the time of the tsunami and at the day of measurement. The measurements need adjusting and this can only be done once we have left Samoa. Further, the data collected about human experiences associated with the tsunami have not been cross referenced with the pre-tsunami context and nor are they compared with the literature. This makes it extremely difficult for the multicultural team members to come to a consensus about the exact nature of the observations they made and importantly, their meaning.

As data is post-processed and finalised, detailed interpretations can be made and we will send these to the Government of Samoa. We appreciate your understanding with these difficult matters.

The work of the International Tsunami Survey Team (ITST) has proceeded under the auspices of the UNESCO International Oceanographic Commission (UNESCO-IOC) according to standard IOC protocols and established procedures. Whilst the team has worked under the umbrella framework, the interpretations and recommendations within this Interim Report represent the views of the member scientists. The views expressed in this Interim Report do not necessarily represent the official views of the UNESCO-IOC.

## **DEDICATION**

The work of our team is dedicated to the people of Samoa in recognition of their strength and resilience in a difficult time. It is dedicated to their spirit of survival. We thank them for their inspiration.

## **ACKNOWLEDGEMENTS**

We thank the many people who willingly gave assistance, advice and encouragement, particularly during the difficult period in the field. Their support is greatly appreciated. We in particular want to thank His Highness, the Head of State Tui Atua Tupua Tamasese Ta’isi Efi, the Government of Samoa, SOPAC, the University of the South Pacific, the International Tsunami Information Center and the UNESCO Apia Office for their support and their extraordinary contributions to the trip. We also acknowledge the support of the New Zealand Government, especially the Ministry of Civil Defence and Emergency Management (MCDEM), the NZ Defence Force and the High Commissioner in Samoa for their total support throughout the entire process of planning this reconnaissance. We also thank the organisations who contributed to the funding of the trip, viz. FRST (New Zealand Foundation for Research Science and Technology), and NIWA. We would also like to thank ESRI for supporting this mission. We gratefully acknowledge the support of the Australian Research Council for their support of this work. We acknowledge and thank each of our own organisations who have allowed us to volunteer our time.

# UNSW



The students and staff of the Australian Tsunami Research Centre, University of New South Wales are thanked for their tireless work behind the scenes to support this team. Nice one guys – you did us proud.

We gratefully acknowledge the enormous assistance of Litea Biukoto of SOPAC without whose efforts this ITST would never have happened.

Dr Jan Steffen, Regional Scientific Advisor for UNESCO and Suzanne Paisley of UNESCO-IOC are thanked for their tireless efforts to ensure the successful completion of our work.

Lastly, we offer our sincere thanks to Ruby Vaa, Acting Campus Director, Alafua Campus Centre, USP, Apia for her dedication, patience, advice and support throughout. She and her team have been truly amazing. Thank you!

Finally, a big thanks to all the people who contributed to this report.

## FOREWORD

The tsunami on 29 September 2009 was a tragic reminder of the need to reduce disaster risks and to further improve existing tsunami warning systems.

UNESCO-IOC has worked to strengthen and support the Pacific Tsunami Warning System (PTWS) since the mid-1960's. In close collaboration with the International Tsunami Information Center and the Pacific Tsunami Warning Center UNESCO-IOC provides direct support to countries to assist them in strengthening their national systems. Just months before this event, at the 23<sup>rd</sup> session of the Intergovernmental Coordination Group for the PTWS in Apia, Samoa, countries assessed the findings of its Pacific-wide exercise conducted on 29 October 2008, in terms of its operational warning and emergency communications and response plans, national and local awareness and preparedness. The session also focused on the southwest Pacific tsunami hazard, where countries examined strategies to address near-source, local tsunamis which will impact on coasts within minutes – no one knew that such a local tsunami would devastate the central South Pacific just seven months later.

While the affected Governments, supported by UN agencies, international aid organizations and NGO's endeavored to do everything in their power to ease the burden of the affected communities, an international team of scientists was also formed under the auspices of UNESCO-IOC and coordinated by the Australian Tsunami Research Centre in order to collect integrated, multi-sectoral, multi-disciplinary tsunami science observations of what happened.

The International Tsunami Survey Team (ITST) for Samoa was comprised of experts from Australia, Fiji, French-Polynesia, Italy, Japan, New Zealand and the USA, who volunteered their expertise in collaboration with teams from several ministries under the Government of Samoa. The scientists were funded to a large extent by their home institutions.

The ITST Samoa, and the Interim Report and data presented to the Government of Samoa, immediately upon conclusion, represents an unprecedented science effort, setting a benchmark for future international post-tsunami science surveys that will support national early recovery efforts, and through tsunami research, improve tsunami mitigation and preparedness and so build the stronger resilience of coastal communities.

Previous post-tsunami surveys were in large part individually organized and conducted, and so left the affected country with a large integration task in order to combine all the studies into a single coherent and comprehensive study. The ITST's success is a tribute to all involved, and a demonstration that when we work together, we can produce outputs that are much stronger and can achieve more valuable outcomes than any one of us could do working alone.

This ITST has succeeded because of (1) the strong desire of all scientists to share their knowledge in a timely manner to immediately help; (2) the commitment by the Government of Samoa and their belief that science can help improve disaster risk reduction practices; (3) engagement with UN and regional organizations who immediately assisted and provided an umbrella framework to pull everyone together; (4) local support from the University of South Pacific that provided the ITST's command center each day and above all; (5) the dedication and strength of the ITST Coordinators who tirelessly provided the leadership necessary to successfully manage the planning, scientific assessments, logistics, information sharing, and finally, the preparation of the ITST Interim Report.

Laura Kong, Director, ITIC  
Klaus Peter Koltermann, Head, Tsunami Coordination Unit, IOC  
Visesio Pongi, Director, UNESCO Apia Office  
Jan H. Steffen, Regional Science Advisor, UNESCO Apia Office



## Executive Summary

The tsunami of 29<sup>th</sup> September 2009 was regionally important within the SW Pacific, a physical disaster for some communities in Samoa and a psychological trauma for the whole country. The earthquake that triggered the tsunami occurred so close to the south coast of Upolu that whilst warning messages were issued, insufficient time existed for low-lying exposed communities to fully evacuate. People within communities claim that either they did not receive a warning message or, that if they did, it came too late. Further, a confused picture is emerging about people's stated reaction to the earthquake, any warning messages, and then the arrival of the tsunami at the coast. Many people state that for whatever reason, they did not know how to react.

Undoubtedly, the efforts of the Disaster Management Office (DMO) of the Government of Samoa in recent years mean that many lives were saved. The 'take home message' from our research is that the Government of Samoa should:

***“retain and enhance its community-based tsunami education activities because they do save lives”***

This simple recommendation is underpinned by many more detailed recommendations that the Government of Samoa may consider for immediate and future possible implementation to increase resilience to future hazard events.

The Terms of Reference (ToR) for this UNESCO-IOC International Tsunami Survey Team, were to:

1. Measure maximum inundation and maximum flood run-up. Such measurements are important inputs for running tsunami inundation models;
2. Collect geological samples of sediments left by the tsunami. This is so that we may characterise the deposits left by the 2009 tsunami. Once completed, we might at a later date, explore the geological record of the coast of Samoa to explore records of older tsunamis in the recent historic (e.g., the 1917 tsunami) or prehistoric (or palaeotsunamis) past. Such work enables geologists to establish longer-term tsunami risk;
3. Collect and measure information about environmental and biophysical system impacts of the tsunami on the terrestrial and marine environment in selected locations;
4. Measure the type and severity of damage to different types of buildings and record what factors appeared to control damage levels;
5. Collect information about survivor experiences and stories through interviews (including for the first time ever in a UNESCO-IOC ITST, video interviews of survivors);



6. Collect information on human and community vulnerability and resilience factors at work in different places: i.e., what made a particular community resilient or vulnerable?; and
7. Where possible, to map the above information.

We divided in to six sub-groups to tackle each of these tasks. Each sub-group team was composed of a representative from an associate relevant Government of Samoa ministry, a local scientist from a partner research institution (e.g., USP) and a local Samoan speaker. Each sub-group clarify its research methods and techniques according to international protocols.

We have attempted an interpretation of the data but we caution that this is preliminary since we have not had time to ‘post-process’ the data that is critical before we are able to come to concrete conclusions. The data we have collected have been made available to the Government of Samoa in raw form in a series of electronic folders.

Our approach to collaboration, partnership and horizontal skills sharing, is a global first for a UNESCO-IOC ITST assessment and is testament to the good will and professionalism of all involved.

Key findings (unprocessed) include:

- Maximum run-up exceeded 14 metres above sea level
- Maximum inundation (at right angles to the shore) was approximately 400 metres
- Maximum inundation with the wave running parallel with the shore (but inland), exceeded 700 metres
  
- Buildings sustained varying degrees of damage
- Damage was correlated with depth of tsunami flow, velocity, condition of foundations, quality of building materials used, quality of workmanship, adherence to the building code and so on
- Buildings raised even one metre above the surrounding land surface suffered much less damage
- Plants, trees and mangroves reduced flow velocity and flow depth – leading to greater chances of human survival and lower levels of building damage
  
- The tsunami has left a clear and distinguishable geological record in terms of sediments deposited in the coastal landscape
- The clear sediment layer associated with this tsunami suggests that older (and prehistoric) tsunamis can be identified, helping to answer questions about frequency and magnitude of tsunamis





- The tsunami caused widespread erosion of the coastal and beach zones but this damage will repair itself naturally and quickly
- The tsunami has had clear impacts on ecosystems and these are highly variable
- Ecosystems will repair themselves naturally and are unlikely to preserve long-term impacts
- It is clear that some plant (tree) species are highly resilient and provided immediate places for safety during the tsunami and resources post-tsunami
- People of Samoa are forgetting their knowledge of the value and uses of indigenous plant and animal species and efforts are needed to increase the understanding of the value of these plants and animals (thus increasing community resilience)
  
- Video recording survivor stories is important
- Sadly, there is no tradition of story telling or memory of past tsunamis so the capturing of survivor accounts means that such stories can be introduced to the cultural memory
- Permitting survivors to tell their stories allows them to heal emotionally, and also provides valuable information for future education and community outreach
  
- The people of Samoa are hurting after the tsunami
- Impacts and effects are highly variable socially and spatially
- Where lives have been lost, the impacts and associated fear are much higher
- Communities require practical and long-term emotional care
- A complex picture is emerging about community experiences of warning and response behaviour that presents challenges to the Government of Samoa in terms of education and outreach for hazard reduction

We have been able to identify a series of factors that appear to influence/control vulnerability and resilience. Not all factors operate at all scales and in all places. We have provided a tool – the ‘coupled human-environment systems framework’ - to the Government of Samoa to enable its staff to continue this process in the coming months as time permits.

From the work of our sub-groups, our top six recommendations are as follows.

**RECOMMENDATION 1: “Retain and *enhance* community-based tsunami education activities” – these saved lives on 29<sup>th</sup> September 2009**



**RECOMMENDATION 2:** Collection and compilation of a detailed near shore bathymetric and coastal topographic datasets to help with future tsunami modelling for risk assessment

**RECOMMENDATION 3:** New buildings should be built on raised 'platform's approximately 1 metre higher than the surrounding landscape and on solid foundations with reinforced concrete columns

**RECOMMENDATION 4:** Complete a national palaeotsunami study to identify long-term frequency-magnitudes of tsunamis

**RECOMMENDATION 5:** Replant damaged coastal areas and protect pristine coastal areas (in partnership with local communities in order to raise understanding) with species shown to increase resilience to tsunami (and extreme wave) inundation

**RECOMMENDATION 6:** Train Samoan experts to continue to collect survivor stories. This helps with the healing process and provides valuable material to help with future awareness raising activities



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## 1. INTRODUCTION

Tsunamis (sunami)<sup>1</sup> are natural events that have caused some of the most dramatic cases of loss of life, property and destruction of the natural environment in history. Unlike tropical cyclones, floods and droughts for which meteorological services can give significant forewarning, the generation of tsunamis by earthquakes close to the shores affected, can mean little time exists to evacuate low-lying and exposed coastal populations.

It has been suggested that “natural events such as tsunamis are not catastrophes or disasters themselves, but only become so when they seriously affect human communities and their assets” (Kaplan et al. 2009). Kaplan et al. (2009) note that this aspect has led to a shift from a study of the nature of the hazard itself, and its damaging effects, to “the interplay of the event and the vulnerability of a society and of its infrastructure, economy and environment” - elements that are to a large extent determined by the actions of the society itself. The UN International Strategy for Disaster Reduction (ISDR) defines vulnerability as: “The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impacts of hazards” (UN ISDR 2004 in Kaplan et al. 2009). It is stressed that, whereas the impact side of vulnerability relates more to exposure, (in the case of tsunamis, to the nature of the physical location of a community), susceptibility and resilience (and ability to recover) relate to the “internal condition of the affected community” (Kaplan et al. 2009).

Kaplan et al. (2009) argue that susceptibility relates mainly to the internal structure of a society and the livelihoods that determine ability to cope with and recover from hazards. Resilience, they argue relates more to socio-ecological systems, taking into account the interdependence of a given society and their dependence on, and health of, ecosystem services and is a measure of the ability of communities to cope with different hazard events.

This is the Interim Report of the UNESCO-IOC International Tsunami Survey Team Samoa (ITST Samoa). Its overarching objective is to *explore the nature of the tsunami and its impacts in Samoa*. However, for the first time ever in a UNESCO-IOC ITST assessment, we will attempt to explore the nature and linkages (if any) between the physical, social, economic and environmental systems in order to provide a more sophisticated understanding of the tsunami and its impacts - one that goes beyond a simple description of ‘maximum run-up’ or ‘total number of lives lost’.

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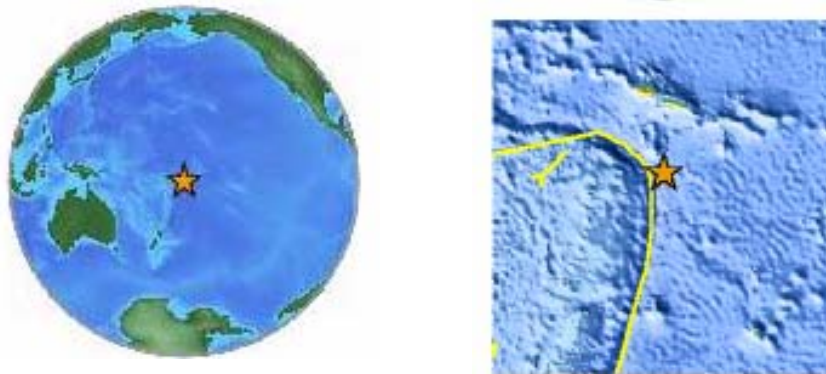
<sup>1</sup> Although the Government of Samoa has officially used the word “sunami” as the working Samoan word for tsunami, there are traditional Samoan words, **galuafi** and **galulolo**. These literally mean “firey”, or “fire wave”, or “wave that swamps or drowns something”, respectively. These words reportedly refer to tsunamis or other monstrous waves.



This Interim Report constitutes the output from multidisciplinary teams of Samoan scientists, members of the Government of Samoa's (GoS) ministries, local and international NGOs, and members of communities affected by the tsunami, together with international tsunami experts from overseas (Appendix 1). It is hoped that the information contained here will provide a better understanding of the interplay between the socio-ecological interactions that were responsible for the devastating, but highly variable, impacts of the tsunami on Samoa and its people. It is further hoped that the report can serve as an important step to establishing a better physical and social scientific understanding of how we can prepare for, adapt to, and recover from future tsunamis and other extreme events which have disproportionately negative impacts on small oceanic islands.

### 1.1 The earthquake

A submarine earthquake (magnitude of Mw 8.0) occurred at 06:48 Samoa Standard Time (17:48:10 UTC) on September 29, 2009 near the northern end of a 3,000 km long segment of the Pacific-Australia plate boundary that trends north-northeast, and curves towards the northwest and then west at approximately 15.6° S latitude and 172.0° W longitude (Figure 1). The epicentre of the earthquake was approximately 190 km south of Samoa, near the outer rise of the subducting Pacific plate under the Australia plate. The earthquake was felt in much of American Samoa, Samoa and northern Tonga and as far away as Wallis and Futuna Islands and Niuaus.



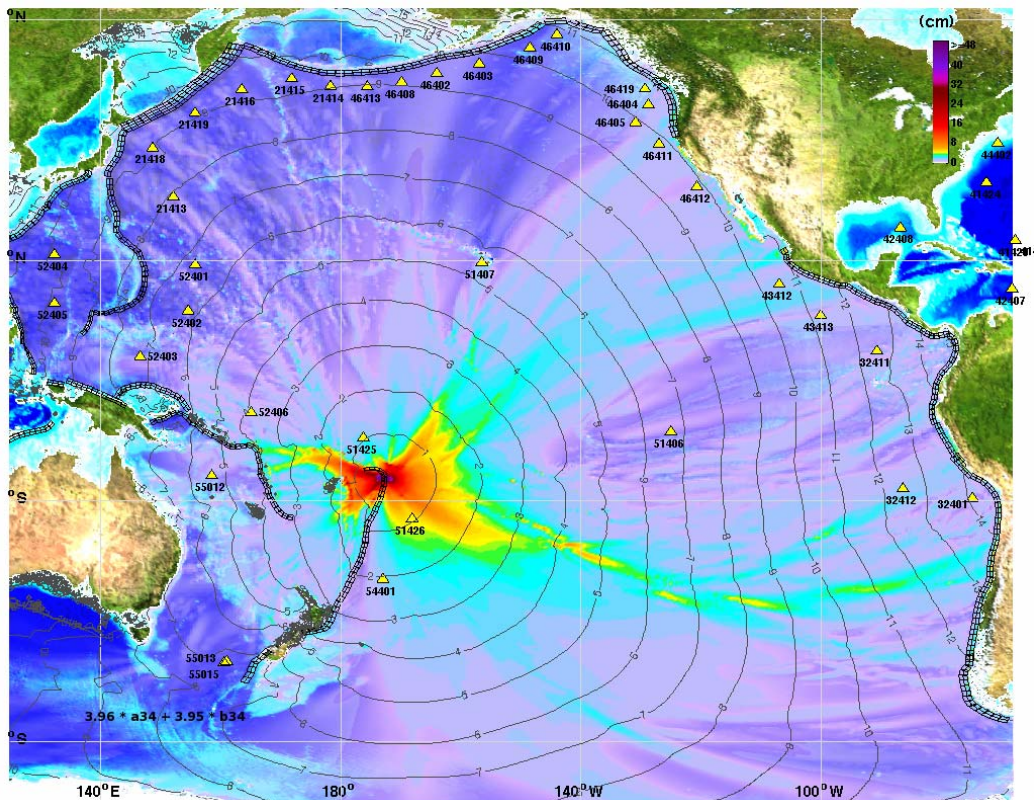
**Figure 1** The earthquake epicentre (Source: USGS)

On the basis of currently available location and fault mechanism information, United States Geological Survey (USGS) suggested that the earthquake occurred as a normal fault rupture near the outer rise of the subducting Pacific plate, while the DART buoys (tsunami detection buoys) suggest the possibility of a reversed fault. The earthquake parameters based on USGS data located the hypocentre at a depth of 10 km, with dip, strike and slip of 52°, 345°, and –61°, respectively.



## 1.2 The tsunami

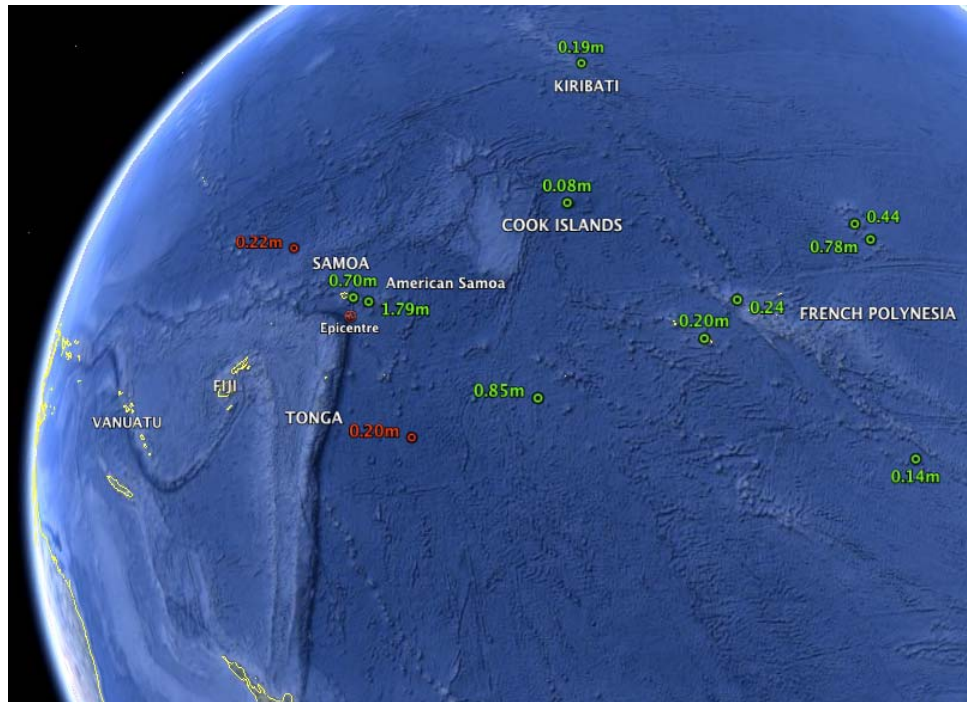
The earthquake generated a regional tsunami (Figure 2) which most seriously impacted the islands of Upolu, Manono and Savai'i in Samoa; Tutuila, the main island of American Samoa, the Niuatoputapu, one of the most northerly of the islands of Tonga, Wallis and Futuna, as well as numerous locations in the central South Pacific.



**Figure 2** Simulation of the tsunami. Colours relate to wave amplitude.  
(Source, PMEL)

Wave heights (peak-to-trough) were recorded at several tide gauges including 314 cm at Pago Pago (American Samoa); 140 cm at Apia (Samoa); 47 cm at Rarotonga and 8 cm at Penrhyn (Cook Islands); 14 cm at Nuku'alofa (Tonga) and 11 cm at Papeete (French Polynesia) (USGS report: [www.usgs.gov](http://www.usgs.gov)).





**Figure 3** Tide gauge (green) and DART buoy (red) readings of the tsunami. (Source: NOAA, The Sea Level Data Facility (UNESCO, IOC), USGS (epicentre location))

### 1.3 The tsunami warning

The Duty Senior Standing Watch Officer at the West Coast and Alaska Tsunami Warning Centre (WCATWC) in Alaska was alerted to a possible earthquake at 17:50 GMT on the 29<sup>th</sup> September 2009 by a Nieu seismic short period alarm. At 17:52 Z, he had an initial auto location of 15.3 S and 171.6 W. DART 51425 was auto triggered at 17:52 Z by the earthquake. At 17:58 Z he had an initial auto Mwp of 7.9. At the same time, he sent an observatory message to the Pacific Tsunami Warning Centre (PTWC), NEIC, QDDS and other NADIN and email subscribed users. At 18:00 Z, according to procedure, he called PTWC. After a brief discussion, PTWC gave him their magnitude and location and said that they were going to issue a warning for their area of responsibility (AOR). Using PTWC's location and magnitude, 15.4 S, 171.6 W, Mwp 7.9, the WCATWC issued a WEPA43 TIS Bulletin 1 at 18:02 for the WCATWC Pacific AOR. At 18:04 Z, PTWC issued a WEPA40 Bulletin 1 warning / watch for the Pacific Islands. Once the Government of Samoa (GoS) had received an official warning message from the PTWC, it enacted its own early warning protocols. Our survey team has not received an official transcript of the timeline of events and response actions from the perspective of the GoS.



Since the epicentre was located just over 100 km from the south coast of Upolu, Samoa, the tsunami arrived on shore in less than 15 minutes (although eyewitness accounts suggest the first tsunami arrived anywhere between four (4) and twenty (20) minutes after the earthquake ceased). The UNESCO-IOC ITST Samoa acknowledges the excellent work of the GoS in recent years to develop an effective tsunami early warning system, to work with community to raise public awareness and to practice drills and evacuation exercises. As will be shown later in this report, *these efforts absolutely helped to save many lives* since the population in many cases knew how to respond. However, for reasons that are not fully clear, some eyewitnesses have stated that their communities or locations either never received an early warning message, or more worryingly, failed to respond appropriately. In other cases, whilst a community did receive a warning, they had insufficient time to evacuate before the arrival of the first wave. The problem here is that the community failed to react automatically when they felt the strong ground shaking associated with the earthquake. That is, they did not react by evacuating without waiting for a warning message. We will return to public confusion about how to respond appropriately to tsunami warnings or earthquakes later in this report.

In Samoa, the tsunami resulted in loss of life and injury to survivors. The exact nature of the casualty figures and their spatial distribution have been described elsewhere and lie outside the scope of this report. At a broad level, the tsunami caused significant damage to infrastructure and buildings, resulting in homelessness and disruption to normal daily activity.

It is not the purpose of this report to provide a definitive summary of the impacts and effects of the tsunami in Samoa as the GoS and its Ministries have already begun systematic assessments on their own and in partnership with other relevant organisations. The purpose of this Interim Report is to add value and depth to specific questions determined as relevant by the GoS and the team of scientists who volunteered their expertise, knowledge, experience and time. Further, as indicated earlier, we wish to explore for the first time inter-relationships between the coupled human-environment systems that might help to explain differential resilience and vulnerability and to use this understanding to make recommendations to the GoS.

#### **1.4 Establishment of the UNESCO-IOC ITST Samoa and its ‘Terms of Reference’**

Given that the tsunami had a significant regional effect, a proposal was made via the ITIC Bulletin Board by the Australian Tsunami Research Centre (ATRC) that an International Tsunami Survey Team (ITST) be established under the framework and structure of UNESCO and its International Oceanographic Commission (IOC) to undertake a technical post-tsunami survey.



Negotiation between the eventual Team Leaders (Dominey-Howes and Thaman), many international scientists of various disciplines, the UNESCO Pacific Regional Office, regional organisations like the Secretariat of Pacific Applied Geoscience Commission (SOPAC), the Secretariat of the Pacific Environment Programme (SPREP), The University of the South Pacific (USP) and the GoS, identified a need for and willingness to undertake and actively support, an ITST assessment. From the start, it was agreed that this survey would partner with a regional research organisation - the University of the South Pacific (USP) to take account of regional scientific expertise, and with appropriate ministries of the GoS to ensure that (1) incoming international scientists undertook their work in a culturally sensitive and appropriate way and (2) outputs were relevant to various ministries of the GoS. The guiding principle of the ITST Samoa assessment has been to be integrative of different disciplines and skill sets, collaborative between agencies and organisations, and respectful of the culture, practices and needs of the people of Samoa.

To these ends, a ‘Terms of Reference’ (ToR) for the ITST Samoa were developed and agreed upon by the GoS and the team (Appendix 2).

The TOR’s asked that we undertake the following key tasks:

1. Measure maximum inundation and maximum flood run-up. Such measurements are important inputs for running tsunami inundation models;
2. Collect geological samples of sediments left by the tsunami. This is so that we may characterise deposits left by the 2009 tsunami. Once completed, we might at a later date, explore the geological record of the coast to identify records of older tsunamis in the recent historic (e.g., the 1917 tsunami) or prehistoric (palaeotsunamis) past. Such work enables geologists to establish longer-term tsunami risk;
3. Collect and measure information about environmental and biophysical system impacts of the tsunami on the terrestrial and marine environment in selected locations;
4. Measure the type and severity of damage to different types of buildings and record what factors appeared to control damage levels;
5. Collect information about survivor experiences and stories through interviews (including for the first time ever in a UNESCO-IOC ITST, video interviews of survivors);
6. Collect information on human and community vulnerability and resilience factors at work in different places: i.e., what made a particular community resilient or vulnerable?; and



# UNSW



7. Where possible, to map the above information.



## 2. RESEARCH METHODS AND TECHNIQUES

The UNESCO-IOC ITST Samoa was divided into 6 sub-groups based upon the ToR's set by the GoS and representative areas of expertise. These sub-groups, which included members from GoS ministry's, USP, Scientific Research Organisation of Samoa (SROS) National University of Samoa (NUS) and NGO's were:

- Sub-group One – Inundation and Run-up
- Sub-group Two – Building Damage
- Sub-group Three - Geology
- Sub-group Four – Ecosystems and Biodiversity (further divided into Group A Terrestrial and Group B Marine)
- Sub-group Five – Video Interviewing, and
- Sub-group Six – Social Sciences

Here we provide a basic statement of the methods and techniques used by each of our sub-groups.

### 2.1 Inundation and run-up

RTK-GPS (Real Time Kinematic-Global Positioning System), laser distance and vertical measurements were used to measure the tsunami elevation, flow depth, run-up and maximum inundation.

Confusion about the terms *run-up height*, *tsunami wave height* and *inundation* can result in misleading information about what happened. This situation can have an impact on the subsequent rehabilitation, reconstruction and future mitigation efforts. Consequently, our entire team agreed together the exact meaning of these critical terms and how to measure these in the field.

- The *run-up height* is the vertical ground elevation from mean sea level at the inland limit of the flow. The *inundation distance* is the horizontal distance from the shoreline at the same point.
- The *inundation depth* or *flow depth* is the depth of water under the tsunami wave as it flows inland, and if already referenced to Mean Sea Level (MSL), it is termed *inundation height* or *tsunami elevation*.



The *run-up height* depends upon the slope of the coastal zone. This influences the ability of the topography to concentrate the wave energy or reflect it. For and given tsunami wave, those areas with a gentle slope inland will experience lower run-up heights but greater inundation distances compared to the areas that have steeper slopes. The flow depth is a direct index rather than run-up height to evaluate force acting on a building. However, tsunami behaviour around structures and vegetation is strongly affected by the buildings and vegetation. Survey results of inundation depth or height may therefore vary significantly in any one area.

During the survey, we attempted to find traces of tsunami flow depth close to the shoreline as well as further inland. Flow traces such as the broken branches of trees and watermarks on buildings that were still standing we recorded. Debris caught in trees and other vegetation can also be used to indicate the flow depth. The run-up height and maximum inundation distances were identified from trim lines on the hillsides or debris left further inland in low-lying areas. Some measurements were also taken of flow direction. This was measured from the alignment of tsunami damage features, for example, building pillars that all fell in one direction.

## 2.2 Building damage

A key activity was the use of dual-frequency GPS receivers for measuring ground profiles and inundation depths in the most affected areas. The equipment consisted of two GPS receivers: One functioned as a base station (Figure 4) that remained at a fixed point throughout the survey, and the other as a rover that was taken to the measurement points. As long as the distance between the two GPS units was not too great (i.e. less than about 10 km), it could be assumed that the satellite signals received by each had experienced the same atmospheric conditions, and it was then possible to correct the measurements for atmospheric and other systematic effects. Positional accuracies of  $\pm 30$  mm horizontal and  $\pm 50$  mm vertical were readily achievable.

The positional accuracies given above were relative within a particular survey, and became absolute only when linked to a reference such as a reliable benchmark. The benchmarks that were used have no horizontal coordinates attached to them and act solely as a vertical control. For horizontal positions, an autonomous GPS measurement was used which will later be corrected on the base of aerial photographs. It was possible to find suitable benchmarks for most surveyed areas. Only in one location (Poutasi) was it necessary to use sea level measurements and tide tables to derive absolute heights.

The RTK GPS requires good satellite coverage to deliver accurate results. However, satellite reception in densely vegetated areas is limited. Hence, it was decided to use precise levelling with a level and scaled staff (Figure 5) as an additional tool to survey topographic profiles as well as inundation distances and depth.



**Figure 4: Setting up the RTK GPS base station**



**Figure 5: Levelling to obtain ground profiles**

Damage to buildings was assessed along these surveyed transects. In this way, the relationships between flow depth (and sometimes also current velocity, although this was usually difficult to determine) and the extent of damage to buildings of different construction types could be determined.

To ensure a consistent survey and damage assessment, a standardised survey template was used throughout. The survey form ensured that necessary information and building attributes were recorded. The following attributes were surveyed:

- Use of Building (residential, commercial, etc.)
- Number of Storeys
- Wall Cladding



- Roof Cladding
- Age
- Floor Height (m above ground level)
- Foundation
- Shielded / Exposed
- Orientation to Wave
- Scouring
- Water Depth (m above floor)
- Debris Impact
- Level of Damage
- Content Damage
- Inhabitability
- GPS Survey Number
- Photo Reference Number
- Detailed Description of Damage

In order to keep the subjectivity of the damage assessment to a minimum it was decided to use a damage classification that describes the level of damage:

- Undamaged
- Light Damage / Non-structural Damage
- Minor Damage / Little Structural Damage Only
- Moderate Damage / Repairable Structural Damage
- Severe Damage / Irreparable Structural Damage
- Collapse

Based on a thorough post-analysis of all the data collected in the field this qualitative damage information can be converted into damage ratios. Damage ratios are defined as cost of repair/cost of replacement and can be derived from subjective estimates of the proportionate levels of damage to the four main structural elements of the damaged buildings. These four elements are: foundation and floor (estimated 15% of total construction cost), walls (50%), roof and ceiling (15%), and fittings and services (20%). A damage ratio of 1 means total destruction whereas 0 is undamaged. These values are subject to high levels of uncertainty, as we had no access to the exact construction costs of Samoan buildings. Table 1 shows the band of damage ratios for the different damage classes.



**Table 1: Damage ratio classification**

Level of damage	Band of damage ratios
Light / insignificant	0 – 0.02
Minor	0.02 – 0.1
Moderate	0.1 – 0.5
Severe	0.5 – 0.95
Collapse	> 0.95

On the first day, the team established a detailed protocol and consistent method for measuring inundation and run-up as well as assessing building damage type. Use was made of existing approaches previously developed by international teams that ensure data generated in Samoa may be compared with similar assessments following tsunamis in other places.

### 2.3 Geology

The geology sub-group focused on documenting the geological tsunami signature and the physical processes of tsunami erosion, transport, and deposition of material. Our studies were of two types: 1) reconnaissance site visits where a number of observations and measurements were made in a short time period, and 2) detailed investigations of selected areas.

#### 2.3.1 Reconnaissance site visits

The visits were usually less than one hour and typical observations and measurements made at each site visited include:

- General morphology and characteristics of the coast;
- Observations of the presence or absence of sedimentary deposits and erosional features;
- Inundation and runup measurement(s) using a laser rangefinder;
- Flow depth and wave height if suitable markers could be identified; and
- Flow direction indicators (in many areas multiple flow directions were identified).

#### 2.3.2 Detailed study sites

Extended studies of critical sites based on initial reconnaissance and consultation with GoS representatives and members of the ITST. In addition to the data collected in the reconnaissance sites, the detailed studies typically included:



- Topographic mapping using both backpack mounted Differential GPS (DGPS; USGS system; requires post-processing for sub-meter accuracy) and/or a backpack mounted Real Time Kinematic GPS (RTK GPS) system with base station (NZ GNS system). The topographic surveys extended from the nearshore (inner reef flat) landward to beyond the limit of inundation. Survey transects were collected in both shore-parallel and shore-normal lines. Line-spacing density was a function of the size of the study area and time spent at the site. Offshore distance of nearshore surveys were partially controlled by tide stage at the time of survey, with lower tides allowing a greater distance to be traversed. The topographic mapping will be used to characterize the study area and for use in model studies of tsunami wave propagation along the coast;
- Surficial and sub-surface sampling of tsunami deposits. Sub-surface samples were either collected by push cores of plastic pipe, gouge core, Russian peat borer (D-core) or from hand-excavated trenches (Figure 6). Surficial samples consisted of scraping the upper layers of sediment in both subaerial and submarine environments;
- Extensive measurements of flow depth and orientation indicators; and
- Where boulder deposits occurred, boulder size (a,b,c axis), orientation of long (a-axis), and location were recorded.



**Figure 6: Shallow trench from Satittoa, on the east coast showing pre-tsunami soil at base with sharp contact to overlying tsunami sand with multiple laminations and capped by a thin mud drape**





Material used for identification of tsunami impact characteristics:

- Marine material deposited landward (Halimeda clusters, coral debris, microatolls, *Foraminifera* sp., and basalt boulders with marine encrustations);
- Transported boulders from shoreline engineering structures;
- Wrack (debris) lines of vegetation and human artifacts (clothing, appliances, household items, cars, plastic debris etc.);
- Ballistic impacts on solid structures such as buildings, trees, and bedrock; and
- Water-level indicators such as watermarks or debris deposits on suitable surfaces.

Indicators used for specific measurements included:

(1) *Flow direction* was recorded from a number of field observations and measured by compass (either magnetic or GPS), alignment of bent vegetation (palm trees or coconut trees; Figure 7), alignment of collapsed building structures (*fale* pillars or water pipes), alignment of fence posts anchored on the seaside walls of some partially destroyed building, and material such as metal roofing wrapped around tree trunks.



**Figure 7: Coconut tree trunk used as a flow-direction indicator**

(2) *Flow depth* was measured with a laser range finder using field evidence such as scratched tree trunks, bark removal, broken branches, rubbish trapped in branches etc (Figure 8).





**Figure 8: Clothes in a mangrove tree at Vaovai used as evidence for measuring minimum flow depth**

Delineation of inundation was made using GPS measurements at the marine water inundation limit. Marine inundation can be recognised in the field by observing the contact between salt-burnt yellow grass and non-flooded green grass, limit of debris wrack line, and eyewitness accounts (Figure 9).



**Figure 9: Vegetation debris rampart composed mostly of tree trunks and branches at Satitua**



A boulder field of particular interest was investigated in Satitua (Figure 10). Boulder granulometry was recorded along both transverse and longitudinal profiles, according to field evidence of the tsunami primary flow direction in this area (N340 to N010): *A*, *B*, *C* axes and long-axis orientation were measured. A waypoint was recorded for each measured boulder. We assumed that the damaged seawall along the coast road was the source for the boulders. A few small rounded boulders were encountered in the field, but were rejected from the collection as they are not the usual material used in seawall engineered structures. They may come from some “marae” encountered in the surveyed area and partially damaged by the tsunami. One hundred and sixty (160) boulders were measured in this location.



**Figure 10: Boulder field and sand sheet at Satitua. In the background, the seawall behaved as a source for boulders**

#### **2.4 Ecosystems and biodiversity (Group A terrestrial and Group B marine)**

This group sought to assess the impact of the tsunami on the terrestrial and marine biodiversity. Central to this was an investigation of the relationships between the affected Samoan communities and their coastal and marine environment and biodiversity, and how this impacted on their ability to survive, recover and adapt to the reality of such extreme events. Specifically, the team gathered information about the impact of the tsunami on coastal, houseyard and agricultural and horticultural plants and coral reefs and associated marine organisms. More generally, it also explored effects on biodiversity and ecosystem services and their interrelationships with tsunami-affected communities.



To achieve economies of scale, this sub-group split into two separate groups, a Terrestrial Environmental Assessment Team (TEAT) and a Marine Environment Assessment Team (MEAT). The study methodologies, which will be discussed in detail under the Terrestrial and Marine Team sections, included: 1) reconnaissance assessments over Days 1 and 2 to determine those priority areas for further study based on the degree of impact and devastation caused and, 2) on days 3 to 5, visits, by TEAT to assess the state of the vegetation and flora and to conduct questionnaire surveys, and site visits by MEAT to affected reefs, channels and offshore islands to assess the nature and extent of damage to coral reefs, the marine environment and biodiversity.

Although there have been a number of studies highlighting the impact of tsunami waves on vegetation, coral reefs and coastal and marine ecosystems and biodiversity and the importance of coastal vegetation, mangroves and coral reefs in mitigating the impacts and assisting in the recovery from tsunamis (Danielsen *et al.* 2005; Barbier 2006; Wilkinson *et al.* 2006; Kaplan 2009;), these interrelationships are, however, still being debated scientifically.

#### ***2.4.1 Group A terrestrial***

This group spent five days in the field covering most of the areas villages and tourist developments that were seriously impacted by the tsunami.

The following methods were used to gather information about impacts on terrestrial biodiversity and ecosystems:

1. Reconnaissance/rapid assessments and inventories of the status of plants in all vegetation types in most of the most seriously affected villages, tourist developments, agricultural areas and other selected sites, such as mangroves, wetlands, river valleys and estuaries, the area of the quarry, etc. (Appendix 3).
2. Rapid assessments and inventories of plants and vegetation in less, or non-affected, areas to use as a standard against which changes could be assessed.
3. The use of aerial photos (acquired from Google Earth, Bing, and New Zealand Air Force) to locate and document important affected sites, important large trees and areas of vegetation and tree stands that either remained intact or had been removed or significantly altered by the tsunami.
4. Digital photo documentation in all sites for further post-field analysis and use for illustrations. The total number of digital photos taken over the five-day survey period was about 2000. Subjects photographed included most plant and vegetation types; degree of devastation and inundation; views of coastlines, rivers, wetlands, reef flats and channels, and seawalls and natural barriers; areas of major erosion, undercutting, water flows location of maximum inundation (location of the “trimline”); affected villages and tourist developments and the status of the biodiversity; re-settlement areas; persons interviewed; limited





- numbers of dead and living animals; and other important features and phenomena.
5. In-depth interviews with relevant respondents, community leaders and members, resort owners, and other persons in all study areas to validate and reinforce observations and gather additional information to corroborate our findings.
  6. Fifteen (15) in-dept questionnaire surveys related to impacts on, the resilience of, and the importance of plants and vegetation as a basis for damage reduction, survival and recovery from the tsunami. These were carried out only in the most-affected areas of Malaelā and Satitōa on the east coast, Lalomanu in the southeast, and Tuialamū and east Saleapaga along the southeast coast. These were areas that experienced maximum damage and where most communities and families had relocated to new residences inland.
  7. Compilation of a comprehensive table of indigenous and introduced species that were affected by the tsunami, with information on the levels of mortality and damage, their abundance, their Samoan, common and scientific names and other related information.

#### ***2.4.2 Group B marine***

The assessment strategy involved the inspection of several sites of over a four day period. The sites chosen were coral reef areas adjacent to the locations of substantial terrestrial tsunami impact. Islands were inspected for beach erosion particularly for turtle nesting sites. Stranded turtles were also documented. Where possible marine protected areas and fisheries reserves were inspected as there was previous data regarding the nature of the marine benthos. Further, the Coral Reef Recovery Planning (CERP) site of Vaovai was inspected in 2006 providing baseline against which the tsunami effects might be compared.

Generally there were four approaches to the marine assessment:

- The broad areas were assessed by manta towing. The percentage of living and dead coral was recorded as well as the substrate types. Assessment of the bathymetry using a GPS linked echo-sounder was conducted.
- Inspection was made of the underwater coral reef communities with special emphasis on the hard corals and substrate using point-intercept-transect (PIT) and photo-assessment.
- Mobile invertebrates (holothuria, mollusks etc.) and fishes were noted.
- The islands were visited and the beaches assessed for damage and for marine turtles and their nesting areas.



Deeper areas were assessed using self-contained underwater breathing apparatus (SCUBA). Generally, the group was divided into two teams. One was confined to the inspection of the shallow reef. This was an attempt to sample the inshore fringing reef or the offshore barrier reef. The second team was tasked with manta towing, bathymetric assessment and island inspection including assessment of the turtle nesting sites and stranded turtles.

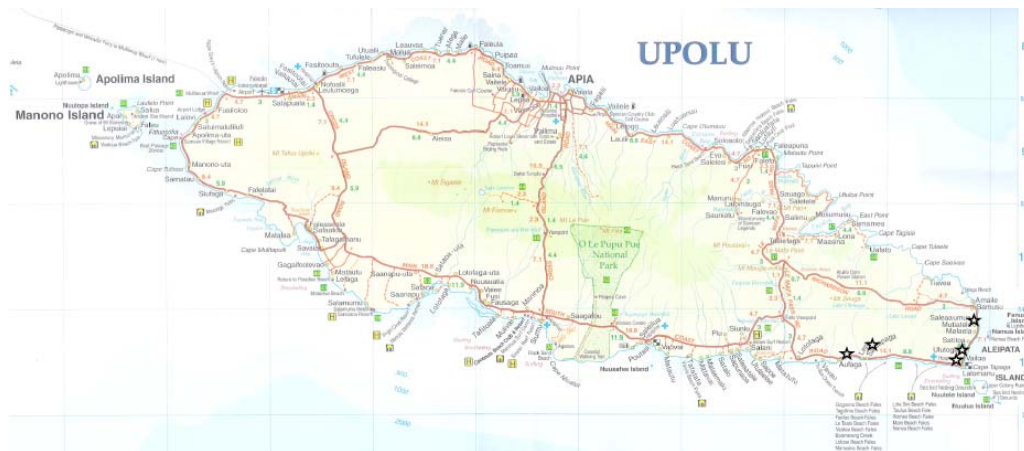
### **2.5 Video interviewing**

The collection of oral histories has long been a valuable part of many disciplines including anthropology, history, psychology and sociology. This technique has been applied to tsunamis as a valuable aid in integrating the physical data acquired through field surveys.

The Survivor Story sub-group (SST) worked in parallel with the Social impact assessment sub-group (see section 2.6) an international team with local counterparts, investigating the needs, how they were being met, impacts on livelihoods and psychological wellbeing of tsunami survivors. The SST first met on Wednesday October 14<sup>th</sup> 2009. The methodology used in this project adapted the protocol for such projects as undertaken previously (Dudley et al., 2009). Ideally, an entire short practice is carried out. However, due to time constraints the team conducted a short run through of the process with camera work, lighting and sound before heading into the field the next day.

A team of three worked together: (1) Project Director, who doubled as producer, director, camera man, and sound and light technician; (2) Field Assistant, who served as production assistant, grip, gaff, etc. and (3) Interviewer, who facilitated the collection of survivor stories.

A site for the interview was then identified. Transport and village selection were done in conjunction with the Social Sciences sub-group and members of the Red Cross who identified hardest hit villages. Locations chosen included Lalomanu on day one; Saleapaga Uta and Lepa on day 2 and selected families in Vailoa and Mutiatele on day three. These areas correspond to zones 1 and 2 from the Early Recovery Framework and can be seen in Figure 11.



**Figure 11: Black stars show locations of survivor video story interviews**

At each location the interviewer approached families and people to introduce the purpose of the research and gauge their interest in taking part in the video interview. The interviewer spoke with people directly and interviews were conducted immediately. Interviewees reflected a range of ages, genders and community positions.

Once acceptance and permission had been established the technical Producer/Director and Assistant began to set up the necessary equipment, after scoping a suitable spot considering lighting and noise levels. While this process was taking place the Interviewer collected biographical data and personal history information that helped put interviews in context and establish family relationships. These conversations helped put people at ease for the video interview.

The interviewee was then asked to state his or her name and village before describing what happened on the day of the tsunami. The interviewee was allowed to speak without interruption about his or her experience. Near the end of the interview, the interviewer asked further questions in order to clarify events or encourage additional comments. At the conclusion of the interview the Interviewee was asked to sign a release form to enable footage taken to be used for scientific and educational purposes. All interviews complied with human ethics standards/protocols dictated by the lead researcher's home institution.

Members of this team included Walter Dudley from the University of Hawaii-Hilo, Jackie Faasisila from the School for International Training (SIT) and Angela Jowitt from the University of the South Pacific (USP), Alafua Campus. The team was also joined by Daisy Bedford from the Red Cross Society on day 1 and Rodney Fu on day 2. They assisted with the initial entry into the villages of Lalomanu and Saleapaga and identified potential interviewees.



## 2.6 Social sciences

The Social Sciences sub-group needed to divide their work in to two separate sections. Part A deals with the broader social science context. Part B deals with establishing post-disaster indicators for monitoring economic vulnerability and resilience. The precise methods used in each part are detailed separately.

### 2.6.1 Part A – *The broader social impacts*

The broad overarching purpose of the project was to work as a team - local counterparts working alongside international team members. The broader objectives of the team were to: a) scope the project and the general pre-and post-tsunami context, b) develop a broad research orientation, c) develop a research instrument and d) discuss and agree upon field methods and locations to complete the interviews. All of this was completed within the first 24 hours of arriving in Samoa, despite team members' differing interests, skills, post disaster field experiences and the fact that many of whom had never worked together before. The remaining three days were spent in the field collecting primary evidence.

Within the first day the team took two strategic steps: first they determined the research techniques to be used by different team members. The Tsunami survivor/Tsunami disaster awareness research survey used (Appendix 4) is described below.

The second step was to build upon, rather than replicate, the work done by local counterparts. Building upon preliminary ideas taken from the Early Recovery Framework Report (Oct 2009), we consulted with local counterparts. For example, during the development of the social impact assessment tool, the team was joined by the Secretary General of the Samoa Red Cross, who contributed to the development of the interview questions to be used in the field. The research tool consisted of seven questions relating people's current and future needs, their sources of livelihoods before the event and how they were affected by the event. The short list of specific questions focused on livelihoods, needs, and sense of personal security. In the field, further probing questions were to be asked by the interviewers based on the answers given.

In addition, a set of shorter questions was included. These were structured in a way to allow for rapid information gathering. Thirteen questions were included in this section, with answers providing information on the nature of the earthquake and the subsequent waves, and also how people responded. Many people that the team approached wished to talk about what they had experienced, about what they had suffered. Participating in the survey appeared to provide an opportunity to do so.

The interview questions then were translated into the Samoan language enabling the interviewer to ask questions in Samoan. The research team agreed that even people who understood and spoke English should be interviewed in Samoan as the use of the native



language provides people a greater feeling of security in the communication with the research team. The research team agreed on field protocol: a) be vigilant and sensitive throughout the time in the field, as many people have suffered great losses; b) respect the need of privacy, as well as the need and right of mourning for everybody and c) conduct interviews in the least intrusive manner allowing participants in the interview the best protection.

Within 24 hours, the research team accomplished their key objectives. Earlier email discussion (completed before arriving to the field) had focused on methodological approaches, specific research questions, field site ethics and important issues related to interviewing post tsunami survivors. This preliminary discussion working as a team had begun before the international team's arrival in-country. An email discussion on possible research approaches prior to team arrival determined that the approach should be measured and sensitive, taking into consideration the needs of the people.

Team members agreed this would also be a learning experience, as robust recommendations could not be formulated in such a short time. The recommendations presented in Section 5 should be seen as preliminary, with further research of the long-term social impacts flagged as a priority.

The Social Impacts Assessment sub-group arrived in Samoa on Tuesday 13<sup>th</sup> and met for the first time the same day and then again on Wednesday October 14<sup>th</sup>. For the purpose of this meeting was to further specify the research approach on social impacts of the tsunami. The team was represented at the release of the Draft Early Recovery Framework at the UN compound on October 14<sup>th</sup>, with the report being submitted to the Prime Minister on Thursday, October 15<sup>th</sup>. The guiding questions used for the Early Recovery Assessment were obtained, allowing the Social Impact Assessment Team to follow up and build upon work already completed by the Early Recovery Team, which consisted of the GoS and the United Nations.

In the field, representatives from the Red Cross, the Ministry of Women, Community and Social Development (MWCSD), the Disaster Management Office (DMO), The University of the South Pacific (USP – Alafua Campus), School for International Training (SIT) and the National University of Samoa (NUS) joined the team from the international science community. They provided valuable input and translation. The representative from MWCSD was able to obtain necessary approvals from the *pulenuu* (village mayor) for the team to interview members of the villages. Teams of two, with at least one Samoan speaker, then approached individuals and families to collect information on the social impacts of the tsunami.

Locations targeted were selected based on the severity of the impact on local communities (Figure 12). It was agreed, with the advice from the Secretary General of the Red Cross, that the hardest hit zones should be selected. Thus, the villages of Lalomanu, Saleapaga, Lepa,





Ulutogia and Satittoa selected. In Lalomanu, interviews were conducted near the hospital, and inland where people had moved to after the event). At Saleapaga, all the interviews were at the new settlement at Saleapaga Uta. The interviews at Ulutogia were conducted at the temporary shelter site at the Primary School compound. At Lepa, the interviews were held in the beach area with families either living at the local church or inland in temporary housing. The interviews at Satittoa were held with people who had moved far inland. These areas correspond to zones 1 and 2 from the Early Recovery Framework and can be seen in Figure 12.



Figure 12: Villages selected for Social Impact Assessment (Source: Unknown)

Compilation and analysis of information gathered occurred over three days, allowing for the identification of recurring themes and issues.

### 2.6.2 Part B - establishing post disaster indicators to monitor economic vulnerability and resilience

The broader question - *what sort of damage and losses have the Samoan community incurred due to the tsunami?* is being asked by a number of stakeholders. The spectrum of impacts and damages spanning across many sectors, such as health, housing, education, and even sense of connectivity to community cannot be fully measured (see Cochrane 1997, Howe and Cochrane 1993, Boisvert 1992, Brookshire and McKee 1992, CACND 1999, Chang et al 2006, Okuyama 2002, Okuyama 2005).

The broad purpose of this scoping study is to build upon the work initiated in section 2.6.1, and present results from a different socio-economic angle. We sought to establish post



disaster coastal people's vulnerability by providing a preliminary disaster loss assessment list that cites evidence that many indirect and intangible loss indicators can be found in the field. Objectives included:

1. Concretely identify the root causes of *post* disaster vulnerability – economic, social and environmental - by establishing a set of indirect and intangible loss indicators (as seen in the field) that could be monitored in two post tsunami phases: a) short period of recuperation and b) longer term of recovery;
2. Based on this list of indicators, better understand post disaster coastal people's sources of vulnerability and how this might narrow the diversity of their post-tsunami livelihood strategies (e.g. fishing, tourism); and
3. Offer recommendations that might assist in building economic resilience and sustainability in communities by addressing the root causes of vulnerability – economic, environmental and social.

We referred to the disaster loss framework developed by the Australian Department of Emergency Services (Table 2) with a singular intent - establish a list of indirect and intangible losses as observed in the tsunami affected areas. Indirect losses occur as a consequence of a disaster, reflecting losses to economic activity within the designated area of analysis. These losses follow-on from the direct losses caused by the hazard, rather than resulting directly from contact with the tsunami wave etc, hence the term 'indirect' (DES, 2002).

Intangible or non-market impacts is a catch-all term which simply identifies direct and indirect impacts for which there is no market and as a result, no commonly agreed method of evaluation. The focus here is on short term quality of life issues (i.e. employment or businesses interrupted) to long term quality of life losses (e.g. economic marginalisation, loss of items of cultural significance and personal memorabilia, stress induced ill health and mortality (DES, 2002).

The methodological approach adopted for this scoping study is strategic. As the international community such as the World Bank, the United Nations, AusAid, NZAID and ADB turns to Samoa in its reconstruction/recovery stage (World Bank consultant pers comm), the focus on intangible and indirect losses of these coastal villages stresses the importance of acknowledging the deeper losses felt by those involved in sustaining coastal livelihoods. The focus on indirect and intangible loss indicators suggests that the sort of post disaster interventions truly required by post disaster communities must go beyond: a) building new community infrastructure in new locations (such as laying down sewage infrastructure to a new site, relocating existing schools), b) providing people with tools to farm taro plantations, and c) even replacing lost fishing boats and gear. This broader approach also suggests a specific path. First, focus on developing a method to monitor human resource recovery. Then, develop a process to guide post disaster livelihood options. In this manner, we address the longer-term challenge of building resilience and sustainability



into communities by addressing the root causes of post disaster vulnerability - human resource recovery.

**Table 2: Disaster Loss Assessment Process (DES, 2002)**

Step 1: Identify the loss event and purpose of the assessment
Step 2: Organise the consultation and information-gathering processes
Step 3: Define the area and time-frame of the assessment
Step 4: Decide the type of assessment to be made and level of detail
Step 5: Describe the extent/timing of the hazard event so affected assets can be defined
Step 7: Identify the types of losses – direct, indirect, tangible and intangible
Step 8: Measure the losses from all sources
Step 9: Decide whether to count ‘actual’ or ‘potential’ losses in the assessment
Step 10: Calculate annual average damages (AID) if needed
Step 11: Assess benefits to the region of analysis
Step 12: Collate and present the results of the loss assessment



### 3. RESULTS AND DISCUSSION

Due to the complex nature of the material we have collected and wish to present, we have chosen to integrate results presentation with an immediate discussion of the significance of that data (rather than separate them out in to distinct sections). This should make reading this material easier.

#### 3.1 Results and discussion of measurements of inundation and run-up

Before describing the results, we restate the relevant task that was to “*measure maximum inundation and maximum flood run-up*”.

The raw data for run-up, inundation, flow depth and other observational measurements are contained in the Inundation and Run-up folder in the accompanying electronic raw data files.

Maximum flow depths of around 8 m occurred at Vaigalu and Vauvau on the southern coast, and a maximum flow depth of 6.2 m was recorded at Saitatoa on the eastern coast. Maximum runup of 14.3 m occurred at Vaigalu. These results are preliminary as the heights are not yet calibrated to the tidal cycles during the measurement period. The distribution of run-up and flow depths are given in Figure 13.

There is a general trend of higher flow depths and run-up in the southeastern corner of Upolo Island. Run-up heights and flow depths decrease towards the west and north of the SE corner. There is an unusually high flow depth of ~5 m at Siufaga along the southwestern coast of Upolo.

A reconnaissance-level survey was also undertaken along the southern coast of Savaii, the results are not included in Figure 13.

The finer-scale variability in run-up, flow depths and inundation distances reflect site specific influences of nearshore bathymetry (reef morphology), coastal topography and the existence of offshore islands. Some topographic profiles are shown in Appendix 5. Further topographic profiles will be processed in future.

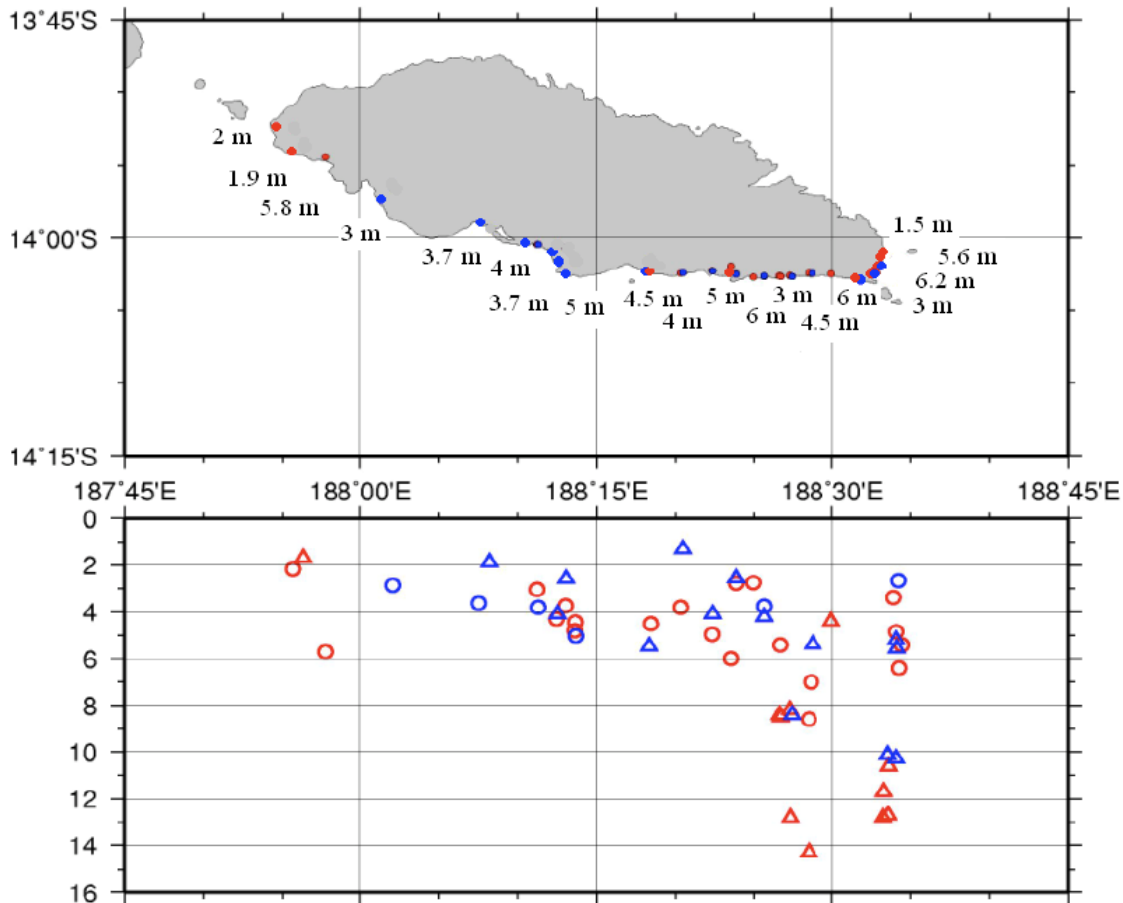


Figure 13: Run-up (blue and red triangle) and flow depth distribution close to the beach (red and blue circle, and numerals on figures above), shows the tsunami characteristics at the coast are very site specific and strongly influenced by the nearshore bathymetry and coastal topography as well as the existence of the offshore islands. Maximum flow depth of up to 8 m occurred at Vaigalu and Vaovau beach at South coast, and 6.2 m at Satittoa. The maximum run up of 14.3 m occurred at Vaigalu. These results are preliminary as the heights are not yet calibrated to the tidal cycles during the measurement period

### 3.1.1 Arrival time of the first wave

The arrival time of the first wave varies from place to place. Based on the eyewitness accounts, the first wave came in shortly after the quake, about 5 - 10 minutes at the east and south coasts. Most of the eyewitnesses felt the quake for around 3 – 5 minutes. Whilst eyewitnesses state this for the period of groundshaking, we know this not to be true. This



indicates the psychologic significance of the event and is a metaphor for how important the event has become for the people. The tsunami mostly consisted of 2 to 3 waves and the second wave was often said to be the largest. Modelling of the tsunami suggests that arrival times of the first wave should have been 10 to 12 minutes at Upolu and Savai'i Islands. According to eyewitnesses the initial wave was often preceded by withdrawal of the sea, but some eyewitnesses did not recall initial sea withdrawal.

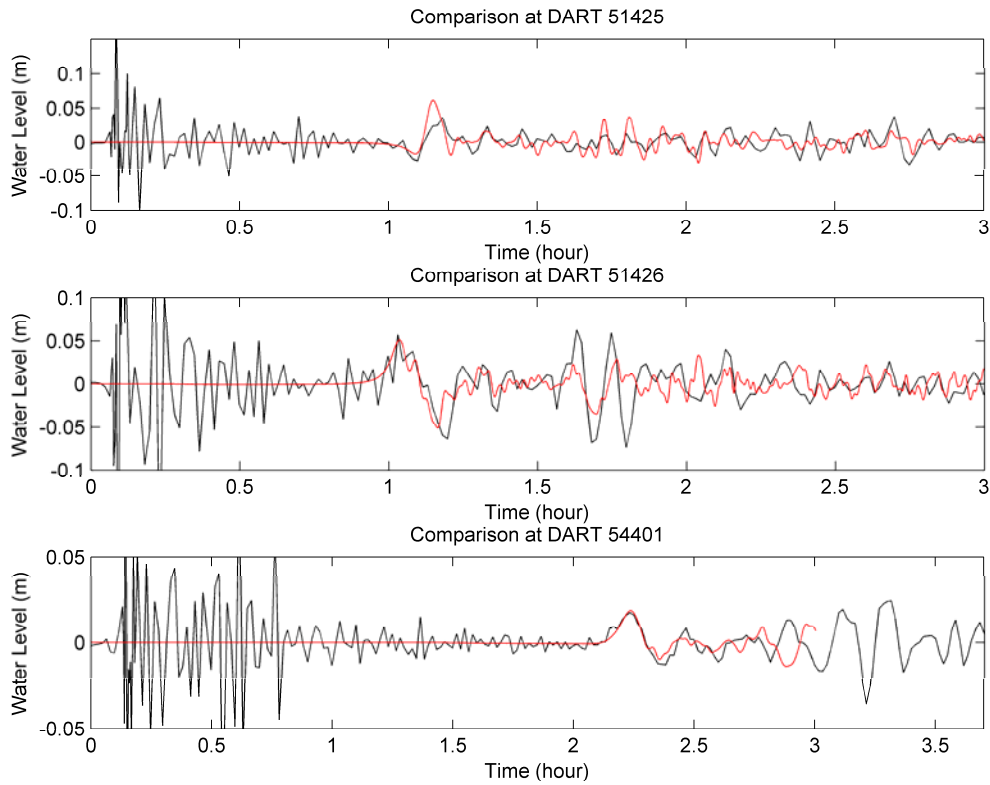
At Coconut Beach Resort (Maninoa), eyewitnesses stated that there were 3 separate waves and the time between first wave and the second wave was about 3 minutes. At this location, the first wave came in without any withdrawal, and the first wave flooded the resort up to approximately 1.2 m height and was followed by a second wave up to 3.5 m height.

Eyewitnesses also stated that the offshore islands and reefs played a significant role in amplifying and or reducing the tsunami impacts at the coast. For example, along the eastern coastline eyewitnesses saw two waves wrap around the Aliepata Islands and meet in the middle.

### ***3.1.2 Discussion***

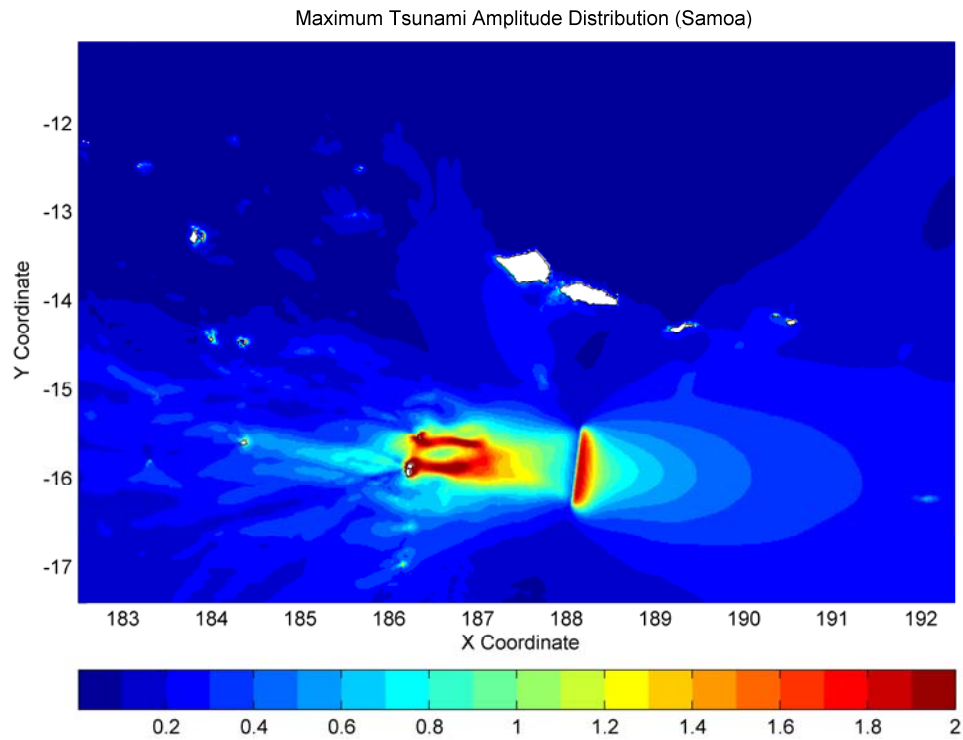
The PMEL modelling of the tsunami shown in Figure 2 based on early data about the earthquake mechanism make it difficult to understand arrival times of the first wave at some locations and high run-up values at other locations (e.g. Siufaga). Consequently, we feel that there may be some error in the original calculations provided by USGS and PMEL. Therefore, we examined the DART buoy data and re-ran the models using different earthquake parameters.

The fault parameters used by us were modified from the USGS earthquake parameters (dip, slip and strike angles) that reflect the *actual* DART buoy measurements (DART 51425, DART 51426, DART 54401). The model results are illustrated in Figures 14, 15 and 16. The faults mechanism of this result is reverse fault (instead of normal fault) with dip, strike and slip angles as  $72^\circ$ ,  $7^\circ$  and  $116^\circ$  respectively.

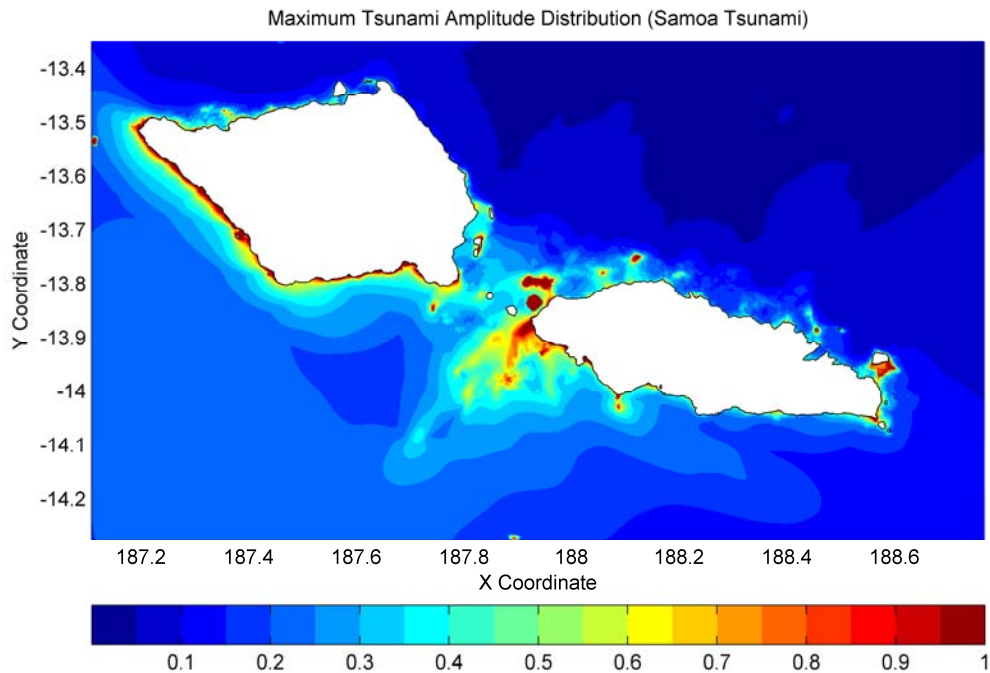


**Figure 14: Comparison of the model results (red colour) and DART buoy measurements (black colour). The fault models used the USGS information with modified parameters of the earthquake with dip, slip and strike angles:  $72^\circ$ ,  $116^\circ$ ,  $7^\circ$ , respectively and depth 5 km (top edge), length of the fault 100 km, and width 50 km**





**Figure 15: The maximum tsunami distribution from the source to surrounding region including Samoa and American Samoa shows that most of the tsunami energy is directed to the west-northwest and east-southeast. The colour bar unit is in metres. The red dark colours representing the maximum tsunami elevations greater than 2 m but less than 5 m**



**Figure 16: The maximum tsunami distribution along the Samoa coast shows the accumulation of tsunami energy at the east, south and west coast of Samoa. The red dark colour representing the areas that have maximum tsunami elevation greater than 1 m. The colour bar unit is in metres**

The modelling we have undertaken here, coupled with the inundation and run-up measurements better explain the eyewitness accounts and the final impacts of the wave at different locations along the coast. It is clear from the geology and marine biodiversity sub-groups that the off-shore reefs played a major role in offering protection (or not) to on-shore locations. Further, coupling of the new modelling shown above with bathymetry shown in Figure 17, indicates that focusing of wave energy towards the south west of the island explains the unusually large wave run-up observed in Siufaga.

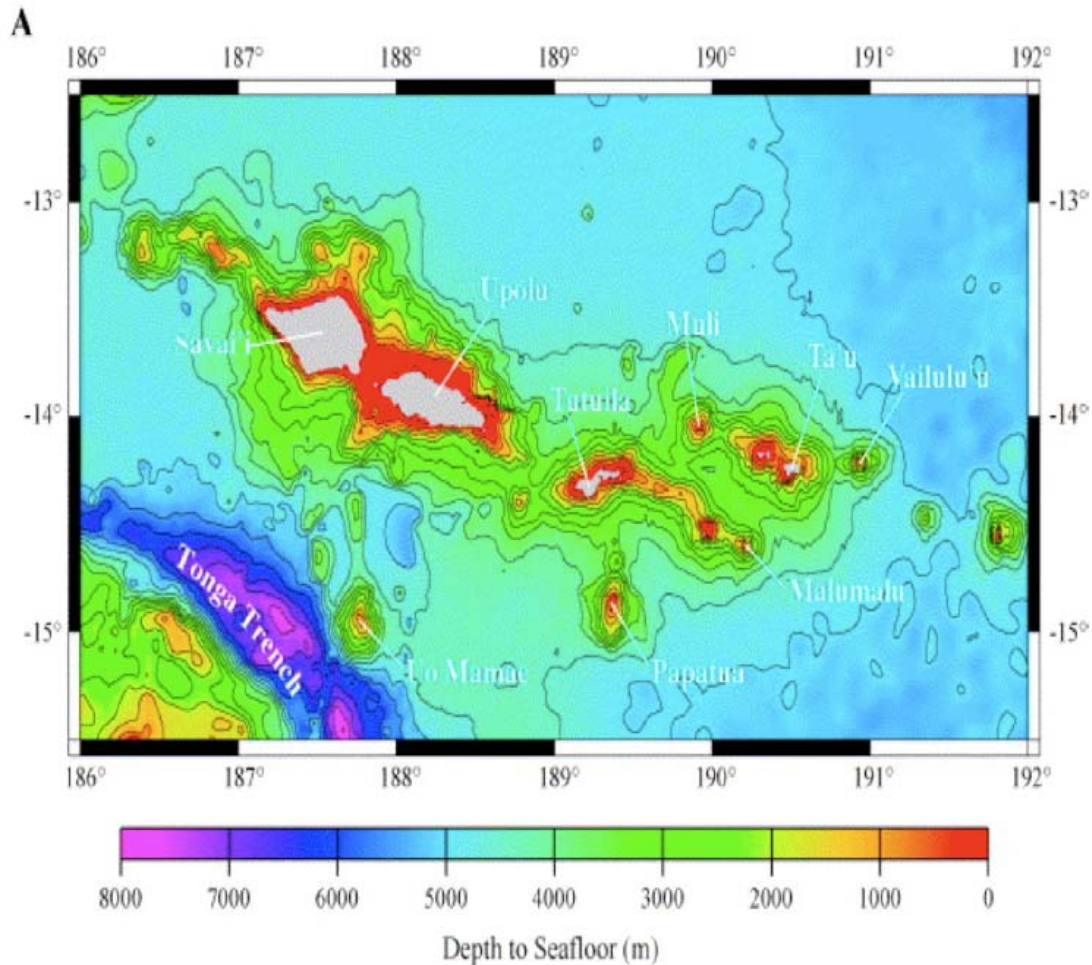


Figure 17: Bathymetry in the region of Samoa (Source: GEBCO)

### 3.2 Results and discussion of assessment of building damage type and severity

Before describing the results, we restate the relevant task that was to “*measure the type and severity of damage to different types of buildings and record what factors appeared to control damage*”.

The building damage sub-group present their survey results day-by-day.

#### 3.2.1 Wednesday 14<sup>th</sup> October - reconnaissance

On the first day, the team established a detailed protocol and consistent method for measuring inundation and run-up (that paralleled the main inundation and run-up sub-group methodology) as well as assessing building damage type. We travelled to the Southeast and Southern coasts of Upolu Island to undertake a reconnaissance in order to identify key locations for more detailed investigation over subsequent days. The group noted variations



in the degree of damage to buildings and noted how some damage types were similar to previously observed building damage during tsunamis. Watermarks on buildings were difficult to identify since more than two weeks had passed since the tsunami event.

Various people were interviewed to get a picture of what the course of the event was like. All people reported that the tsunami hit the coast during mid tide, when the water was relatively calm. Most stated that the water first receded and left the reef bare. A roaring sound, like a jet engine (as confirmed by survivor accounts – see Section 3.5.1), was then heard shortly before the tsunami arrived. The majority described two, sometimes three, incoming waves, arriving only a few minutes apart and with no complete withdrawal between. All people reported the second wave as being the largest.

Some people remembered that the incoming wave broke at the coast or amongst the palm trees and then surged through the developed areas. Others described it as a surge rather than a breaking wave. Most people only started to seek higher ground at the sight of the waves. A lack of information or education caused some people to get into their cars and drive parallel to the beach where they were caught by the tsunami. In some areas, boats and other obstacles were picked up by the incoming waves and became missiles that were responsible for some of the damage to buildings.

### ***3.2.2 Thursday 15<sup>th</sup> October – Ulutogia and Satitooa***

Ulutogia and Satitooa are villages at the Southern end of the east coast of Upolu (Figure 18). Both villages lie in a flat area with a steep hill about 300m inland from the road. The road runs parallel to the beach and parts of the coastline were protected by a rock seawall. The settlement area covered the area between the road and the hill.

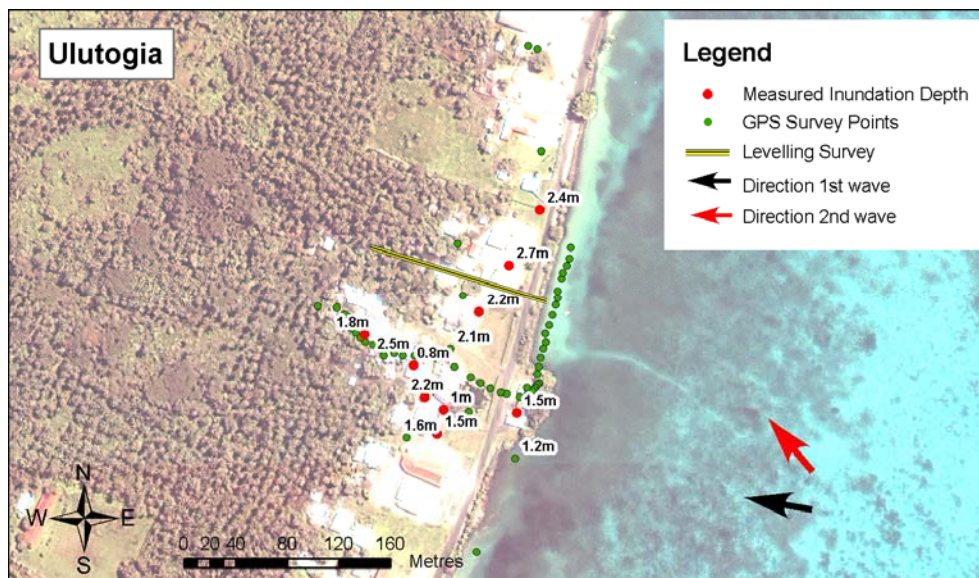




**Figure 18: Location of Ulutogia and Satitooa**

### 3.2.2.1 GPS Surveys

The GPS base station was setup over BM 3100 (elevation 4.2639 m) above the rock pool at Lalomanu. Figures 19 and 20 show an overview of the surveyed area with measurement points and observed inundation depths.



**Figure 19: Survey points in Ulutogia**

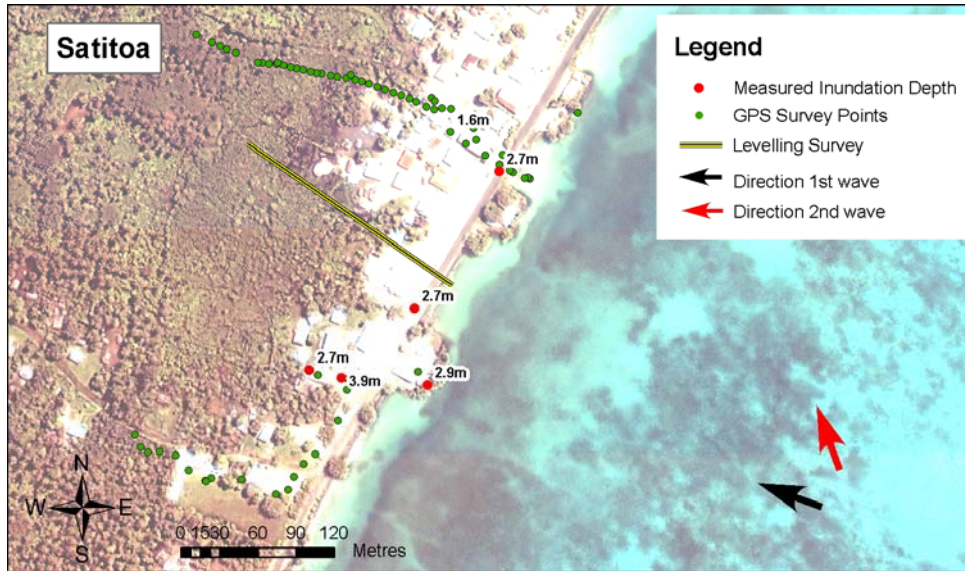


Figure 20: Survey points in Satittoa

### 3.2.2.2 Levelling survey

Two transects were taken at Vailoa, one of them was measured perpendicular to the coastline (blue line on Figure 21). The second transect (purple line in Figure 21) was taken parallel to the first, moving a few meters southward in respect to the first one in order to measure the furthest inundation point (174 m). Both transects have the first 6 points in common.

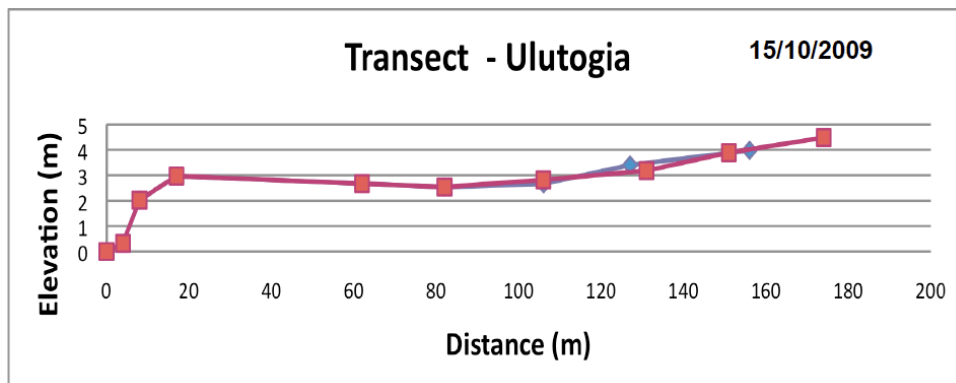


Figure 21: Transects 1 & 2 at Ulutogia

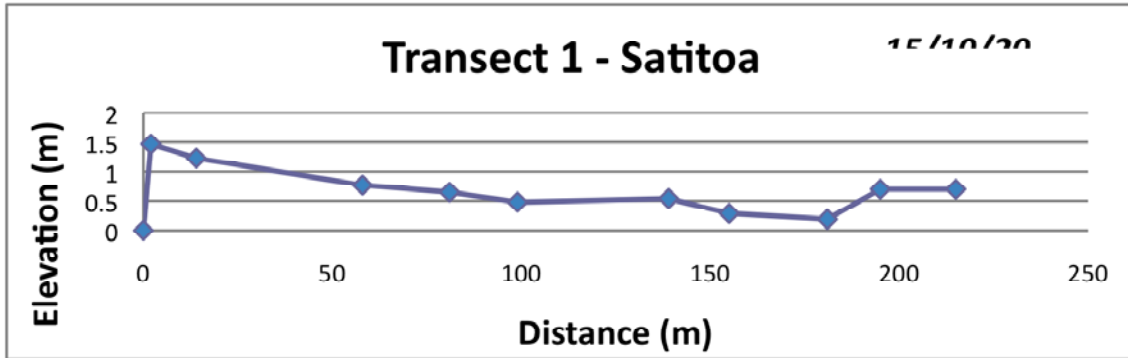


Figure 22: Transect 1 at Satitoe

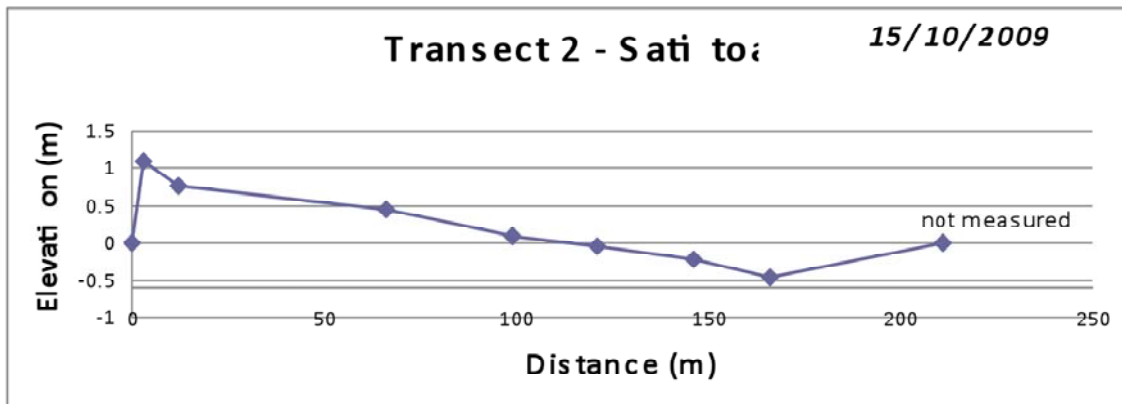


Figure 23: Transect 2 at Satitoe

### 3.2.2.3 Damage

Most of the buildings in Ulutoiga and Satitoe were of residential use with numerous fale in-between, in particular along the main road. Amongst the residential houses and along the road a few shops and other buildings such as a school and churches were found. Thirty-one buildings were inspected of which 18 were residential, 5 open meeting houses, 1 school, 1 petrol station, 2 shops, 2 churches and 2 buildings where the use could not be determined due to total collapse.

One factor that had significant influence on the degree of damage is shielding. Buildings shielded by other buildings or large obstacles showed 3-4 times lower damage than buildings directly exposed to the waves.





#### *3.2.2.4 Eyewitness accounts*

Various people have stated that they have considered relocation but might be forced to stay due to the lack of resources (they do not have insurance) and the land ownership. A man from Satittoa told us that he was engulfed by the tsunami and found himself pulled out to the reef edge where he attached himself to floating debris. He then rode the next inundation to shore where he found safety on the land. His mother was killed by the tsunami. His attitude was that of wonder at being alive. He was happy and smiling, and showed his mother's fresh grave with little sign of grief.

#### *3.2.2.5 Ground Profile and Inundation*

Five transects / profiles were completed and about 30+ buildings inspected. The survey showed water depths of about 3-3.5 m around buildings close to the sea, which dropped to 2-2.5m approx. 50-70 m inland (see Figures 19 and 20). The RTK data requires post-processing before any further details can be presented.

#### **3.2.3 Friday 16<sup>th</sup> October – Saleapaga and Lepa**

Saleapaga is a small village at the Southeast Coast of Upolu seven kilometres west of Lalomanu (Figure 24). The area is fairly flat with an adjacent moderate-sloping narrow beach (Figure 25) protected by a rock seawall. Approximately 200m inland (Figure 26) from the shore is a steep slope that confines the buildings to a relatively narrow strip between the Southern Coast Road and the cliff. Before the tsunami, the area had primarily residential houses, churches, shops and a school. Most of the residential buildings were brick/masonry, some with reinforcements such as concrete beams and columns.



**Figure 24: Location of Saleapaga and Lepa**



**Figure 25: Overview of beach looking east**



**Figure 26: Overview of inland relief at Saleapaga**

### *3.2.3.1 GPS survey*

The GPS base station was setup over BM 3108 (elevation 4.4131 m) next to the road in Saleapaga. Figures 27 and 28 show an overview of the surveyed area with measurement points and observed inundation depths.

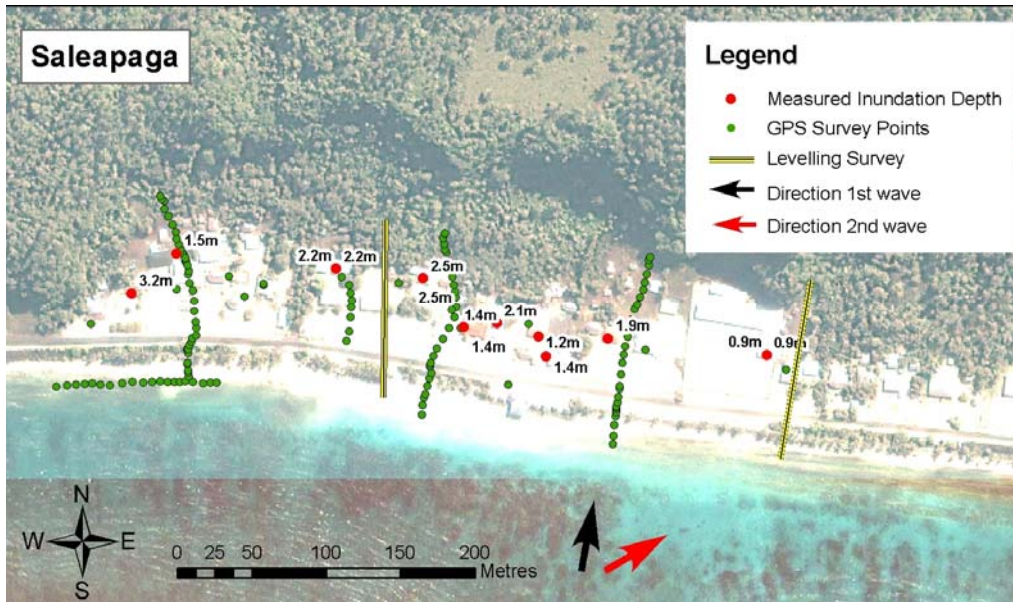


Figure 27: Survey points at Saleapaga

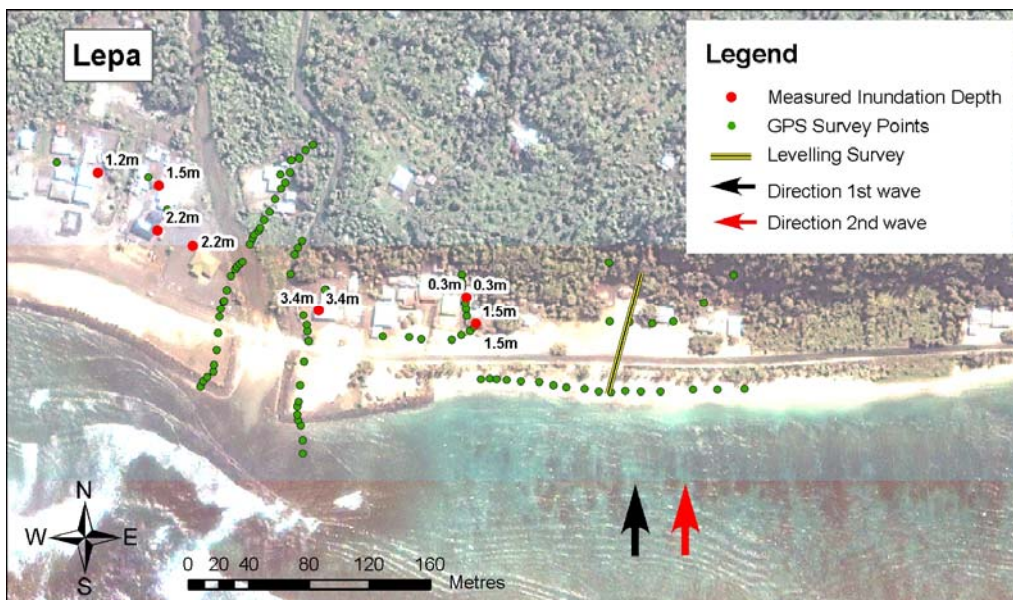


Figure 28: Survey points at Lepa

### 3.2.3.2 Levelling survey

Two transects were taken at Saleapaga. The first transect is shown in Figure 29, the inundation line was measured at 123 m.

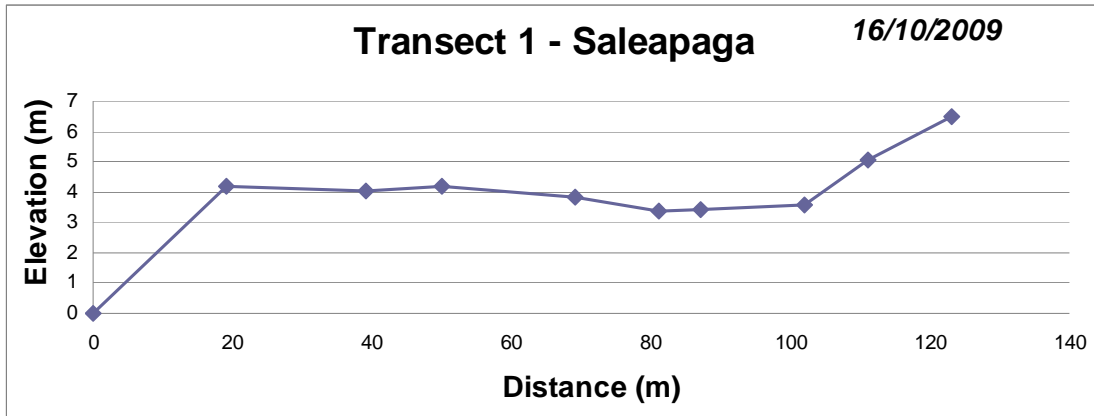


Figure 29: Transect 1 at Saleapaga

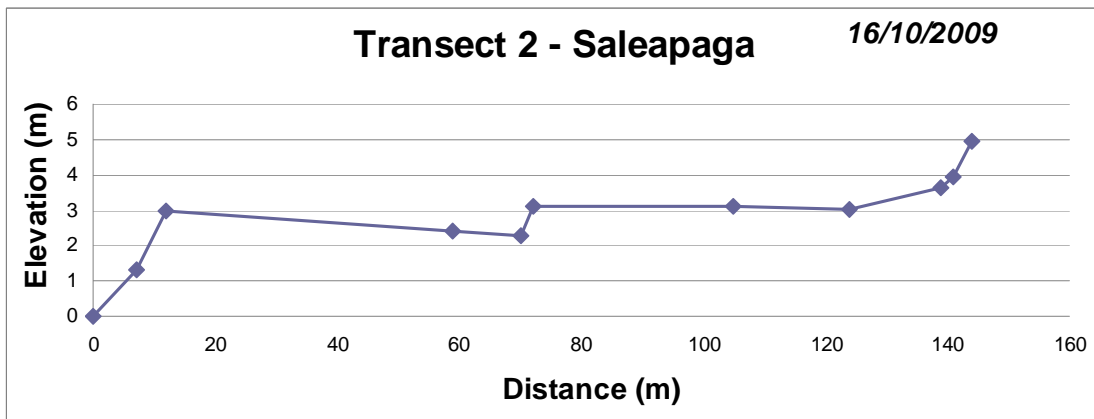
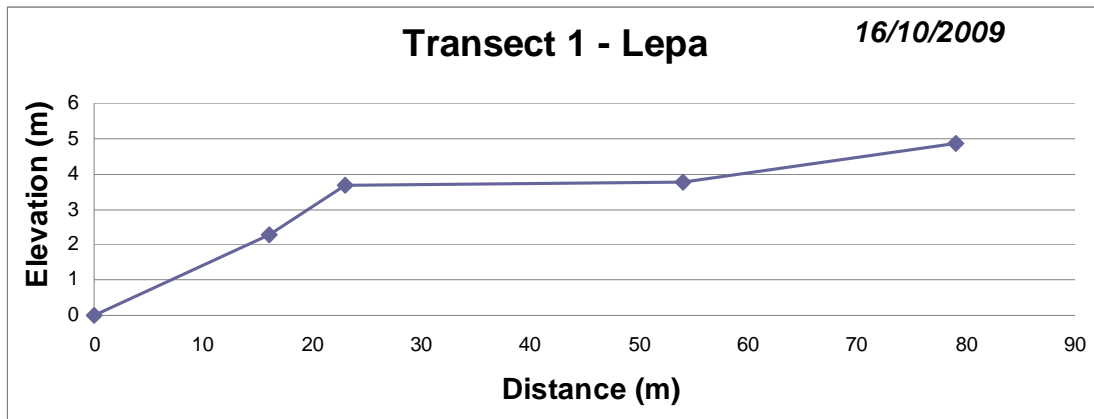


Figure 30: Transect 2 at Saleapaga

The second transect at Saleapaga is shown in Figure 30. A 1.5 m run-up mark was found at the wall located at the end of the transect.

One transect was taken at the Eastern side of the river at Lepa (Figure 31), where the inland penetration reached 79 m. The slope increases 4 m along a 24 m distance inland, forming a plateau to about 54 m.





**Figure 31: Transect 1 at Lepa**

### 3.2.3.3 Damage

In Saleapaga 19 buildings were inspected most of them made of brick/masonry. Three buildings that were surveyed had a reinforced concrete structure and hence suffered only minor damage. In contrast to Lalomanu where all buildings were destroyed a large percentage of buildings remained standing in Saleapaga. Amongst the surveyed buildings a lot of the observed damage was caused either by debris or insufficient or un-armoured classic foundations with rockfill. Several fales that sat right at the beachfront were completely destroyed. All of the surveyed timber framed buildings were also completely destroyed. One of the shops that is located along the road sustained only minor damage despite water inside of about 1.5 m. The shop re-opened within a day or two. One building was elevated by about a meter compared to the adjacent buildings and also sustained less damage.

Twelve buildings in Lepa were surveyed showing different degrees of damage. Buildings on both sides of the river suffered severe damage as the river obviously channelled the tsunami wave upstream. Hence, the flow depth along the river was obviously higher than elsewhere.

### 3.2.3.4 Eyewitness accounts

Eyewitnesses in Saleapaga claimed that the first wave was fairly small compared to the second one and travelled only ~50 m inland. The first wave was said to have come perpendicular to the coastline whereas the second wave, which was much higher and caused all the damage, approached from the southwest. Most people seemed to have reacted only when they saw the wave. According to several eyewitnesses, there was little or no awareness of tsunami risk, not even after having felt the earthquake. Consequently, the number of fatalities was very high (35 people died in this village).



A shop owner was trapped inside the kitchen of a shop and reported a water depth of up to chest level inside. The shop only sustained minor damage and reopened pretty much straight away (Figure 32).



**Figure 32: Shop in Saleapaga**

Eyewitnesses in Lepa also reported having seen two waves with the second one causing all the damage. Out of a total population of approximately 190, 5 people died in this village. One woman described the waves approaching the village “like a snake” perpendicular to the coastline. It was clear that some of the water was re-directed up the stream.

According to the locals all people from the affected areas in Lepa will move up to the plantation and build new houses. All people seemed to have felt the earthquake but very few evacuated after the earthquake. The majority obviously started self-evacuating when they saw the wave.

#### *3.2.3.5 Ground profile and inundation*

Nine transects / profiles were completed and about 30 buildings inspected. The survey showed water depths up to 2.5 m at Saleapanga and up to 3.5 m at Lepa. The RTK data requires post-processing before any further details can be presented.





### 3.2.4 Saturday 17<sup>th</sup> October – Coconut Beach Resort and Poutasi

Figure 33 shows the locations of the Coconut Beach resort and Poutasi study sites.

Coconut Beach Resort was a luxury resort with a number of buildings in close proximity to the sea. Most of the resort lies behind a 3 metre-high seawall and the resort grounds are fairly flat with moderately sloping terrain behind. Most of the resort's buildings were built with concrete-bound volcanic rocks, some with timber walls on one side.

Poutasi (Figure 33) is built on a broad plain on both sides of a river mouth with low-lying lagoon/wetland. Most of the affected residential buildings and the school were built on low ground. Approximately 300m from the sea, the ground rises on a moderately steep slope to the coastal road and beyond.



**Figure 33: Location of Coconut Beach Resort (west) and Poutasi (east)**

#### 3.2.4.1 GPS survey

Due to the distance between the two surveyed locations, two base station setups were necessary to collect accurate GPS data. For the survey of Coconuts Beach Resort, the GPS base station was setup over BM 3143 (elevation 18.2400 m) next to the road in Siumu close to the store. For the survey of Poutasi, none of the close benchmarks could be located and the base station was setup on the grounds of the high school. Measurements of tide levels will be used to calibrate the survey points vertically. Figures 34 and 35 show an overview of the surveyed area with measurement points and observed inundation depths.



Figure 34: Survey points at Coconuts Beach Resort

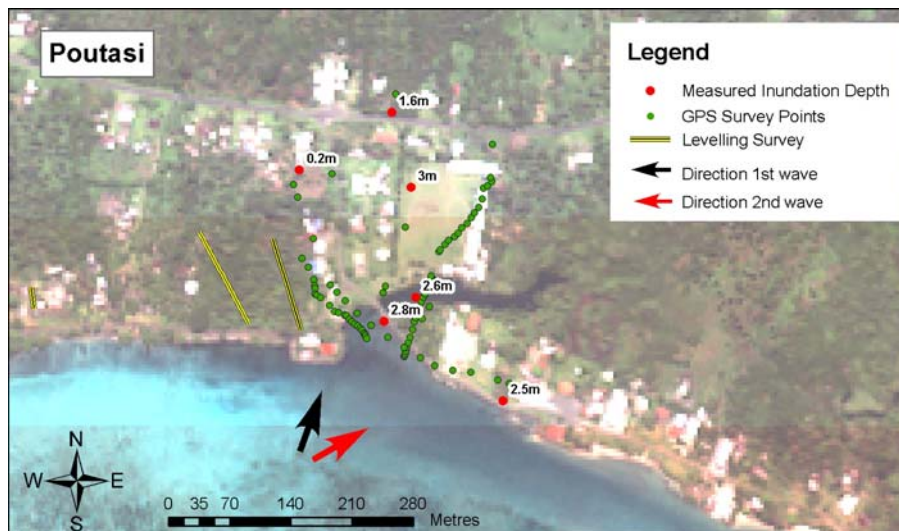
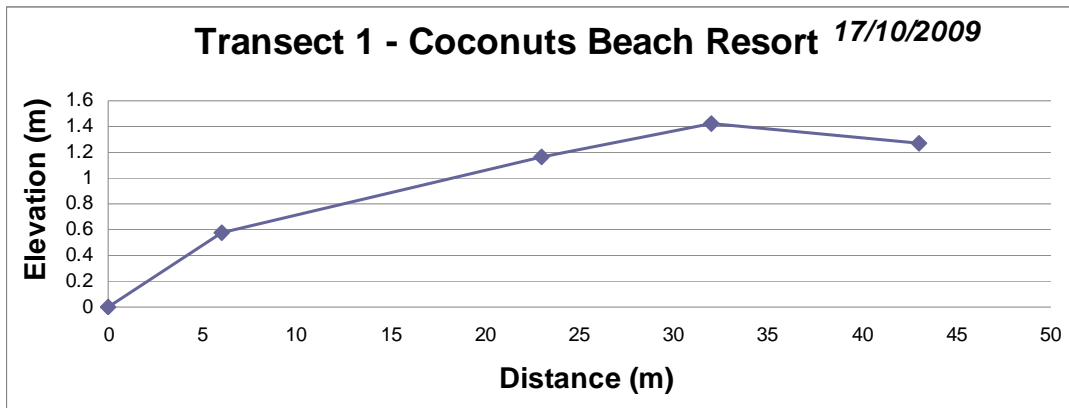


Figure 35: Survey points at Poutasi

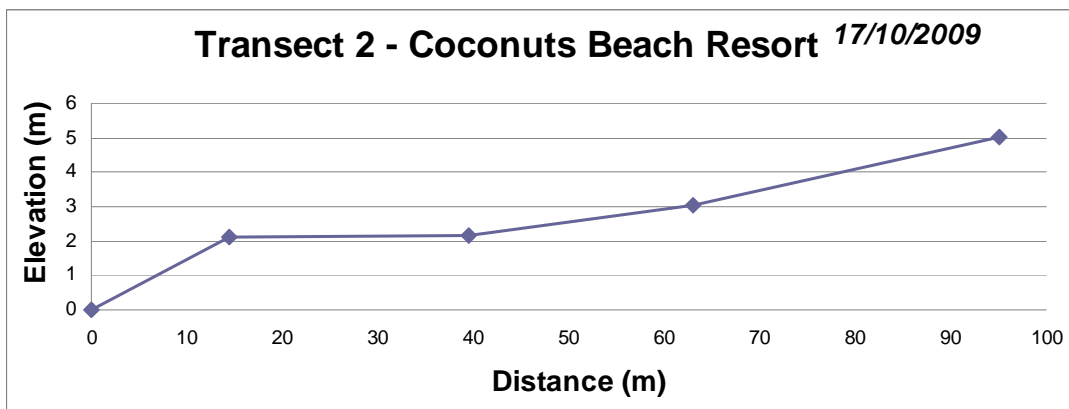
#### 3.2.4.2 Levelling survey

Two transects were made at Coconut Beach Resort. The first one is shown in Figure 36. Along the first transect, three values of inundation depth were measured on buildings facing the coastline. They measured 2.90 m, 3.10 m and 3.80 m above ground level from east to west, respectively. The slope increases smoothly from the coastline to about 45 m inland.



**Figure 36: Transect 1 at Coconut Beach Resort**

Transect 2 at Coconut Beach Resort (Figure 37) was taken west of Transect 1. In Figure 37, it can be seen that the slope still increases smoothly, with a plateau between 15 and 40 m. The inundation line was measured at 95 m inland from the shore.



**Figure 37: Transect 2 at Coconut Beach Resort**



Two transects were taken at Saleilua. At this location, some information from eyewitnesses was recorded, but no watermarks or accurate descriptions could be obtained, so the inundation depth was not measured along these transects. In this village, a steep scarp (see Figures 38 and 39) close to the coastline protected the houses located on the plateau at the top of the scarp. The first transect was taken perpendicular to the coast, whereas the second transect was taken diagonally, following the probable direction of the first wave.

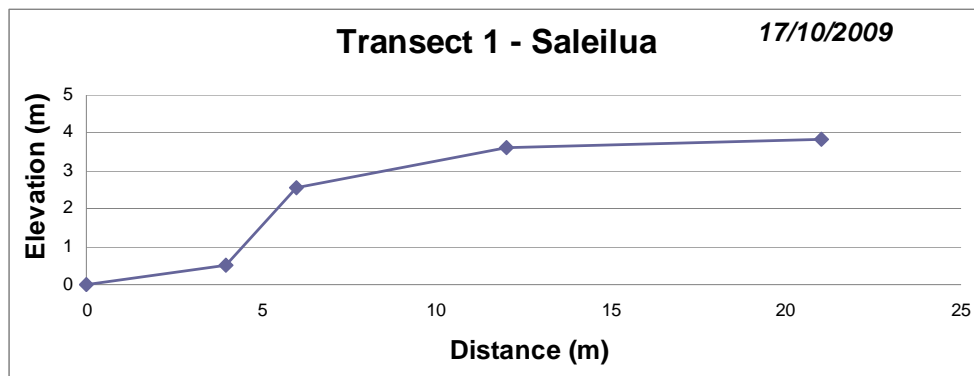


Figure 38: Transect 1 at Saleilua

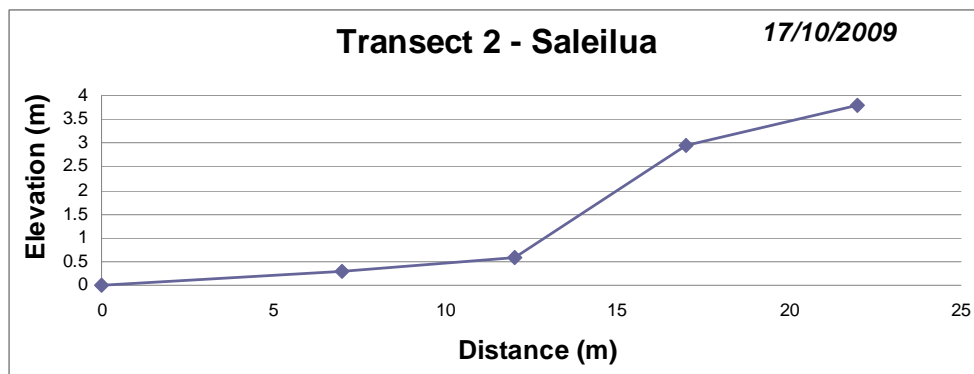


Figure 39: Transect 2 at Saleilua

In the adjacent village of Poutasi, inundation depth could be measured along Transect 2 at a building. According to an eyewitness description and observation of damage, it reached about 3.50 m above ground level. Based on eyewitness description the inundation depth was also measured at another building where it reached about 0.8 m above ground level. The water penetration at Transect 1 was 107 m whereas at Transect 2, it was around 161 m. The two transects taken at Poutasi are shown in Figures 40 and 41.

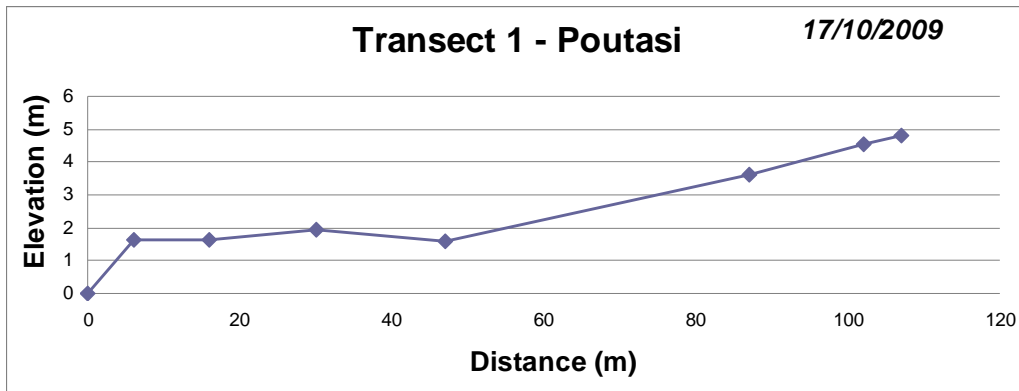


Figure 40: Transect 1 at Poutasi

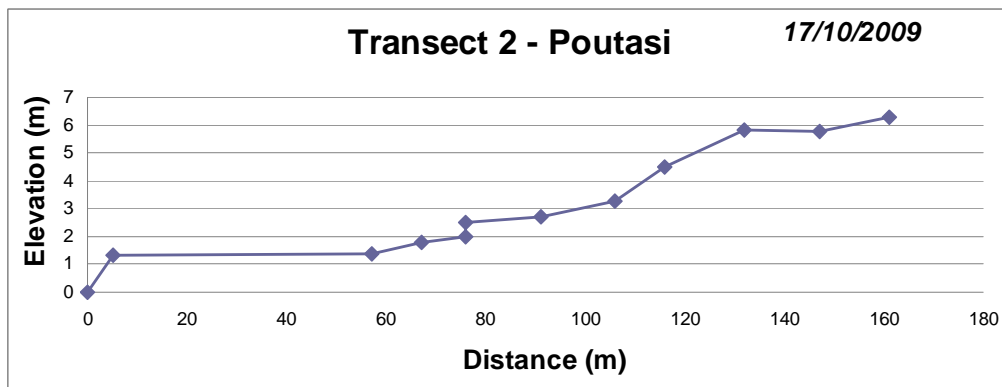


Figure 41: Transect 2 at Poutasi

### 3.2.4.3 Damage

At Coconuts Beach Resort, different levels of damage were observed, ranging from complete destruction of whole buildings (reception block) to minor damage in some of the guest accommodation (Figures 42 and 43). The resort has been operating for almost 20 years at the present location, but all of the current buildings are of recent construction and less than 5 years old.



**Figure 42: Spa at Coconuts Beach Resort**

Most of the buildings were constructed from volcanic rocks, held together with mortar. There is little or no reinforcing or concrete in these walls. Most of these buildings resisted the tsunami relatively well.

Other buildings were made of stone and had a kind of pole construction. These buildings have a stone wall to window sill level (typically 1 m high) with timber pole construction above that. The timber poles are approximately 300 mm in diameter with brackets and bolted connections. Panels between the poles are either windows/doors or timber. Most of these structures survived intact, with the exception of the restaurant/bar and reception buildings. These two buildings sustained major damage with many of the timber poles displaced or destroyed. These seem to have taken the full force of tsunami, with impact damage likely.





**Figure 43: Guest room, Coconuts Beach Resort**

In addition to that there were pole constructions similar to above, but without the stone wall. The 2-storey hotel block is also this type of construction. The hotel did not sustain significant structural damage. Water height was almost to the ground floor ceiling. The hotel is set further back from the water and is sheltered by the other buildings and a stone wall. Some of the pole construction buildings with less shelter sustained some damage, particularly with failure of connections.

The resort had a number of over-the-water bungalows that were constructed on reinforced concrete piles over the sea. These have all been destroyed. All buildings had roofs with a timber frame construction and a plywood roof. The plywood is lined with bituminous sheeting for waterproofing and then topped with coconut palm leaves to create a thatched effect. A section of the poolside building roof was dislodged when the wave engulfed the building, but the framing was undamaged. There were also timber constructions made out of conventional timber frame with rusticated timber weatherboards. The timber construction has sustained significant damage, but less where the building is sheltered or elevated.

The reception building was completely demolished, even though the reception and bar were shielded by a stone or concrete wall (approx 2m high). The construction materials could not be ascertained. The toilets also sustained extensive damage with a clear correlation of exposure (proximity to the sea) and damage.



Some debris was found around the buildings. A boat was deposited on the roof of the bar. Large boulders were found inside the bar building and several cars, boats and other large items around the site.

There is a stone seawall along the water frontage of the site. Most of the seawall survived intact, but one section in front of the pool has been broken. There was also a lot of scouring around the site, with some large holes. Most of this has now been repaired. Repair work is underway across the resort as the owners plan to re-open as soon as possible.

The shape of most damage indicated that the destructive wave came almost parallel to the coast from the east. Most of the guest accommodation is located either at the back of the resort or along the western reaches, where they were partially sheltered by the buildings in the east. Consequently, these buildings suffered less damage and are mostly structurally still sound with the exception of all west facing walls which were made from timber and are all destroyed. Much of the resort's attractions like pools and bars were destroyed or severely impacted.

Further along the beach at Maninao Surf Camp, all of the wooden buildings along the water's edge were destroyed, but the reception building which is set back from the water and up a small rise has survived.

Sinalei Resort lost a jetty structure, dining area and shop that were by the water, but the remainder of their buildings were high enough above sea level to escape major damage. The resort plans to re-open on November 1<sup>st</sup>.

In Poutasi, a high level of damage was sustained by most buildings (Figure 44) close to the shore. The bridge over the mouth of the river was destroyed. Water entering the flat area behind the beach from the river seems to have increased the destructive power of the tsunami. Several buildings of the high school were completely destroyed and the buildings left standing sustained severe levels of damage. Most residential buildings were either completely washed away or are left in a state that is beyond repair.



**Figure 44: Damage in Poutasi**

#### *3.2.4.4 Eyewitness accounts*

At the time of the tsunami there were approximately 30 guests staying at the resort. The siren, located at Sinalei, was activated about the same time that the wave was noticed. The staff and guests evacuated inland, either up the access road, or through the vegetation at the rear of the bungalows. There was one casualty – a female guest with a broken leg could not be evacuated and drowned. Although the evacuation was successful, it did not happen in an orderly manner with some degree of panic and confusion. Tsunami evacuation procedures or notices were not in place at the resort.

The hotel had participated in the earlier national tsunami drills with staff and guests, but the owners felt that this might have lead to a sense of complacency, as there is a perception that there will always be a siren before a tsunami and that there will be ample time to evacuate.

The owners also would like to clarify the procedures for activating the tsunami siren. The nearest siren is at Sinalei Resort and it was activated. The owners were under the impression that the siren is activated automatically from a central location. However, they understand that on Sept 29, the siren was activated manually by someone at Sinalei. They would like to know how the siren is supposed to be activated, and if it is done manually, what is the procedure for this.

Eyewitnesses in Saleilua / Poutasi reported that there were two waves, the first arrived from an easterly direction while the second arrived more from the west. The arrival time of the tsunami was around 7 a.m. Other reports were quite contradictory. One boy (about 10 years old) claimed that there were three waves, with the third one the strongest. Another boy (about 13 years old) said there were two waves, the first moving eastward, the second westward. He felt the earthquake at 7 a.m. and 3 minutes later the first wave arrived.



In Poutasi, people reported that they felt the earthquake and left their houses to see what had happened. An old lady reported that she heard some noise as if rain was about to start and then she realised the sea had withdrawn. Five or ten minutes later she saw the first wave approaching the coast quickly and slowing down as it approached the coast. She saw a splash when the wave struck the first buildings. The second wave came more from the west and joined the first one inland between the other buildings.

#### *3.2.4.5 Ground profiles and inundation*

Eight transects / profiles were completed and about 30 buildings inspected. The survey showed water depths of up to 3.5 m at Coconuts Beach Resort and Poutasi. The RTK data requires post-processing before any further details can be presented.

#### **3.2.5 Discussion**

In total, 92 buildings were surveyed. Table 3 shows the different (use) types that were found. The most dominant category was residential buildings followed by tourist buildings and fale. Residential buildings were primarily made of timber or brick/masonry and so were most of the shops. Surprisingly, schools, shops, and offices were built the same way without any specific reinforcement. The most solidly built buildings are churches, which had very massive, solid foundations and walls. The ones observed only sustained light structural damage.

**Table 3: Number of surveyed buildings by category**

<b>Building Use</b>	<b># of surveyed buildings</b>
Offices	1
Hospitals	1
Halls	1
Petrol station	1
Churches	2
Schools	4
Shops and combined use	5
Toilet blocks	5
Unknown	5
Meeting houses (fale)	8
Accommodation	13
Residential	46
<b>Total</b>	<b>92</b>



The main features of the damage to buildings are as follows:

### **Timber**

- single storey houses and shops
- post and beam construction, primarily 100 mm x 100 mm posts, light and flexible walls
- $\leq 1.0$  m of water – minor to moderate damage,
- 1.0-1.5 m of water – moderate to severe damage
- $>1.5$  m of water – severe or destroyed

### **Brick/ Masonry without any reinforcement**

- single storey, houses and shops
- single-skin brick walls,
- $\leq 1.0$  m of water – light to minor damage,
- 1.0-2.0 m of water – minor to moderate damage
- 2.0-2.5 m of water – moderate to severe
- $>2.5$  m of water severe to collapse

### **Brick with some kind of reinforcement**

- one and two storeys, houses and shops
- single-skin brick walls with reinforcement e.g. concrete columns or beams, bars of 8 to 14 mm
- $<2.5$  m of water – minor to moderate damage
- $>2.5$  m of water – moderate to severe

*Note: limited number of samples*

### **Robust concrete buildings**

- Very rare, often churches or comparatively new buildings
- reinforced concrete columns of at least 200 mm x 200 mm, probably with 4 to 6 bars of 8 to 12 mm reinforcement
- $\leq 1.0$  m of water – light damage,
- 1.0-2.0 m of water – minor damage
- 2.0-3.0 m of water – minor to moderate
- $>3.5$  m of water moderate to severe

The importance of reinforcement was very clear – traditional light timber buildings were essentially totally destroyed at an inundation depth of 1.5m or higher, whereas adding minimal reinforced-concrete columns reduced the damage levels significantly.

Concrete buildings, for instance, showed only minor damage such as broken windows/ doors, without any structural damage at the same inundation depth (Similar observations



were made following the 2004 Indian Ocean Tsunami by Dominey-Howes and Papatoma, 2007). Table 4 shows the percentage distribution of damage levels for the different construction types. For some categories the sample size was fairly small, hence the results may not be representative.

**Table 4: Percentage distribution of damage levels by construction type**

	Light	Minor	Moderate	Severe	Collapse	samples
<b>Timber framed</b>	5%	16%	21%	16%	42%	19
<b>Brick/masonry</b>	6%	27%	21%	31%	15%	48
<b>Brick/masonry reinforced</b>	0%	0%	25%	75%	0%	4
<b>Concrete</b>	14%	43%	14%	29%	0%	7
<b>Lava rock</b>	0%	43%	14%	43%	0%	7

In addition to wave height, flow velocity is another critical parameter. But collection of empirical velocity data in the aftermath of an event is usually not possible, unless indirect approaches are used. However, this secondary data can only be collected immediately after the event. For example, watermarks at the front and rear of a building (head loss or pressure loss) can be used as an indication for flow velocity. Since the teams only began their work two weeks after the tsunami, all of this evidence was lost and hence no velocity calculations could be made. However, geological analysis of sediments may enable velocity and possibly flow depth calculations to be made – something not possible without this interdisciplinary approach.

There are various other parameters that influence the degree of damage that a building sustains. Shielding, for instance, is obviously beneficial. A building that is located behind another building is likely to suffer less damage than the directly exposed ones (Dominey-Howes and Papatoma, 2007; Dominey-Howes et al., in press). Sometimes even trees or dense vegetation could reduce the energy of the incoming waves. In some instances, concrete walls around a property have reduced the impact on buildings. However, a reduction in damage is only achieved as long as the “protection” does not become debris itself. Table 5 shows the obvious influence shielding has on the degree of damage. All buildings in the category light damage were shielded whereas 79% of the collapsed buildings were exposed.

**Table 5: Influence of shielding for the vulnerability of a building**

	Light	Minor	Moderate	Severe	Collapse
<b>Exposed</b>	0%	31%	52%	53%	79%
<b>Shielded</b>	100%	68%	48%	47%	21%

The results clearly show that debris also plays a major role in regards to the level of damage a building sustains. A preliminary analysis suggests that the damage can be 3-5 times higher if



the water carries debris. Some debris originates of course from the natural environment but often collapsed buildings or man-made objects such as un-anchored water tanks become missiles and increase the damage to buildings or objects that bear the brunt of the force (Dominey-Howes and Papathoma, 2007). Depending on the type of coastal protection, sometimes seawalls can also turn into missiles if not the right size.

The flow depth of a tsunami naturally decreases with distance from the shore. Hence, the proximity to the shore is also relevant. Even a small distance back can make a significant difference to whether a building remains intact.

The same applies to vertical distance. Buildings that were elevated or had extremely high foundations usually showed significantly less damage than adjacent buildings. However, these buildings have a high risk of undermining if the foundation is not properly constructed or armoured (Figure 45) (Dall’Osso et al., 2009). But the benefit is obvious. Churches for instance tend to have massive foundations and sustained only minor damage.

Another obvious factor that influenced the flow depth and consequently the degree of damage was the size of the coral reef. There seems to be some correlation between the width of the reef and the wave height or energy, respectively. The areas with extensive reefs evidently had lower flow depths and thus sustained less damage.

Quite a few buildings were surveyed that should have withstood the force of the tsunami but did not. This was often due to poor workmanship, poor quality of the building material or people not following the building code. As mentioned before, the most frequent example of poor workmanship were insufficient or defective foundations.



**Figure 45: Large sections of the foundation are undermined**



The quality of the building material was also not up to standards in some cases. Timber was found that obviously had not undergone quality control and showed signs of termite damage or signs of decay. Some concrete blocks seemed also not to be up to standards. In other cases, reinforcement steel bars showed signs of corrosion which could have been caused by inappropriate handling (use of salt water). Another example was roofs not fixed to the walls so as to become easily detached from the main structure. Building codes and standards are essential not only for tsunamis but for all types of hazards.

A good example of using natural products could be seen at the Coconut Beach Resort where some of the guest houses were made of lava rock and remained intact whereas the timber part of the building was almost completely destroyed.

In summary, the damage assessment results suggest that buildings are more likely to survive with less damage if they have:

- elevated floor levels,
- reinforced concrete or core-filled concrete block walls,
- sound foundations,
- are shielded,
- and are well constructed.

### ***3.3 Results of geological surveys and assessments***

Before describing the results, we restate the relevant task that was to “*collect geological samples of sediments left by the tsunami*”.

We have successfully collected samples to take back to our laboratories for detailed multifaceted analyses. However, here we also report on the effects of the tsunami on the coastal geology. Figure 46 shows areas travelled and study sites on Upolu for the geology sub-group and Figure 47 shows the three sites where extensive surveys were carried out. Various types of geological data were collected including boulder measurements, trenches, samples, and water levels. Example topographic profiles in trench sites are shown in Figures 48 and 49. Table 6 is a listing of boulder measurements (incomplete) and Figure 50 is a plot showing boulder volume and long-axis orientation for the study site at Satitua. These figures, tables, and spreadsheets are not a complete listing of all data collected but are meant to show examples of the data collected during the field survey. A more complete compilation will be completed and forwarded to the ITST Samoa for transmission to the Government of Samoa at a later date.



**Figure 46: Map showing areas traveled (green lines) based on hand-held GPS track logs and areas where measurements and observations were gathered (white dots).  
Base map is a Google Earth image**

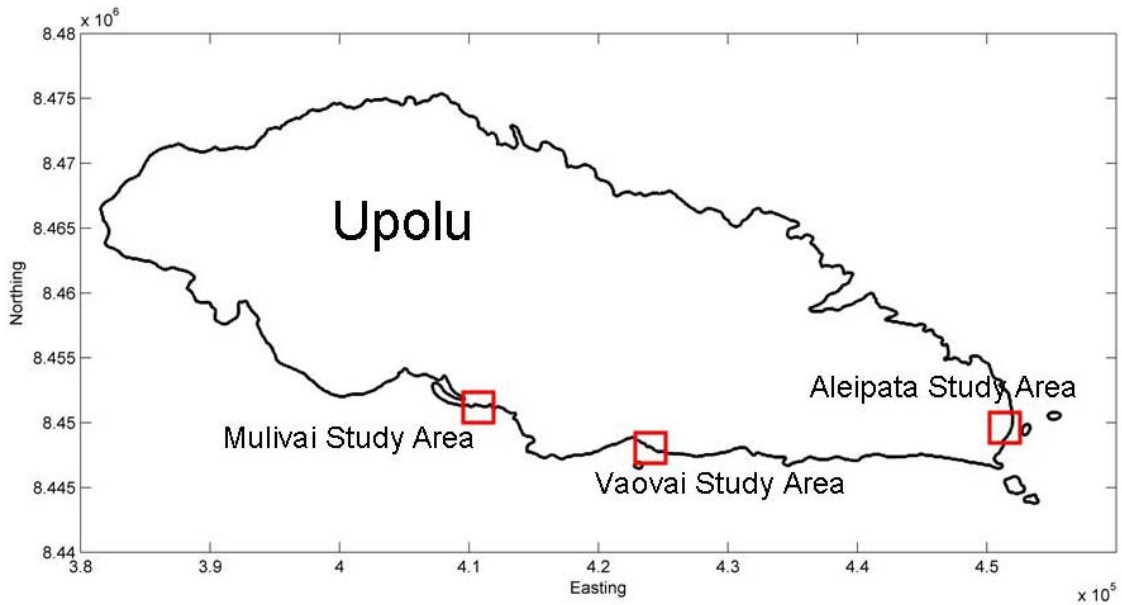


Figure 47: Map showing the location of the Aleipata, Vaovai, and Mulivai detailed study sites

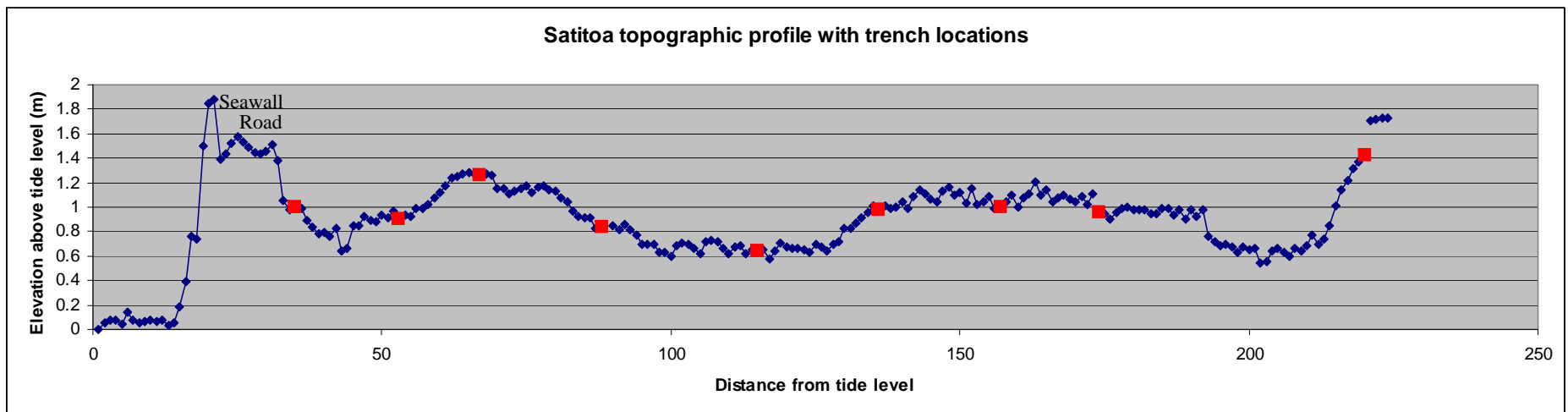


Figure 48: Topographic profile along the Satittoa transect. Blue points and line show ground surface. Red points are the locations of trenches examined by the tsunami geology sub-group (starting at T09 on the coast). Profile reaches to the inland extent of inundation. Note the elevations are in metres relative to the tide level at the time of the survey (11.30 am 20<sup>th</sup> Oct, 2009). The elevations will be calibrated at a later date but the adjustment is expected to be less than 0.5 m

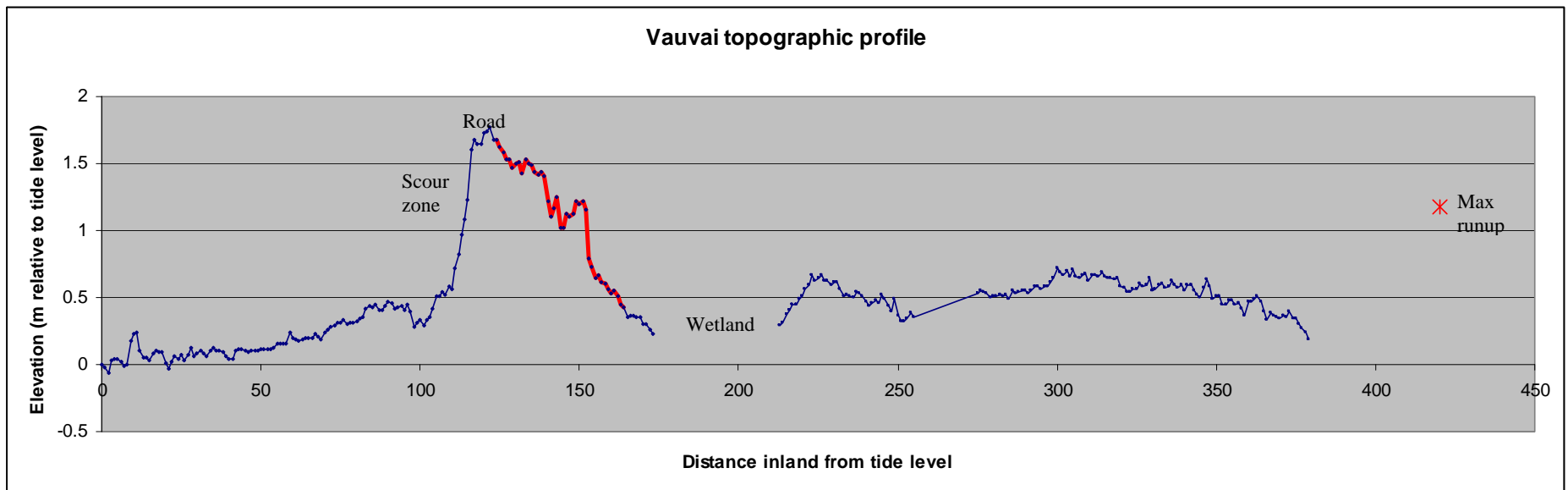


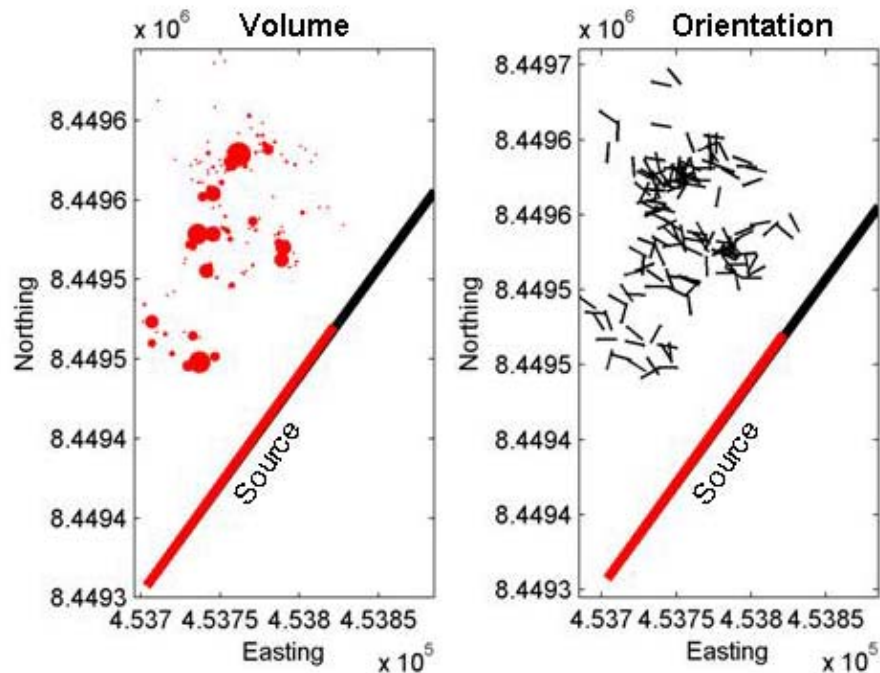
Figure 49: Topographic profile along the Vaovai transect. Blue points and line show ground surface (some gaps due to wetland). Red line shows the extent of the sandsheet examined for sedimentary properties by the tsunami geology sub-group (starting at T09 on the coast). The high tide line is at approximately 110 m. Note the elevations are in metres relative to the tide level at the time of the survey (2:00 pm, 19<sup>th</sup> Oct, 2009). The elevations will be calibrated at a later date but the adjustment is expected to be less than 0.5 m





**Table 6: Boulder measurement data (incomplete) collected by the geology sub-group**

Type of measurement	Number of measurement	Location
<b>Flow depth</b>	<b>50</b>	<b>All</b>
	29	Satitua
	7	Siumu
	2	Return to Paradise Beach
	8	Vaovai
	4	Poutasi
<b>Flow direction</b>	<b>35</b>	<b>All</b>
	23	Satitua
	5	Malaela
	1	Savau
	2	Siumu
	1	Silanei Reef resort
	3	Vaovai
<b>Inundation limit</b>		
<b>Boulders</b>	<b>231</b>	<b>All</b>
	160	Satitua
	67	Vaovai
	4	Savai



**Figure 50: Plots of relative boulder volume (red circles) and boulder long-axis orientation for the Satittoa boulder study site. The red and black lines show the shoreline orientation and revetment source of the boulders. The black line segment is a section of revetment that showed minimal damage**

### *3.3.1 Example of a field site description and data collected at one site on 10/14/09*

Reconnaissance site visits to the east and southeast coasts to examine the extent of tsunami inundation and impacts and select sites for detailed geologic studies.

Aleipata District, east coast Upolu.

Broad low-lying coastal plain bordered by a barrier reef backed by a shallow lagoon. The reef is connected to several offshore islands resulting in a region of complex physiography.

Data collected included:

- 2 shallow trenches approximately 70 m from the shoreline showing tsunami deposited sand overlying soil and covered by a thin mud drape.
- Tsunami inundation of about 300 m near Satittoa Village.



- Flow direction of 314° (towards the NW) along a shoreline oriented roughly N-S (185°).
- Land surface showing abundant evidence of recent inundation including scoured and eroded soil, deposition of marine debris (Halimeda, fish, etc.), stripped vegetation and massive vegetation debris piles, and widespread destruction of structures.

Lalomanu, SE Upolu. Steep hinterland and narrow coastal plain fronted by a shallow barrier reef (~ 200 m wide).

Data collected included:

- Preliminary run-up (11.06 m) and inundation (143.22 m) using laser rangefinder.
- Erosional scarp of 1-2 m produced at shoreline probably by return flow.
- Measurements to the west of Lalomanu were run-up (9.19 m) and inundation (23.61 m) along a steep stretch of coast at Cape Tuiolemu.

Vavau (Resort) Area, SE Upolu. Narrow coastal plain backed by cliffs.

Data collected included:

- Backbeach area severely eroded by return flow.
- Fale concrete posts show flow direction of 351° (to the NW).
- Two sites measured for run-up (12.06 m, 12.12 m) and inundation (48.64 m, 64.5 m).
- Beach sand composed of mostly terrigenous sediment with patches of gravel and boulders along base of eroded scarp.

### 3.3.2 Discussion

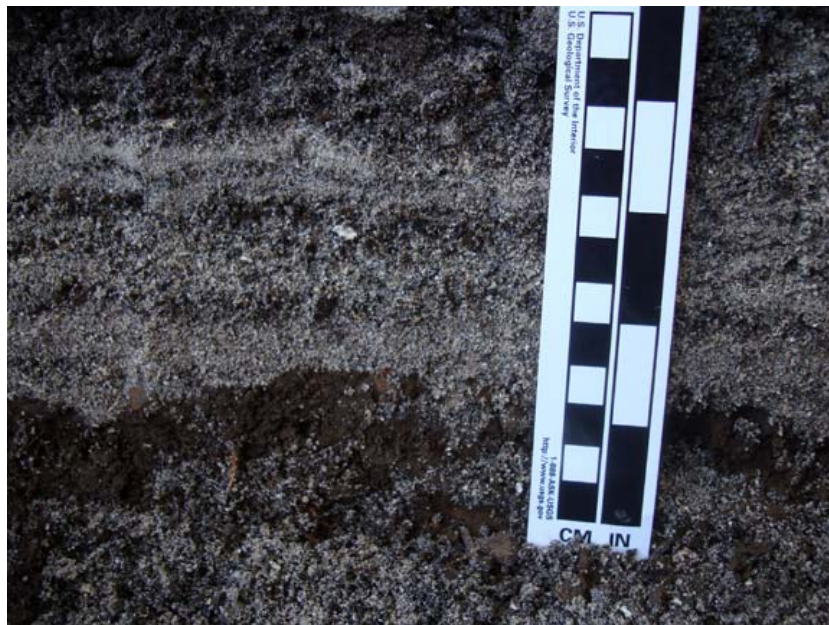
The tsunami left a clear geologic imprint along sections of the east, south, and west coasts of Upolu and the south coast of Savai'i. Geologic evidence of tsunami modification to the coastal zone is in agreement with evidence derived from the other UNESCO-IOC Samoa ITST study team findings. Where measurements of inundation and run-up were conducted by both the geology and inundation-run-up sub-groups, there was good agreement between the types of evidence used and absolute measurement values. Observations by the building damage sub-group were consistent with the geology sub-group observations regarding scour, transport and deposition of sediment, and direction of failure related to tsunami flow directions. Damage to coastal ecosystems and the environment as observed by the geology and the ecosystems and biodiversity sub-groups highlight the resilience of natural ecosystems to extreme events.

Key findings of the geology sub-group include:

- In areas where there is a suitable supply of sediment and sufficient tsunami wave forces occurred, tsunami sedimentary deposits are widespread, and for the most part, distinguishable from the pre-tsunami sediment at the ground surface.



- Areas with sufficient beach sand deposits often produced tsunami sand sheets that filled in topographic lows and thinned on topographic highs. Physical structures, such as walls or stairs, often had thick (10-20 cm) shadow sand deposits in the lee of the structure. In Aleipata sand sheets extended up to  $\sim 250$  m from the shoreline.
- Mud drapes on the upper surface of tsunami deposits were common and represent fine-sediment deposition from the final stage of tsunami inundation. The largest source of fine-grained sediment is most-likely from soil erosion of the land surface with additional input from either marine or coastal wetland environments. A maximum mud drape thickness of  $\sim 4$  cm was measured near the limit of tsunami inundation behind Satitooa.
- Internal sedimentary structure of the tsunami sand deposits is complex (Figure 51), showing a wide variation in grain size, composition, and number and type of laminations. Internal structure varied with distance from the shoreline and is thought to have recorded complex interactions between wave forces, microtopography, and sediment supply.



**Figure 51: Close-up of a trench face near Satitooa Village approximately 250 m from the shoreline showing, from top to bottom: tsunami mud drape, multiple alternating light and dark layers of tsunami sand, and basal pre-tsunami soil surface**

- Erosion at the shoreline was widespread and resulted in the transport of sediment and debris in both landward and seaward directions. The shoreline clearly provided sand and gravel (including revetment boulders) to the onshore sedimentary deposits. Maximum erosion of back beach areas, up to  $\sim 2$  m, appeared to be driven by offshore



return flow of the tsunami in many localities as evidenced by offshore-directed flow indicators associated with major beach scarps.

- Exploratory trenches in a number of inland sites show the existence of a number of buried sand deposits separated by paleosols. These sand layers very strongly indicate the presence of past extreme wave deposits that deserve further investigation using the analytical techniques outlined in Goff et al. (1998; 2001).
- Flow direction indicators often show numerous directions at any one locality and in some cases the relationship between oldest (bottom) and latest (top) gives an approximation of tsunami flow direction through time. The complexity is derived from the interaction between multiple tsunami waves and locally complex topography and bathymetry.
- Coastal slope exhibits a strong control on run-up, inundation, and return flow characteristics. Steep coasts typically exhibit high run-up, limited inundation and strong return flow indicators, whereas low-lying coasts show lower run-up, greater inundation, and less pronounced return flow indicators.
- Maximum transported clast size is dependent upon size of available material. Where coastal protection structures are constructed, mostly of basalt boulders, it is common to find boulders transported inland several tens to  $\sim 100+$  m inland. Cars and appliances appear to be particularly likely to be transported by the tsunami.
- Wrack lines of thick vegetation debris (vegetation ramparts) are common and occur where landward transport of vegetation of thick debris piles no longer occurs. They are typically seaward of the tsunami inundation line and represent a zone where coastal vegetation significantly retards tsunami flow.

### ***3.4. Ecosystem and biodiversity: results of assessment of impacts and effects on natural environment and ecology***

Before describing the results, we restate the relevant task that was to “*collect and measure information about the biophysical system impacts of the tsunami in different places*”.

#### ***3.4.1. Group A – terrestrial***

The places visited by this group include:

##### **Aleipata I tupa I luga (District)**

Saleaumua

Mutatele

Malaelā associated mangrove area

Satitua

Ulutogia

Vailoa



## **Aleipata itu pa I lalo (District)**

Lalomanu

(Lata , Lefaga & Tuialamu)

Saleapaga

Lepā

Aufaga

Vavau

Lotofaga

## **Falealili District**

Salani

Utulaelae

Siuniu

(Salesatele)

(Sapunaoa)

Malaemalu

Satalo

Matavai

Tafatafa

(Vaovai)

Poutasi

(Saleilua)

## **Siumu District**

Saaga

Maninoa

## **Tourist Development Area**

Beach fale resorts - Lalomanu

Lupesina Resort – Saleapaga

Faofao Beach fale area – Saleapaga

Vavau Beach Resort - Vavau

Salani Surf Resort - Salani

Iliili beach resort - Saleilua

Sinalei Resort - Siumu

Maninoa surf resort - Siumu

Coconut beach resort - Siumu

## **Other significant sites**

Salani River valley

Quarry

Fusipu – Pandanus swamp

Salesatele River valley

Malaemalu River valley





The main findings relate to: 1) the overall impacts of the tsunami on, and protection afforded to, communities and the environment by plants and vegetation; 2) the nature of accelerating deforestation, loss of traditional knowledge of plants and their role in increasing the vulnerability of communities; 3) damage due to events prior to the tsunami; 4) the differential durability and value of native and introduced trees and plants; 5) trees that saved peoples lives; 6) impacts on and value of mangroves and wetlands; 7) impacts on agricultural production and biodiversity; 8) impacts on village houseyard and tourist development gardens; 9) loss and damage to livestock; 10) impact on marine life from a terrestrial perspective; and, 11) increased vulnerability to invasive species.

#### ***3.4.1.1. General impressions of the nature of the tsunami wave and impacts on vegetation, coastline and structures and the role of vegetation in protecting coastal areas and settlements***

In terms of impacts and intactness of the coastal vegetation and the associated coastline, there were a number of observations:

- There were very different levels of damage and mortality for larger indigenous coastal trees and shrubs e.g., talie, fetau, pu'a, toa, leva, lau lala) and some introduced trees (e.g., pulu, tamaligi, pua, introduced palms, etc.), to very high levels of damage for some of the non-indigenous trees, such as poumuli, guava, and some citrus trees, and that the ability of these latter plants to survive was further complicated by the prolonged two-week drought that followed the tsunami (Appendix 3).
- Overall, native coastal trees and a range of introduced trees provided significant protection to the immediate coastal areas, stabilized soils and substrates, and provided places for people to take refuge, hang onto, or become stuck in as a basis for survival.
- Smaller shrubs and herbaceous plants, including indigenous coastal species, some ornamental plants and lawn grasses provided significant protection to the underlying soil and substrate thus preventing erosion of further sediment.
- There was also considerable damage to food and ornamental plants on the coastal plain and in run-up areas, with apparent differential recovery rates, and need for the replanting and rehabilitation of these areas and well as for a systematic program for the propagation and replanting in both coastal and newly settled inland areas.
- There were some signs of serious tree-fall of some of the larger coastal trees in areas of most serious beach and coastal erosion. This was probably due to serious undercutting of back-beach embankments and terraces and back erosion, which led to a very significant retreat of back-beach ridge (first terrace behind the main supra-tidal beach area). It was in this zone that many of the beach fales in the tourist zone were located, and subsequently totally obliterated by the tsunami.
- Susceptible plants and structures directly landward of intact trees and groups of trees, such as mangroves, stands of beach mahogany (fetau) or Tahitian chestnut (ifi), suffered less mortality and damage than plants in areas without such protection. For example, trees, such as poumuli and, to a lesser extent, breadfruit (ulu) and mango (mago), which seemed particularly susceptible to seawater inundation and saltspray



(but not so much to knockdown) seem to have survived better in these more protected sites.

Overall, field observations and damage assessments, in-depth interviews and questionnaire surveys indicated that intact vegetation provided multiple benefits in terms of mitigating the impacts of the tsunami. Some of these benefits are listed in Table 7.

**Table 7: Benefits of trees, shrubs and durable herbaceous vegetation in mitigating the impacts of the tsunami**

Benefits
<ul style="list-style-type: none"> <li>• Coastal stabilization/reduction in coastal erosion and cutback</li> </ul>
<ul style="list-style-type: none"> <li>• Reducing the speed and depth of the waves due to increased flow interruptions and increased friction under the waves</li> </ul>
<ul style="list-style-type: none"> <li>• Reinforcing seawalls, breakwaters, house foundations, etc</li> </ul>
<ul style="list-style-type: none"> <li>• Soil retention and consolidation/reduction in tsunami sediment loads</li> </ul>
<ul style="list-style-type: none"> <li>• Protection of houses, tombs/graves and other structures</li> </ul>
<ul style="list-style-type: none"> <li>• Provision of a safe haven, place to escape, hold on to, and to wait for the tsunami to subside</li> </ul>
<ul style="list-style-type: none"> <li>• Protection of more vulnerable less deep-rooted and less resilient plants</li> </ul>
<ul style="list-style-type: none"> <li>• Provision of poles and building materials needed in post tsunami recovery</li> </ul>
<ul style="list-style-type: none"> <li>• Coastal stabilization/reduction in coastal erosion and cutback</li> </ul>
<ul style="list-style-type: none"> <li>• Reducing the speed and depth of the waves due to increased flow interruptions and increased friction under the waves</li> </ul>
<ul style="list-style-type: none"> <li>• Reinforcing seawalls, breakwaters, house foundations, etc</li> </ul>
<ul style="list-style-type: none"> <li>• Soil retention and consolidation/reduction in tsunami sediment loads</li> </ul>

### *3.4.1.2. History of deforestation, devegetation and tree removal and the loss of traditional knowledge*

Respondents indicated that there has been an increasingly long history of the removal of a wide range of larger coastal trees that, in the past, afforded protection to the coastline, coastal plain and human settlements, as well as having multipurpose cultural utility (Thaman 1992, Whistler 2000). This has been due mainly to the construction of new houses, community buildings, churches, seawalls, wharves, tourism accommodation and clearance for the erection of powerlines. The major causes of de-vegetation included:

- removal of a large percentage of larger coastal trees, such as fetau, talie, pu’a, milo, futu, tausuni, leva and tau’anave, to accommodate beach fale and associated platforms, the widening of coastal roads and the construction of seawalls. Most dramatic was the rapid proliferation of tourism developments along the southeast coastline, which included the “construction” hundreds of extremely vulnerable beach



fale (Samoan thatched huts and small-unit accommodation), often along the interior margins of the main beach below the back-beach ridge or terrace. These were essentially totally destroyed and removed by the tsunami.

- removal of mangroves and plants that grow on the margins or wetlands or behind the main settlements, including the mangroves (togo) themselves, groves, thickets or individual trees of beach hibiscus (fau), Tahitian chestnut (ifi), namulega and aloalo.
- The removal of low-lying coastal and wetland vines and herbaceous plants, such as native coastal grasses (mutia tai); sedges (mumuta and selesele), creeping vines (fue moa and fue sina), mangrove ferns (sa'ato) and swamp pandanus (lau totolo).

The extension of developments into this outer coastal zone and the widespread removal of trees and other indigenous vegetation are believed, by most communities, to have made their areas much more vulnerable to devastation and loss of life. Both the testimonies from local communities and observations of the distribution of damage indicate that damage was less in those areas with more trees and intact vegetation.

#### ***3.4.1.3. Damage due to prior extreme events***

The team was careful to insure that signs of devastation and damage to biodiversity were, in fact, due to the tsunami rather than to some other cause. This was because some apparent impacts and signs of destruction were, in fact, related to prior events, such as the impact of Tropical Cyclone Heta in 2002, tree falls during strong winds, storm waves, or even human cutting, etc. For example, there were many areas where there was significant tree fall, some of which on careful inspection, was due to snapping or truncation of trees before the tsunami and others due to deliberate felling after the tsunami. Examples include:

- On the beach just west of Coconuts Club in Siumu, there were over a half a dozen fallen or uprooted coconut palms, the majority of which, according to informants and on-site inspection, were the result of events before the tsunami.
- Similarly, a coconut trunk about 6 m long was lodged and resting horizontally at a height of about five meters (5 m) in the upper branches of a rain tree about 400 m inland from the coast in Malaelā along a road through the back swamp to the resettlement area. Upon consultation with locals, it was found to have been the result of the fall and snapping of the upper portions of a very tall coconut palm before the tsunami.

#### ***3.4.1.4. Durability and value of native and introduced trees and plants***

There were a large number of mainly native, but also some introduced plants, that showed very high ability to withstand the impacts of the tsunami.

Native coastal littoral trees that showed extremely high resistance to the tsunami and which provided considerable protection from the waves and debris included fetau (*Calophyllum inophyllum*), talie (*Terminalia catappa*), pu'a (*Hernandia nymphaeifolia*), niu (coconut palm, *Cocos nucifera*) and fasa (*Pandanus tectorius*). Toa (*Casuarina equisetifolia*), and fau (*Hibiscus tiliaceus*) also showed great ability to withstand the tsunami, although there was evidence of some breakage fau of branches and defoliation.



Due to the antiquity of the settlements, it is difficult to determine whether these trees are remnants of the original coastal littoral forest or deliberately planted trees or trees groves. The latter may be the case with a number of the denser, more intact trees stands of groves, such as the stand of fetau, on the coast immediately seaward of a zone of the greatest impact in Malaelā, and the stand of ten (10) pani (*Manilkara dissecta*) trees about 100 m inland in the high impact zone in Satitōa.

There are a number of very durable and culturally important coastal plants, that were seen at only a few locations, and that are now rare or relatively unknown to the younger generation. These should be propagated and replanted to protect shorelines and help mitigate and adapt to tsunamis. These include the rare trees: tausuni, tau'nave, milo, ifilele and fao and the shrub, to'ito'i.

Introduced trees that showed very high durability, resilience and ability to withstand and recover from the tsunami include the Indian banyan or rubber tree and the Benghal banyan (both pulu, *Ficus elastica* and *F. benghalensis*), araucaria pines (paina, *Araucaria heterophylla* and/or *A. columnaris*), poinciana or flame tree (tamaligi, *Delonix regia*), kapok tree (vavai, *Ceiba pentandra*), and the rain tree (tamaligi, *Samanea saman*). Other trees that were strong, but suffered considerable damage were breadfruit and mango (ulu and mago). In the case of breadfruit trees, the cultivars puou and maufala were considered most resistant.

A number of smaller herbaceous species seemed to be only marginally affected by the tsunami anchored the soil and probably played a significant role in reducing the sediment load. Species included in this category are the creeping plants, beach morning glory (fue moa, *Ipomoea pes-caprae*), beach pea (fue sina, *Vigna marina*), the sedges (mumuta, *Cyperus stoloniferus*), giant swamp sedge (selesele, *Mariscus javanicus*) and the introduced sedge *Cyperus involucreatus*, wedelia, *Sphagneticola trilobata*, crinum lilies (*Crinum* spp.), and a low-growing hybrid Burmuda grass or couch grass (mutie palagi, *Cynodon* x hybrid), which is commonly planted as bowling greens or greens on golf courses. Where these plants remained the level of the current substrate was significantly higher with the original topsoil at its original level. Areas of low-growing pandanus (lautotolo and laufala) also played a role in protecting areas from erosion and reduced the capacity of the flow to cause damage. As, suggested below, wedelia and couch grass should, however, be considered as potentially very invasive pests that will outcompete the indigenous coastal species, which in addition to their protective roles, are also important for local medicine.

#### **3.4.1.5. Trees that saved people's lives**

Although some people were obviously caught in trees or killed or injured by floating tree trunks, branches, etc., trees were seen generally as “saviours” of many people who were either trying to escape from or who were swept away by the tsunami, with at least 16 tree species were mentioned as being responsible for saving the lives. The mechanisms for saving lives included:

- people climbing trees to escape the tsunami wave itself;



- people being swept into the trees or branches while submerged in the tsunami;
- people deliberately hanging on to tree trunks as the tsunami passed;
- people hanging on to exposed roots (e.g., the exposed roots of pu'a near the beach in Lata, Lalomanu) as the tsunami passed over;
- people placing children onto the branches of trees;
- people, who were floating or swimming on the surface of the wave deliberately swimming to or grabbing onto emergent trees as the wave passed; and,
- people holding onto floating trunks or branches of trees, including floating banana trunks, as life rafts or life preservers.

The trees that were mentioned as being most important in saving lives or serving as safe havens or “holdfasts” were ifi, fau, togo, ulu, talie, fetau, and poumuli. All of these trees, plus pu'a, tamaligi, lopā, koko, niu Lotuma, mago and even moli (lemon and fa'i (banana), were said to be responsible for the survival of people.

Based upon a limited number of surveys (20 respondents) in the four most seriously impacted villages, it was estimated that these commentaries accounted for 40 to 60 survivals. If it is estimated that this might have include perhaps 10 to 20% of experiences related to trees responsible for saving lives (i.e., they related their own stories and stories that they had heard about), it is estimated that trees may have been directly responsible for saving the lives of possibly as many as 250 to 600 people who were not able to escape directly from the tsunami.

On the negative side, as mentioned above, there are obviously a high number of people who, most unbeknownst to us, were caught in trees, unable to escape and later found after the tsunami receded.

#### ***3.4.1.6. Impacts on and value of mangroves and wetland areas***

Observations of mangrove and swamp areas and responses from informants indicated that these areas provided significant protection from the waves. Specifically, they protected landward structures, trees and other vegetation protected sandy and muddy substrates from erosion, and created friction to slow and reduce the flow depth, wave velocity and ultimate run-up. Mangrove trees (togo) and associated trees, such as ifi and fau, the shrub lau lala (*Dendrolobium umbellatum*), the mangrove fern (sa'ato), and beach saltgrass (mutia, *Paspalum vaginatum*) seems to be relatively unaffected by the tsunami and appeared to have reduced sediment erosion.

There were also examples of where wetlands protected inland areas from excessive damage. These included:

- the pandanus wetland, known as fusi pū, between Utulaelae and Salani, which appeared, and was reported by informants, to be responsible to cushioning the impact of the tsunami on Utulaelae;
- the intact beach hibiscus thickets (fau) and associated vegetation seaward of Sapoe Village, which protected the village and inhabitants from the brunt of the tsunami.



Conversely, in the adjacent village of Utulaelae, where this vegetation had been cleared, damage to housing and structures was much more widespread;

- the protection of the houses, gardens and fruit trees immediately behind the relatively intact mangroves and associated ifi trees in the areas behind the mangrove depression in Vaovai; and,
- areas protected by fau trees in the back-beach basin behind the Coconuts Club Beach Resort and Spa in Siumu.

#### ***3.4.1.7. Impacts on agricultural production and biodiversity***

Although most of the tsunami-affected communities have the majority of their gardens inland from the coastal plain in areas above the escarpment, agricultural production was seriously affected on the coastal plains, back-beach basins and lower portions of the escarpment in almost all highly impacted study sites from Saleaamua in the northeast to Poutasi and Siumu in the south. Areas that were the most highly affected included Tuialamū and Saleapaga because of limited or difficult access to inland garden areas. Considerable gardening and cropping had been confined to the areas around residences and extending inland from behind residences to the “trimline”. Findings included:

- Important affected ground crops included taro, ta’amū, and, to a lesser extent, sugarcane, pineapple, and yams which were grown around, and in areas extending behind, residences. Although taros survived, there was evidence of rotting of the root tubers (corms), some of which should be harvested before they go bad;
- Of critical food security importance, are large food trees such as a range of cultivars of breadfruit, coconut palms and mangoes and Tahitian chestnut trees, the latter which was commonly seen in the inner margins of the coastal plain or along the margins of mangroves, often growing “naturally”. Also seen in reasonably good condition in some places were the Pacific vi-apple (vi), the Malay apple (nonu fi’afi’a), carambola (vineka) and the red-bead tree or Samoan peanut (lopā);
- Other important affected food crops included small tree crops, such as bananas, plantains and a range of citrus trees (mainly lemons and limes), which suffered varying degrees of damage; and papaya, guava and soursop, which suffered almost 100% mortality in the most affected areas. It was difficult to quantitatively assess the levels of damage to these latter species (numbers of trees lost) because many areas had been totally cleared of fallen and damaged vegetation by the time of the surveys;
- A number of families, and some tourist developments (e.g., Lupe Sina/Boomerang Resort) also had short-term vegetable gardens with crops such as Chinese cabbages, tomatoes, beans, cucumbers and hibiscus spinach (laupele), and possibly pumpkins, which were totally destroyed;
- Also of critical importance is the degree of destruction and loss of plants of importance for handcrafts and house construction and maintenance. These included pandanus (lautotolo, laufala, lau paogo, lu’ie) and sago palm (niu o Lotuma or niu tumu). Of particular concern was the widespread death, seemingly due to saltwater immersion of poumuli (*Flueggea flexuosa*), one of the most commonly planted houseyard and agricultural area plants, which is widely used as house poles and which





will be so important for rebuilding. However, some of the salt effected plant can be, or have already been used, in the process of reconstruction.

As to which of these will recover, this can only be determined in the next few weeks after the impact of the recent rains.

#### ***3.4.1.8. Impact on village houseyard and tourist development gardens***

There was also very substantial damage of important houseyard and ornamental gardens, which are very important to Samoan communities and tourist resorts. In the most seriously affected communities almost all flowering ornamental plants, with the possible exception of *Araucaria* pine (e.g., Norfolk Island pines) and Indian rubber plants (*Ficus elastica*), and in some of the less affected areas frangipanis (*Plumeria* spp.) and some hedge plants survived. Again, the exact extent of survival was difficult to determine in those highly impacted areas where clearance of debris, cutting of damaged plants, etc. had drastically altered the landscape.

Also found in a high percentage of houseyard gardens were a number of important indigenous medicinal and multipurpose plants. Examples included nonu, aloalo, which should be considered for rehabilitation and replanting both in re-establishing coastal houseyard and tourist development gardens, and in the houseyard gardens in the new homestead in the interior.

#### ***3.4.1.9. Loss and damage to livestock***

There was significant, but undetermined level of mortality to livestock, particularly pigs, chickens, cats, and dogs, with dogs seeming to have had a relatively high level of survival. This was evidenced by the existence of a reasonable number of dogs staying at abandoned households, particularly in Tuialamu and Saleapaga. In some areas, such as Satitoo, there were reports of kids running to safely holding their young dogs.

There were also a number of areas, such as in the devastated ground of the Surf Camp at Salani where extensive areas had been rooted up by free-ranging pigs, thus causing pits and depressions subject to standing water which could serve as mosquito breeding sites, which constitute a public health hazard.

#### ***3.4.1.10. Impact on marine life from a terrestrial perspective***

On land and in the coastal areas, there was considerable evidence of the displacement of marine biodiversity from the surrounding reefs and ocean to the beaches and coastal plain. These included:

- The deposition of numerous large coral heads, broken branching coral and other materials on beaches. This was most pronounced in Vaovai on the extended small point directly landward from Nu'usafe'e Reef Islet, there were numerous fresh entire coral heads, representing a range of genera, but mainly massive and "finger" *Porites* spp., and some *Pavona* heads, along with smaller fragments of branching corals (*Acropora* spp.). These were found strewn along a stretch of the beach, mainly to the



east of the small, possibly reclaimed point in Vaovai which extends toward Nu'usafe'e Islet.

- The abundance of sea life that was washed on-shore by the tsunami. This included turtles, sharks, rays, tunas, and a wide range of other coral reef-associated fishes and invertebrates, such as bêche-de-mer, crabs and a range of seaweeds. Many of these were collected and consumed by the survivors.

#### **3.4.1.11. Increased vulnerability to invasive species**

Small geologically-recent oceanic volcanic islands, such as the islands of Samoa, are particularly susceptible to invasion by, and the spread of, invasive plants, animals and diseases. This is particularly true in disturbed habitats that favour invasives over long-established native plants, local animals and insects, and long-established cultivars of food crops and other plants (e.g., the catastrophic invasion of Samoa by the taro leaf blight shortly after Tropical Cyclone Val and Ofa in the early 1990s is a dramatic case in point).

The plants most obviously poised for potential spread into disturbed sites are wedelia (*Sphagneticola trilobata*, formerly *Wedelia trilobata*), and, possibly African tulip tree (*Spathodea campanulata*), albizia (tamaligi, *Albizia falcataria* and *A. chinensis*), cinnamon (*Cinnomomum verum*), and pulu mamoe (*Castilla elastica*) and pulu vao (*Funtumia elastica*). Wedelia, also known as the trailing daisy or creeping oxeye, is a groundcover with attractive bright green leaves and bright yellow daisy-like flowers. It is listed, among the world's 100 worst invasive plants and animals, along with the African tulip tree, tilapia, the malarial *Anopheles* mosquito, and the brown tree snake that has brought almost all of Guam's native birds, bats and lizards to extinction. Wedelia is found growing as a groundcover in the Coconuts Resort, the Sinalei Resort, Vavao Beach Resort and the Salani Surf Camp, and in many villages along the north coast road to Alepata. It is capable of spread in salty waters and could spread into other areas, such as rubbish dumps, river banks and other areas where its cuttings and stems, which propagate vegetatively, can become easily established and outcompete native coastal, mangrove margin and streamside vegetation. It should not be planted in the new settlement areas.

African tulip tree is spreading in some areas of Samoa and has become a very serious pest in Fiji, the Cook Islands and Tahiti, which have similar environments to Samoa. It is a commonly planted ornamental in some villages, but should be eradicated and/or the planting of it prohibited in both coastal areas and the new inland settlements because it is not only very invasive, but is also extremely vulnerable to windfall and wave fall, and constitutes a serious hazard to human life and structures.

Care must also be taken to immediately establish quarantine and phytosanitary procedures to monitor and prevent the possible spread of other potentially invasive and destructive plants, animals and diseases in the process of moving post-tsunami debris for one site to another, of settling new areas, in the movement of planting materials, and in the movement of boats from assisting countries, which could bring in new insects, plant diseases, marine invasives and, if assistance comes via Guam, the dreaded brown tree snake!



### **3.4.2. Results of marine ecology survey**

#### **3.4.2.1. Namu'a Island: October 15 Thursday**

The survey was conducted on both sides of Namua Island in the back reef zone of the barrier reef. High surf prevented inspection of the reef flat so the survey was confined to the area behind the reef on what was previously a sandy bottom habitat. The current across the reef was very strong as the wave generated currents flowed into the lagoon. A snorkel survey revealed substantial deposition of boulder materials graded from the back reef area as larger boulders to mixed reefal material comprised as rubble with coral fragments. This was confirmed to be new substrate by Ifopo and Ward who had experience in the marine protected area.

The coral fragments represented the varied reef flats species, as well as those occurring in the lagoon. The percentage of living coral fragments varied between 10-30% with some areas being more numerous probably due to the *in situ* nature of the large stands of branching *Acropora*. Large *Porites* colonies (<1m) were displaced and strewn across the sand bottom forming boulder and rubble moraines extending into the lagoon.

Holothurians were abundant on the rubble (*Stichopus chloronotus*, *Holothuria atra*) with assemblages of juvenile fishes hovering over the broken rubble (e.g. Parrot fish and varied small coral fishes). The team did not observe any edible-size fishes.

Rubble, boulders and recently dead coral fragments were characterized by a greenish tinge of newly colonized algae.

Manta tows revealed large piles of rubble/coral fragments forming ridges extending north-west between Namu'a and Fanuatapu. Large *Porites* (~1m diam.) were intact.

#### **3.4.2.2. Vailoa: October 16 Friday**

This site is an inshore fringing reef composed largely of *Porites* species. The beach had numbers of colonies of *Pocillopora damicornis* and *Pavona* spp which had been washed up and were evident as bleached colonies.

Three contiguous point intercept transects (PIT's) were conducted to provide a description of the benthic assemblage. Both branching and massive *Porites* species were observed (e.g. *Porites rus*, *P. cylindrical*, *P. lobata*, *P. lutea*?, *P. anne*).

Manta-tow revealed some damaged corals (*Acropora* spp.) with lots of rubble.

#### **3.4.2.3. Lalomanu: October 16 Friday**

On land, this area suffered some of the greatest damage from the impact of the tsunami waves. Offshore, the barrier reef is relatively close to shore with a narrow channel running east to west. Large waves seaward of the barrier reef prevented inspection of the outer reef flat and crest. The assessment was by snorkeling transecting taking notes and taking photographic images of the inner reef and inshore area.



The beach was littered with rubbish and building material from the destruction of the homes inland. This extended in to the inshore channel where coral bommies and piles of rubble with living coral fragments characterized the environment. Substantial coral rubble was evident on the channel bottom throughout extending to >5m depth.

On the abruptly sloping inshore margin of the barrier reef, large boulders and plates were evident. On the reef flat damaged coral occurred as rubble piles with intervening areas of bare reef rock with the sand having been removed. Further seaward, corals suffered less damage. There were substantial corals on the inner reef flat which were protected by their position within reef holes or other protective features of reef morphologies. Larger reef structures such as bommies offered protection from damage on their lee margins.

Opposite the reef passage, the amount of upturned tabulate corals and shards of coral plate material increased. Among the coral boulders was substantial debris such as clothing, roofing materials and other house construction items.

#### **3.4.2.4 Vaovai Coral Reef Area: October 19 Saturday**

This area is characterized by two channels on other sides a fringing reef located at the mouth of a river. Adjacent is a barrier reef system containing an island which borders an extensive lagoonal system.

This area is a marine protected area developed by the United Nations Development Programme (UNDP). It was also a focus of a CERP assessment in 2006 in which a coral reef description based on photo transects was conducted.

Extensive damage to the back reef with rubble piles and broken coral fragments was observed. Displaced large colonies were evident and considered the main source of damage through abrasion and impact. By contrast, the reef flat further to seaward and adjacent the reef margin showed little damage with a higher level of coral diversity. Colonies in this area were not generally damaged nor displaced. This was considered to be the result of adaptation to a wave environment.

Off the reef edge, a similar phenomenon of increased coral fragmentation and damage observed with decreasing little damage in the offshore area. This offshore area was characterized by large plate corals (*Acropora hyacinthus*, *A. cytherea*, *A. clathrata*) with many of these undamaged. This also included the large branching species such as *Acropora nobilis* and *A. intermedia*.

Manta tow surveys and bathymetric assessment were carried out. Starting from the channel (on the landward side of Nuusafee) moderate damage was noted on broken tabulate corals. Towards the western side of the Nuusafee fringing reef little damage was noted.

Damage to the existing living coral resulted from the same mechanisms as on the reef flat with the lack of displaced boulders, colonies, fragments rubble and sand reducing the impact of the tsunami to successive but short lived periods of high currents. Despite this generalized relationship, there were areas of substantial damage. Large plate corals (*Acropora hyacinthus*, *A.*



*cytherea*, and *A. clathrata*) were upended, broken and dead standing. Closer inspection has surmised that though the tsunami has moved substantial material creating rubble piles and impacting other corals, many of the colonies were long dead. Coralline algal covered surfaces indicated that death may have been due to the 2005 coral bleaching event or that disease which was present amongst the tabulate corals has been responsible for much of the death. Bioerosion has predisposed the dead standing coral to displacement and breakage. The large plate size with relative thin attachment has made this material vulnerable to removal from the surface. This appears to be the case with the large living colonies as well, where the large table portion of the colony is not adequately supported by the stem like attachment allowing displacement and upending.

### ***3.4.2.5. Marine Turtles Stranded on Land after the tsunami***

#### ***3.4.2.5.1 Introduction***

The tsunami waves that swept through parts of the Samoa Islands on 29 September 2009 brought a lot of marine life with them, portions of which were stranded on land when the waves subsided (Goff and Chagué-Goff, 2009). In addition to the reef fishes of varying sizes, marine turtles, a few sharks and dolphins were also stranded. Only two dolphins were reportedly left on land dead and were buried. This report focuses on marine turtles and attempts to give an account on the number and fate of marine turtles that were left on land after the tsunami waves.

The MPA work in both districts of Safata and Aleipata as well as general conservation effort contributed significantly to the high numbers of stranded turtles being returned to the sea. For example, the first turtle that was tagged and released was brought to the home of the MPA officer by a construction worker because he knew turtle conservation is part of the officer's tasks. The other four turtles tagged and released were held by Police Officers posted in one of the affected villages and communication with SPREP lead to these being brought in for tagging and then releasing. The other two turtles that were tagged and released were kept by a village in the Aleipata District MPA. The release of other turtles for which no information was recorded is believed to be linked to the successful campaign and positive response of the communities and individuals to conserve marine turtles.

#### ***3.4.2.5.2. Methodology***

Most of the information was obtained from interviews with certain individuals (e.g. Pulenuu, fishermen) in villages most affected by the tsunami. The tagging, tissue sampling and measurements and recording of information on turtles that were available were conducted by DEC and SPREP representatives. Turtle tagging was done using a Stockbrand applicators and titanium tags with the SPREP R-series.

Turtle tissue sampling was done using a sharp blade to cut out a small piece of tissue from both the hind flippers of each turtle sampled. Each tissue was transferred directly to a separate vial containing DMSO.

It was only possible to visit two offshore islands where turtle nesting occurs, Nuutele Island off Aleipata and Nusiafee Island, off Vaovai/Poutasi. DEC has been monitoring turtle



nesting on Vini Beach for several years. Turtle nesting on Nuusafee has only been reported by the community but no monitoring has been conducted there to assess and confirm actual turtle nesting. For this report, visual inspections on the beaches were conducted and using past photographs for comparison where available. It was only possible to visit Vini Beach on Nuutele Island during this preliminary survey due to sea conditions. The whole island of Nuusafee was inspected.

### **3.4.2.5.3. Results**

#### **3.4.2.5.3.1. Turtles**

*Number of turtles stranded on land and fate:* Table 8 summarizes data on reported and actual observations of turtles washed up by the tsunami and stranded on land. At least fifty one marine turtles were reportedly stranded on land of which seven were released by DEC/SPREP, at least 41 were reportedly released by communities, Government officials, resorts and individuals where they were found, one consumed and the fate of three reported is unknown. The 41 includes seven turtles that were reportedly taken to another village near town which were kept in a river but swept away/escaped after heavy rain making the river to rise. Reports relayed to the team on the releases of turtles back to the sea indicate that more than 51 turtles were stranded, almost all were released back.

A total of seven marine turtles were tagged with titanium tags, tissue samples collected, length measurements taken and then released. Table 9 lists information recorded for these turtles. Of these seven, one was brought in by a construction worker, four were brought from the Police post at Malaela after arrangement by SPREP and DEC, and two were tagged at Malaela after the village found them in the mangrove area and stocked them in a smaller pond. One of these two turtles was already tagged when checked. Records in the DEC turtle tagging database confirmed that this particular turtle (green) was tagged and released at Satitola in October 2008 (it was caught in a fishing net at that time).

*Species composition of turtles stranded on land:* All of the seven turtles tagged and released by DEC and SPREP were green turtles. The turtle that was consumed was a hawksbill turtle. One of the turtles with an unknown fate was also a green. All of the turtles released at Tafitoala Safata were described as green turtles except one.

*Turtle stranding by village affected:* The highest numbers of stranded turtles reported were at Malaela, Aleipata (19+ turtles) followed by Tafitoala Safata (13 turtles). It is noted that the areas in both villages where turtles were mostly found (alive) have inland waterways and surrounding vegetation, e.g. mangroves areas. The vegetation seems to have acted as a filter when the wave went out]. Four stranded turtles were reportedly released in Lalomanu, at least 2 were released at Coconut Beach Resort, 2 released at Vaovai, Falealili and 1 at Salesatele.

*Size of stranded turtles:* Carapace measurements were only possible on eight turtles (7 tagged and released + 1 consumed). These measurements are recorded in Table 9. Of the seven turtles (green) tagged and released, two (with curved carapace lengths of 91.5 cm and 101.5 cm) seem to have reached maturity stage. The hawksbill turtle that was consumed has also reached maturity length (curved carapace length of 100 cm). One of the turtles, a green with an





unknown fate, stranded at Ulutogia, also seemed to have reached maturity length. Most of the turtles reported seem to have been sub-adults.

*Cuts on individual stranded turtles:* Of the seven turtles tagged (Table 8) and released, only one seemed to have a major crack on its carapace. This involved the large green caught by the village in the mangrove area. It was informed that the crack resulted from handling when moving the turtle from the mangrove area, where it was caught, to the small pond when the turtle fell on a rock. The green turtle saved by the construction worker from Falealili also had a crack in the centre of its carapace. Parts of the tips of its front flippers also showed peeling of the skin showing the white layer underneath the skin. The large hawksbill that was consumed had large cuts/cracks on the side of the carapace indicating that it was knocked around quite a bit.

#### **3.4.2.5.3.2 Turtle nesting islands**

*Vini beach on Nuutele Island:* Turtle nesting occurs on the north and south sides of Nuutele, where there are sandy beaches. It was only possible to visit Vini Beach, on the south-west side of the island, during this work. For the last couple of years, large rubbles have been accumulating on the part of the beach where turtle nesting occurs, making most of it unsuitable for turtle nesting. Comparison with the beach profile in 2003, 2004 and 2007 clearly shows the rubble accumulated up to 2007. The inspection on 15 October, 2009 indicated that the tsunami waves seem to have “removed” the rubble layers on the beach and exposing the sand layer that was there before. However, it is necessary to conduct a more thorough survey to examine the sand in depth whether it is suitable for turtle nesting. The angle at which the tsunami wave hit the beach seems to have helped in the removal of the top layer of rubble. It also seems the wave swept across it at an angle as opposed to bounding upon it! Also looks like it was just water with no debris at that time.

*Nuusafee Island:* The impact on Nuusafee however was different as it seems the wave hit it directly from the south-east? Slaps of calcium material along the shore were torn and washed up onto the beach. With the exception of what appears to be a new deposit of sand on the west tip of the island and small fraction (5 meters across) on the south-east side, the rest of the island is unsuitable for turtle nesting due to high rubble build-up on the sand making it impossible for any turtle to crawl across to any suitable area under the bushes, deep erosion making it impossible for any turtle to crawl up, and rubble covering suitable sand areas for turtle nesting. The sandy beach area may not be suitable if the sea reaches it during high tide- in addition, it is too exposed not having any vegetation over it.

**Table 8: Marine turtles reported stranded on land after tsunami**

	Fate	Date	Place	#	Village total	Species
Confirmed	Tagged/ Released	1-Oct	Aleipata, Malaela	4		Greens
Confirmed	Tagged/ Released	15-Oct	Aleipata, Malaela	2	6	Green
Confirmed	Tagged/ Released	30-Sep	Falealili, ??	1	1	Green
<b>TOTAL</b>				<b>7</b>		
Confirmed	Consumed	29-Oct	Safata Tafitoala, consumed in Fusi	1	1	Hawksbill female
<b>TOTAL</b>				<b>1</b>		
Reported	Released	??	Aleipata, Lalomanu	4	4	unknown
Reported	Released	6-Oct	Aleipata, Malaela	1		unknown
Reported	Released	15-Oct	Aleipata, Malaela	10+		
Reported	Escaped from river at Laulii where they were kept when river	15-Oct	Aleipata, Malaela/Laulii	7		



	flooded					
Reported	Released	Before 1-Oct	Aleipata, Malaela	1	19+	unknown
Reported	Released	??	Aleipata, Salesatele	1	1	unknown
Reported	Released	17-Oct	Falealili, Vaovai	2	2	unknown
Reported	Released	29-Oct	Safata, Tafitoala	8		7 green?, 1 hawksbill?
Reported	Released	29-Oct	Safata, Tafitoala	5	13	All green?
Reported	Released	30-Sep	Siumu, Maninoa	2+	2+	unknown
<b>TOTAL</b>				<b>41+</b>		
Reported	Unknown? Released?	30-Sep	Aleipata, Ulutogia	1	1	Green
Reported	Unknown	30-Sep	Aleipata, ??	1		unknown
Reported	Unknown	6-Oct	Aleipata, Lotofaga,?	1?		unknown
<b>TOTAL</b>				<b>3</b>		



**Table 9: Information on tsunami-stranded turtles that were tagged and released by DEC and SPREP (Tissue samples for genetic analysis were collected from all these turtles)**

Date	Place Obtained	Species/ Sex	Measurements (cm)	Tags	Info/Observation	Release Date/Place
15 Oct 09	Malaela, Aleipata	Green female	CCL <sub>Min</sub> : na CCL <sub>Max</sub> : 101.5 CCW: 90.5	Already tagged: Left: R39447 Right: R39448	<ul style="list-style-type: none"> <li>• Tagged and released by DEC on 30 Oct 2008 at Satitua;</li> <li>• Upper left side carapace cracked (from handling when moving from mangrove by village)</li> <li>• No bleeding from cracks and turtle seemed to be well and strong when released</li> </ul>	15 Oct 2009 Malaela beach (infront of affected village)
15 Oct 09	Malaela, Aleipata	Green female?	CCL <sub>Min</sub> : 72 CCL <sub>Max</sub> : 75.2 CCW: 65.2	New tags: Left: R47080 Right: R47079	<ul style="list-style-type: none"> <li>• No cuts, well and strong when released</li> </ul>	15 Oct 2009 Malaela beach (infront of affected village)
1 Oct 09	Malaela, Aleipata	Green	CCL <sub>Min</sub> : 67.5 CCL <sub>Max</sub> : nm CCW: 59.0	New tags: Left: R47089 Right: R47090	<ul style="list-style-type: none"> <li>• Turtle brought in from Malaela</li> </ul>	1 Oct 2009 Mulinuu, Apia from boat slipway
1 Oct 09	Malaela, Aleipata	Green	CCL <sub>Min</sub> : 57.0 CCL <sub>Max</sub> : nm CCW: 53.0	New tags: Left: R47095 Right: R47096	<ul style="list-style-type: none"> <li>• Turtle brought in from Malaela</li> </ul>	1 Oct 2009 Mulinuu, Apia from boat slipway
1 Oct 09	Malaela,	Green	CCL <sub>Min</sub> : 91.5	New tags:	<ul style="list-style-type: none"> <li>• Turtle brought in from</li> </ul>	1 Oct 2009

	Aleipata	female	CCL <sub>Max</sub> : nm CCW: 82.0	Left: R47093 Right: R47094	Malaela • Seemed weak while tagging but strong when released	Mulinuu, Apia from boat slipway
1 Oct 09	Malaela, Aleipata	Green female?	CCL <sub>Min</sub> : 70.0 CCL <sub>Max</sub> : nm CCW: 65.5	New tags: Left: R47091 Right: R47092	• Turtle brought in from Malaela	1 Oct 2009 Mulinuu, Apia from boat slipway
29 Sep 09	Falealili	Green	CCL <sub>Min</sub> : 56.0 CCL <sub>Max</sub> : 56.4 CCW: 50.0	New tags: Left: R47098 Right: R47097	• Turtle brought in from Falealili	29 Sep 2009 Sogi, Apia



#### **3.4.2.5.4 Discussion**

Each site had unique characteristics. Namua exhibited the creation of new habitat with the boulder rubble extending over the lagoon floor. The abundance of fragmented but living coral provides hope for subsequent growth of the fragments with restoration of the living coral cover and other benthos.

A general conclusion was that damage was greater on the barrier back reefs and the more inshore portion of the fringing reefs due to the transport of shingle, boulders and displaced coral colonies. These caused damage to the attached coral through impact and burial. Seaward the wave was manifest as large but normal wave where there is a short period of rapid water flow as the wave passes. Without entrained material, the wave is not particularly, of itself, destructive to well attached corals.

Protection of coral reef areas by islands or reef features is important to survival of attached organisms.

It appeared evident that the width of the reef may be important in the reducing of impacts ashore. The direct nature of wave impact and refraction around the island with reinforcement of the energy as the waves converge, augmenting damage in both the marine environment and on shore.

The inshore *Porites* dominated fringing reef community at area of Vailoa suffered little damage. Though the reticulated nature of the *Porites rus* was occasionally displaced as boulder-like material the remainder of the massive *Porites* colonies survived at a low relieve consolidated community. Branching colonies exhibiting higher relief and the abundance of *Pocillopora* colonies on the beach illustrates the hazard of growth extending above the general living substrate.

#### **3.5 Results of interviews of survivor experiences and accounts**

Before describing the results, we restate the relevant task that was to “*collect information about survivor experiences and stories through interviews?*”.

Twenty three video interviews were collected over a three day period. Sites visited included Lalomanu, Saleapaga Uta, Vaigalu Lepa, Vailoa and Mutiatele. Interviewees included 16 females ranging in age from 10 to 52 and 7 males from 21 to 83 years of age. Two pregnant women in the eighth month of pregnancy were interviewed, as well as one fa’afafine and an auntie who lived with her special needs niece. Gender and age are shown in Tables 10 and 11.

Most of the 23 interviews were conducted in Samoan but three were in English. Interviews in English included a Samoan doctor from New Zealand at Lalomanu District Hospital, a family member from Auckland New Zealand who was interviewed in Saleapaga Uta and the Samoan owner of Namua Beach Fales who was interviewed at her home in Mutiatele. She was comfortable telling her story in English.



**Table 10: Number of interviews by gender by location**

Village	Number interviewed	Males	Females
Lalomanu	7	1	6
Saleapaga (new settlement)	5	1	4
Vaigalu Lepa	5	2	3
Vailoa	5	3	2
Mutiatele	1	0	1
<b>Total</b>	<b>23</b>	<b>7</b>	<b>16</b>

**Table 11: Number of interviews by age range**

Age range	# of participants
Under 18	1
18-30	4
31-50	12
51-80	5
Above 80	1

Before the earthquake struck people were going about their daily business, heading for work and getting ready for school or still asleep. After the earthquake people generally carried on with what they were doing and did not evacuate until they either saw the sea receding, saw the wave coming, heard the wave or saw other people running.

People described the wave and being caught up in it in various ways. These are outlined in the discussion section below. There was overall, a sense of concern for others expressed. Several of the survivors lost family members including a mother, uncle, grandchildren, niece, and wife/mother-in-law/auntie. Others were washed by the waves, ingested sea water or were treated for other injuries. Most people expressed a definite fear of the sea, living close to the sea, and of experiencing another event such as this. A few people mentioned that they had prior knowledge of tsunamis and therefore felt that they knew what to do.

People were willing to tell their stories and keen for material to be recorded that would benefit others in times of natural disasters in the future. This illustrates Samoa is an oral culture and stories will be an important way to remember the tsunami.

The raw video clips for each interview will be made available to the GoS at the future date.



### *3.5.1 Short summaries of individual video accounts*

In the following paragraphs, a short synopsis of survivors accounts are provided. They provide a rich description of the difficult experiences faced by those that experienced the tsunami.

#### *Interviewee 1*

This woman was out picking up the rubbish near her house at Lalomanu when the earthquake started. She was worried about her mother and went to get her out of the house. She described the wave as very black and animal-like. She tried to get her mother inland but the wave caught them and she lost her mother's hand. She was washed by the wave and thought she was going to die. She was pushed under the water and nearly drowned. She finally grabbed a floating breadfruit tree and clung to it, saying where it was going she would go too. Eventually she got near enough the shore that some children could get her to safety. They took her to the hospital. As she was lying there she turned to see her mother's body (dead from drowning) on one side and on the other side her uncle-also drowned.

#### *Interviewee 2*

This nurse was on duty the day of the tsunami and every day since. She felt the earthquake and knew they needed to be prepared for the emergency. She saw people running up the hill past the hospital and then the dead and injured started arriving. They put the dead bodies on one side and tried to do the best they could with the injured. There were just so many people. Doctors from the National Hospital arrived within a couple of hours and in the following days many international organizations sent medical aid including medical personnel and supplies. She appreciated the relief efforts and the Red Cross headquarters for the area was set up outside the hospital. Having teams of doctors and nurses available to go out to do follow-up treatment in the villages most seriously affected has been helpful.

#### *Interviewee 3*

She described the earthquake as the worst ever. After the earthquake she went back and forth between some of the family's houses and then back to her house where she started to pray. Before she said Amen, she heard people shouting to her and she started running inland. She did not look back and nearly did not make it there. She has heard about tsunamis but didn't believe it would happen. They lost 2 European houses and two Samoan guest houses. No one in the family was injured seriously. They are currently with family inland and plan to build their own house further inland when they can.

#### *Interviewee 4*

This woman's husband was about to head to work at Taufau Beach Fales but she wanted him to get her 3 lemons for her medicine. She was at the tap when the quake started and said she thought the pipe was going to fall into the earth. She went back in the house to her baby and



her husband headed down the beach joking with her to “Watch out for the wave.” He said this 3 times and then he saw the wave and called to them to watch out and run. He picked up 4 year old child and started running. She looked toward the sea. She saw a black cloud but did not believe it was a wave. It started crawling towards her and looked like a thief. She became very frightened, picked up her four month old baby and started to run. She was very scared and didn’t know if she could make it, but they reached safety.

### *Interviewee 5*

This 21 year old male worked at Taufua Beach Fales which was totally destroyed. When he felt the quake he rushed to warn the tourists and have them run to safety. He finally started running himself and was almost caught in a wave. He found something to hold on to and eventually made it to safe ground.

### *Interviewee 6*

This ten year old girl had for a Samoan medicine treatment and then on to excuse someone in her family from work at the Taufau Beach Fales. As she was walking back to her home, she was taken by the wave but able to hold on to something.

### *Interviewee 7*

A 61 year old man and his family were just waking up when the earthquake struck. It was bigger than any he had ever felt. They turned on the television to see if there was a warning from Apia. His daughter was getting her children ready for school. He decided they needed to run inland so they started to do that. When he was almost up the hill, they realized that one of the little boys was missing. He went back to get his 4 year old grandson who was holding tightly to one of the posts of the house. He remembers three waves, with the second and third being the strongest. He got the child and headed inland. They were caught by the wave but were far enough inland that they were safe. One of his nieces was buried under the cement posts of another fale.

He had heard of tsunamis and knew to run inland but they did not have much time. The family’s home was destroyed. The family has moved to their land further inland and plan to stay there. He has sold crops at the market since the tsunami.

### *Interviewee 8*

This 33 year old mother was getting the children ready for school. The earthquake was stronger than usual so she told her parents they should go inland. She began to pack some clothes and realized a tsunami was coming. She heard people calling out “Galu” and people shouting everywhere. They started inland and then she realized she had left her 4 year old son behind. She feared he was taken by the wave. She cried out frantically and her father went back for the child. At that time, she was feeling weak and faint from hunger. She was also worried about her mother who is asthmatic. Now she is afraid to look at the waves. They collected what could be salvaged and have built a temporary house inland. She was thankful



for programs that explained tsunamis earlier because she knew what to do. She is not planning to send her children to school for the rest of the year unless there is a school building built inland.

She was busy doing her morning chores which included making food to sell to the school children. The earthquake was the worst she ever felt in her life. She heard people screaming and looked to see the wave which looked like a cloud. She didn't worry about anything, just picked up her youngest child from the bed and started running. She lost her shoes and the sheet got caught on some branches of a cocoa tree but they were safe. She said there were three waves but the second one was the worst. Everything seemed dark and she heard sounds from the earth but all she could think of was running. They now have no houses, but have salvaged timber and tin to make a house inland. She has no desire to return to the sea and won't send her children to school until there is school building inland.

*Interviewee 9 (interview conducted in English)*

She was at work in Auckland when she heard the news of tsunami. She cried as she told of hearing her village's name on the news and then coming back to see that much of the village was gone. She came back a few days after the tsunami to help her family and was surprised at the damage. They were busy working around the house where the family now plans to live inland.

*Interviewee 10*

This 32 year old woman works at Faofao Beach Fales. She was getting ready for work when the earthquake started. She said it was strong and the dishes fell out of the cabinet but did not break. After the quake, she was worried about being late for work so she started down the road, fixing her hair as she went. As she neared the beach fales, she saw many of the guests running inland. She looked to the sea and saw the wave higher than coconut trees. She heard noises than sounded like war and machine guns. She ran inland warning another family as she went. After the quake she went back to see if her children and family were safe. They were safe but had no houses or goods. Now they are trying to build a new village inland called Saleapaga Uta.

*Interviewee 11*

She felt the worst quake ever and heard some loud noises. She called to someone to come and look at the sea. When they saw it receding, she started running. She heard people shouting and crying for help. She heard the waves crashing on things. Her father had gone to a friend's house and started back home to check on them but was caught by a wave. He was thrown from one place to another, and hurt his knee. He was hospitalized for two days. Her father's car was also taken by the wave and moved to another place. They salvaged things to build the house they are now living in but want to move inland. Her father is the only one who wants to stay where they are. Maybe they will stay with him, but they are afraid.

*Interviewee 12*

This woman is about 8 months pregnant. She had just woken up when the quake shook. They saw the sea receding so her husband took their two children and started running inland. She watched the sea for while but then started running too. She fell and was under the wave for a while. She was saved by her younger brother who tried to pull her up and finally they found a tree that saved them. Check-ups indicate that the baby is fine.

*Interviewee 13*

The earthquake was longer than any he had ever felt—6-10 minutes. He saw the sea receding and knew that something would happen because he had heard warnings before. In less than 5 minutes the first wave came hitting the sea wall near the shore and bouncing up high. The second wave was the strongest. He ran up the rocky hill behind their house but knows that the river diverted the water inland. Their house was only partially damaged and they were repairing it, but then want to move inland to other family land and leave the house near the beach for guests.

*Interviewee 14*

He was at a friend's house in the eastern part of the village when the quake occurred. They felt the earthquake, but they had felt many before with no tsunmai so he continued walking up the hill to the plantation. He looked down and saw waves coming from the western side of the village because of the break in the reef there. No one died but everything is gone. The house was destroyed and all the dishes and windows broken. He said everyone would have been dead if the quake had come earlier in the morning or at night. He is afraid to stay near the beach but wants to keep the land there.

*Interviewee 15*

This 41 year old woman was sleeping in her house with her special needs niece. Her niece felt the earth quake and started crying, but she had no idea that something would happen. She told the girl to continue with her chores until she heard someone calling out and realized the danger. She looked out at the sea and saw only black lava rocks, the water had receded. She heard noises and a bang and saw people starting to run. She closed all their windows and locked the door and start inland. The river near their house was very strong and almost pulled them in.

*Interviewee 16*

This elderly matai and his wife sleep in a two storey house on the inland side of the main road at Vailoa, Aleipata. Their family had a shop and petrol station on the seaward side of the road, so the wife usually went there early in the morning. She was gone when the quake shook. The house almost fell. He heard someone from Falealupo calling 2AP about why they didn't send out a warning notice, but the announcer said that he had tried 3 times but with no reply. Then



the man heard the loud rumbling sound of water and saw children running on the road, calling out “ The tsunami is coming.” He looked across the road the road and the shop was still standing. He tried to make it down the stairs as he wanted to see his brother who lived a couple of houses away. He was caught in the wave between the houses and taken inland, and then washed back. His leg was injured by a tree. He tried to crawl to his brother’s house and expected that no one would be there, but his brother was there. “Where are the family?” he asked.

“They have gone inland,” he said. “Why did you come and not stay in your house?” To’o felt like he had almost died at that point.

Later he saw the family carrying someone across the road in a sleeping mat. It was his wife but he did not know she was dead. They took her to the hospital and when he knew she was gone he asked the nurse in charge to call the funeral home in Apia. She told him they needed to wait for the police. He heard people crying out in pain and for those who had died. He contacted his family overseas and his wife was buried next to his parents in front of his brother’s house on Monday, 5 October 2009.

#### *Interviewee 17*

This young woman who was eight months pregnant, woke up to the house shaking. Her mother-in-law had come from their house across the road and was having her tea. She got her two year old child ready and was standing at the front door of their house holding the child when the wave hit from behind. They were all washed inland. They were pushed by the water and almost drowning. Then the wave went back out and they were pulled into the sea. They found a piece of timber to hold one to. Her mother-in-law called out that she was tired, but she told her not to worry. Then the second wave came. They were separated from the old lady and she, her husband and the child were washed back up to the main road. Ian called for someone to look for the old lady. Talavou, her husband’s cousin, helped find her.

#### *Interviewee 18 (interview conducted in English)*

This manager of Namua Beach Fales was on the small island of Namua with 17 guests on the day of the tsunami. A school group from St. Peter’s in Palmerston NZ was booked for a one night stay by the tour guide with whom they had come. The group included 7 girls, 6 boys and 3 teachers. A woman had called to make the same booking but for two nights. The tour guide did not know who that might have been.

The woman usually goes to Apia to take her children to school but stayed to look after the guests. She didn’t think the earthquake felt any different from other earthquake. The family was preparing breakfast for tourists and she sent one of the boys to the mainland to get some butter. She was surprised when her husband called to see what she was doing to keep the guests safe and wondered if they were going to evacuate. She looked at the sea and it was calm. She went to the kitchen fale and told the cooks not to make a Samoan breakfast for the young guests; some eggs and ham would do. The radio had not sent out a warning. Then she





heard a noise like an airplane about to take off. She looked to the east to the direction of Fanuatapu. She saw a dark thing coming up so ran outside and warned the students. They all began running higher up the mountain in the middle of the island. Her brother carried her youngest son and she carried another child. They heard the noise of bottles breaking and tin but didn't look back.

When they were all on higher ground, she looked across to the new wharf but what she saw did not look like a wave. It looked like a beast jumping up from the sea and running. She saw things flying out of it and was very frightened. She had done stupid things before like watching cyclones but now she stood looking at this monster that stood up from the channel. A wave was created there. The second wave came from both sides of the island and the waves met in front of the island and moved inland. She thought no one on the main island would survive but her village did not suffer total destruction.

She thought about the boy she had sent to get the butter. The teachers were fearful and didn't want to go back down. In about 10 minutes the water died down and the seas was calm. Her husband called and so did other people. They eventually went back down to the beach very quietly. All of the fale were still standing but some of them were tilted to one side. She didn't feel like doing anything and just sat, but one of the Kiwi teachers suggested they do some work. They started to clean up the kitchen area so they could prepare some food.

A second warning came later in the afternoon so the group decided to spend the second night. They slept inland in the taro plantation. The following morning (Wednesday) they took kayaks and took the guests back to the main island. The students had left most of their bags at Lalomanu but those fale were totally gone. The sea looked brown and there was sand where there shouldn't be sand. She believes the event happened because Samoans have forgotten that Samoa is founded on God. Tourists come to see Samoa and they are not the ones who change us, she said. The locals are the ones who party on Sunday. She thinks that maybe her tourist fale were saved because she has only 10 and has not advertised on the internet. If she opens again, she will not have new visitors or day trips on Sunday. She believes that these bad occurrences are not over and that Samoa must pray, ask forgiveness and be thankful for those who were saved. She also prayed that those who were taken will rest in peace.

#### *Interviewee 19*

This 83 year old man was in his house in a straight wooden chair facing the sea. The earthquake was the worst he had ever experienced. He was worried that the roof of the house would fall. He first heard the sound of the wave. He could hear water in motion that sounded like large motor vehicles in a low gear. It looked white and came from two directions. The wave had split around Capa Tapaga, It was high and hit the house with lots of force breaking all the windows in the front of the house and the door came crashing in. The force of the waves took him and his chair to the other side of the room. The small things like television, radios, and chairs went out through the door but the bigger pieces of furniture were projected from one side of the house to the other.



He was in the house with his daughter-in-law and her three children. He told them to go inland, but the woman cried saying that they would die there with him. He thought they had gone and only later learned they stayed in the room behind him. He prayed silently to God; the sea was about four feet high in his house.

He looked out at his brother's two story house which was still standing and hoped he was there. His brother, however, had come to see him and was caught by a wave. His son helped get him back into the house. He described the wave as hot which in Samoan give the name *galu afi*. And said there was a very bad smell.

#### *Interviewee 20*

This 29 year old woman was in a house not far from the beach with her 83 year old father in law and three of her young children. Her husband had gone inland with one of the children to feed their pigs. After the quake, she saw children running from the near by school and wanted them to leave too. The old man didn't want to go but told them to go ahead without out him. She asked him repeatedly to leave the house but he refused so she told him to sit tight in his wooden chair and she and the children went into the bedroom which was separated from the front room by a half wall and some trellis like wood over the window. She tried to get the kids up as high as she could. She stood with her back facing the wall on the seaside and held her young baby tightly to her chest. The other two children stood one on each shoulder. Two waves came and they were under water. The things in the room were moved by the waves. She held on to the kids but knew that if they died, they would die together. They are still in the house but she says she does not sleep and keeps wanting her husband to checking the ocean. She had some minor scratches and the baby was admitted to the hospital for two days for ingesting seawater.

#### *Interviewee 21*

This 39 year old man had gone with his young son to feed the pigs. He felt the earthquake but was more concerned when he heard and saw people running inland. He looked to the sea and saw that it was receding. He threw down his knife and the coconuts and left his child. He started toward their house, but the wave was coming inland. He could not walk against it so swam. He swam through rubbish, rocks and furniture. People told him he was going the wrong way but he wanted to see his wife and children. He heard his kids inside the house and his wife calling out but before he could check on them, he saw his uncle rolling around in the water. There were rocks and debris coming from all directions. It took him about 5 minutes to get his uncle, who face was bloody and leg bleeding and broken from being hit by a tree stump. He was naked but only wanted to see his brother who was inside the next house. He took him inside, but then looked toward the sea where his auntie and other family members lived. He wanted to find them too. He was caught by a wave heading back out. It nearly overpowered him but he caught a big tree and quickly was taken to the main road which was covered by the sea at that time. He saw his cousin and his wife and children who had been separated from Ian's mom (his auntie). Then he heard someone calling that someone was floating in the ocean. He knew it must be his auntie. He tried to swim but couldn't get there.



He dived under the ocean and it was very dark. He saw someone else holding on to something and told her to be strong, but he finally got to his auntie. She was floating in the sea and bloated from the seawater. He tried to drag her and finally did. On the road he saw lots of big fish, 3 or more feet long. He was not injured, but was very very tired.

The final two interviews with medical staff provided additional information but are not recorded in story form.

### ***3.5.2 Discussion***

The video interview sub-group in thinking about the meaning of the interviews they completed divide their discussion around significant themes.

#### ***3.5.2.1 Before the earthquake and tsunami***

As the earthquake and tsunami occurred before 7 am, most people were just waking up or going about their daily chores. One woman was awakened not by the earthquake, but by her niece with special needs who was crying because of the quake. Others were tending to daily chores, getting children ready for school, making food to sell or heading off to work at beach fale. One of the males was working at Taufau Beach Fales when the quake shook and the owner of Namua Beach Fales had just sent someone to get butter for her guests' breakfasts.

Most people were in or near their houses at that time, but the youngest interviewee had gone to excuse a family member from work at the beach fale and another, worried that she was late, was walking to Faofao Beach Fales. Another had gone inland to feed the family's pigs.

#### ***3.5.2.2 The earthquake***

Most people described the earthquake as being the biggest, worst and longest they had ever experienced in their lifetime. The woman on Namu'a, however, paid little attention to the quake thinking it was just another of the many earthquakes felt in Samoa. Several of the people ran immediately after the quake shook, but many waited to see what would happen. A mother who was at the tap when the quake struck said she thought the earth would fall in. After the shaking stopped she went back to her baby and asked her husband to pick three lemons for her before heading to work at some nearby beach fale.

Many people did not understand or believe that a tsunami would follow the earthquake or that it would come so quickly. Some people went back to what they were doing or carried on with the tasks of the day. One man who was at a friend's house continued inland to his plantation after the quake stopped. Another woman went back to her house to say a prayer but before she had said "Amen", people yelled out that the wave was coming. Others continued their usual chores until they saw or heard the wave or other people yelling "*Gali*" (or Wave). School children and tourists were the ones who called out most often to warn others. Several people mentioned turning on the television or radio awaiting a warning or further information.



### ***3.5.2.3 The tsunami***

The majority of the people ran to higher ground, but several people stayed where they were or were caught in the wave. All five people interviewed at Vailoa, Aleipata were directly impacted by the wave. A 75-year-old man was in his two-storey house during the earthquake but went outside to check on his older brother who lived nearby. He was caught by the wave and injured but was later saved by his nephew. His wife had gone to the family shop nearer the sea. She had called out to her daughter in law, who was getting the baby ready in the morning. A few minutes later the mother and baby stood at the front door looking inland when they were washed in by the first wave. As the wave rushed back to the sea, they were pulled out and soon separated from the mother-in-law. The second wave washed the mother and child inland to the main road, but the older woman was lost at sea.

Nearby the 83-year-old older brother was sitting in a wooden chair in his cement house. He refused to leave but told his daughter-in-law and her three children to head inland. The wave hit with such force that all the louvres were broken and the door came crashing in. The force of the water moved him from one side of the room to the other and water marks on the wall showed that he was neck deep in water, but survived. To his surprise, his daughter-in-law and three grandchildren had not headed inland, but rather hidden in the bedroom just behind him. The woman held her one year old child tightly to her while the other two, ages five and seven, stood one on each shoulder and held on as tightly as they could watching the clothes, chests and other items in the room as they washed from side to side.

One mother was getting her children ready for school but told her parents they should all go inland which they did. Another mother continued making food to sell at the school canteen until she heard people screaming and looked to see the wave. At that point she did not hesitate but grabbed her sleeping child and started running.

A worker at Faofao Beach Fales felt the quake and ran to warn tourists. Another beach fale employee was getting ready for work when the quake shook dishes from their cabinet, but none of them broke. She was worried about being late for work so hurried down the road, fixing her hair as she went. Seeing tourists running inland warned her and she started running too and warned the families near by.

One man headed off for work and walked backward along the beach calling out jokingly to his family to, “Beware of a tsunami” three times before he himself saw the wave, grabbed his child and started running inland.

### ***3.5.2.4 Sights, sounds and feelings***

Most interviewees described the tsunami wave as black or dark. One woman stood observing the wave for a while thinking “it was a big black cloud” but when it started “crawling forwards like a thief” she ran. Another woman said the wave was black and animal-like. The perception of the second wave from Namu’a was that it looked like a “beast jumping up from the sea and running”. Rocks and other things were flying out of it. It looked like a “monster that stood up from the channel”.



A woman walking on the road saw the wave which was “higher than the coconut trees” and heard sounds like “war and machine guns”. Many people describe the loud rumbling sound of the water and one compared it to an airplane about to take off. The sound of the wave was what warned many people, especially the older ones. The eldest man who was surrounded by water in his own house describes the water as hot, validating the Samoan name *galu afi* (or Fire Wave).

### ***3.5.2.5 Psychological and physical wellbeing***

Speaking to medical staff at the Lalomanu District Hospital provided an insight into the psychological state of the people. Along with the grief over losing loved ones to the tsunami were stories of nightmares, insomnia and the changing of people’s “normal” personalities. Some people were described as having completely shut down. The medical staff were relieved to see people crying and letting out their pain eventually after a period of 3 weeks. Medical staff described how some family members would tease others for jumping up in the middle of the night to start running, as if they had gone mad.

Many people had not sought immediate medical care for their personal physical injuries due to the urgent tasks of searching for loved ones in the rubble and providing a roof over the family’s head. Two weeks after the tsunami, medical staff were beginning to see people with wounds that had become infected and illnesses from ingesting tsunami water. They also commented that many wounds that had received primary suturing after the event were not adequately cleaned which lead to infection and the need to re-open the wound.

### ***3.5.2.6 Concern for others***

Many people were concerned about others in their family. One woman was out sweeping leaves but rushed to get her mother and head inland. The wave caught them and they were separated. The woman survived being taken back and forth by a wave and finally was able to hold on to a breadfruit tree that had been uprooted. She made it back alive but as she was being treated for her own injuries, looked down to see her mother lying dead on one side of her and her uncle lying dead on the other.

Two daughter-in-laws tried to save their in-laws. One succeeded and the other did not. The woman who stayed in the house with her father-in-law knew that if they died, they would die together, but she stood her ground. Her husband, who was feeding the pigs inland at the time, came looking for his children. As he fought the waves to reach his house, he heard his children but also the cries of his uncle who was injured and tired from fighting the waves. He was able to get his uncle to safety, before being washed out to sea. He then searched for his auntie who was found floating and bloated with sea water.

A grandfather who had made it safely to higher ground returned to rescue his four year old grandson who was in their Samoan fale holding tightly to a post. The manager of Namua Beach fales was on the island at the time with 17 guests-13 school children from Palmerston North New Zealand, three of their teachers, and one tour guide. No one was injured as they all sought safety on higher ground and spent the second night there in the taro plantation. The young worker at Taufau helped save some of their guests too.



In order to save family members, tourists and themselves people took a number of actions of varying degrees of desperation: running uphill and inland and generally calling out to others to run, going back for family members, pulling family out of the water, grabbing on to a floating breadfruit tree or other trees or floating debris.

### *3.5.2.7 The aftermath*

Most of those interviewed were left with no permanent housing and few personal belongings. Moving away from the sea is one of their first priorities. A few people interviewed are still on the coast, but hoping to move soon. The woman who held her children on her shoulders said she has not slept since the tsunami. She keeps listening to sounds and asking her husband to check the sea.

The basic needs for food, shelter and clothing have been met for the present. Permanent housing needs to be built but people have salvaged things from their old homes or using tents provided by aid organisations. Building is taking place and a number of families were working on projects during the interview process. Family members from overseas were present in some homes and the Lepa families living in New Zealand had sent two containers which were being distributed among the villagers.

The people living inland are now near their plantations and some have even sold crops at the market. Sources of livelihood connected to tourism or the ocean have stopped but people are content at the moment to help with the recovery efforts. People with family businesses are waiting to see if any assistance from the government will be forthcoming.

Health needs including clean water and hygienic toilets were observed but not mentioned by the interviewees. Doctors from Apia were also making house calls in Saleapaga. Efforts need to be made to provide potable water, provide and maintain portable toilets and educate people about hygiene related issues and diseases that may affect them at this time.

The biggest result of the tsunami seems to be FEAR, not only of the ocean in general but also fear of when another tsunami event might occur. Several mothers do not plan to send their children to school for the rest of the year or until a school is built inland. The psychological impacts of the event continue to plague both the old and the young. Telling the stories seemed a way to share the burden and people were pleased to know that sharing their stories may help others.

Overseas visitors were also observed to be grieving for lost family members and for their village and family homes that had been destroyed. Word of the devastation quickly reached New Zealand. One woman said that once her village name was mentioned she was determined to come and help however she could. In some cases family members from overseas in New Zealand had joined the family to help with clean up and to bring supplies and monetary assistance.





### 3.5.2.8 *The future*

It was clear from all interviews that people now have a great fear of the sea and most of them wish to relocate inland. Even the family whose house still stands, plan to build housing inland. Land is available and people are moving on.

The owner of Namua Beach Fales is still considering whether or not to reopen the business but is adamant if she does, she will not take new guests or day trips on Sunday. One of the workers at Faofao is uncertain whether she will return to work if the beach fale re-open as transport will be difficult from inland. Another family is waiting to see what assistance there will be from Government to help them get their shop/petrol station business back up and running.

### 3.5.2.9 *Interpretations of the event*

One interviewee believed the event happened because Samoans have forgotten that Samoa is founded on God and that the tsunami was a form of punishment. Tourists come to see Samoa and they are not the ones who change us, she said. The locals are the ones who party on Sunday. She thinks that maybe her tourist fale was saved because she has only 10 and has not advertised on the internet. She believes that these bad occurrences are not over and that Samoa must pray, ask forgiveness and be thankful for those who were saved. She also prayed that those who were taken will rest in the peace.

Others expressed their faith and belief that God would look after them. Older people especially ones who could not go inland or physically move from their houses accepted if it was their time to go then they would.

## 3.6 *Results of social science analysis*

Before describing the results, we restate the relevant task that was to “*explore the human and community vulnerability and resilience factors at work in different places – i.e., what made a particular community resilient or vulnerable?*”.

As noted in section 2.6, the social sciences sub-group divided their work into two separate sections. Part A deals with the broader social context and Part B with post-disaster indicators.

### 3.6.1 *Part A – the wider social context*

The Social Impacts Assessment Team interviewed 72 people during the three days of fieldwork. Table 12 provides a breakdown of the formal interviews according to the villages where interviews were conducted and the gender of participants (Table 13 provides their ages). During this time, many informal discussions were held with key informants and local counterparts, and many local stakeholders contributed to discussions in our daily focus groups.

Most of the interviews were conducted in: a) the new settlement of Saleapaga (Uta) and b) Ulutogia at the temporary shelter site at the Primary School compound. In Saleapaga (Uta) it was possible to experience the starting point of a new settlement. For future research it will be worthwhile to observe this process over a longer period of time, possibly a couple of years.



The people of Ulutogia still have the challenge ahead of them to move away from a place – where generations of their families had lived - or to take the decision to stay in the coastal area, where their village is located.

**Table 12: Interviews conducted 15-17 October 2009**

Village	Number of persons interviewed	Male	Female	Unknown *
Lalomanu	9	6	3	
Saleapaga (new settlement)	29	9	17	3
Vaigalu Lepa	5	2	3	
Ulutogia	21	9	10	2
Satitua	5	2	3	
Vailoa	2	2		
Mutiatele	1		1	
<b>Total</b>	<b>72</b>	<b>30</b>	<b>37</b>	<b>5</b>

\* Relevant information is incomplete. In a few cases the person who conducted the interview were not available when the compilation of results was done. It is expected that at a later point of time these gaps will be filled.

**Table 13: Age of Participants**

<b>Under 18</b>	0
<b>18-30</b>	11
<b>31-50</b>	31
<b>Above 50</b>	24
<b>Unknown</b>	6
<b>Total</b>	<b>72</b>

Source: Interviews conducted between October 15 – 17, 2009

It was attempted to talk to the head of a particular household when possible. In all cases where only children were present when research teams arrived in a particular household no interviews were conducted.

The impact of the tsunami varied greatly across the villages visited, in many places even within villages. Field site observations were limited, because we visited a few sections of villages, often those on higher ground. Such sites were not immediately affected directly by the tsunami waves (i.e. the waves did not reach up to there). However, other socio-economic impacts are also expected to have occurred there (i.e. people might have been employed in nearby resorts. There are cases where resorts / beach fales have been totally destroyed, and

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people lost their employment / source of income, while their own house is still intact or only slightly damaged. Keeping these micro-spatial variations in mind, the immediate and ongoing response will need to consider targeting activities and support at the most needy, without, however, being too inflexible. Table 14 provides a summary of issues that were addressed by people of the villages structured according to the four major fields of investigation.

Table 14: General trends\* and emerging themes

Location	Needs	Livelihoods	Preparedness	Personal sense of security
<b>Saleapaga</b>	<ul style="list-style-type: none"> <li>• Houses</li> <li>• Water tanks</li> <li>• Toilet facilities, roads tarred, proper road access</li> <li>• Multi-level emotional and spiritual support, dealing with shock</li> <li>• Building and agricultural tools</li> </ul>	<ul style="list-style-type: none"> <li>• Taro plantation</li> <li>• Shops</li> <li>• Fishing</li> <li>• Remittances</li> <li>• Tourism (beach fale)</li> </ul>	<ul style="list-style-type: none"> <li>• Not sure what to do</li> </ul>	<ul style="list-style-type: none"> <li>• Uphill Resettlement</li> <li>• Developing old location/coastal zone for family meeting place and tourists</li> <li>• Sense of fear associated with living along the coast: driving force to move people inland</li> </ul>
<b>Lalomanu (incl. Cape Tapaga)</b>	<ul style="list-style-type: none"> <li>• Cooking pots</li> <li>• Utensils</li> <li>• Building materials and housing</li> <li>• Clothes</li> <li>• Water</li> <li>• Food</li> </ul>	<ul style="list-style-type: none"> <li>• Family remittances</li> <li>• Taro plantation</li> <li>• Fishing</li> <li>• Tourism (beach fale)</li> <li>• Handicrafts</li> </ul>	<ul style="list-style-type: none"> <li>• Not knowing about tsunamis</li> <li>• Saw 2004 tsunami on TV</li> </ul>	<ul style="list-style-type: none"> <li>• Uphill Resettlement</li> <li>• Developing location for tourism</li> </ul>



<b>Lepa</b>	<ul style="list-style-type: none"> <li>• Houses</li> <li>• Water pipes to new location</li> <li>• Tools for farming (axes, machetes etc)</li> </ul>	<ul style="list-style-type: none"> <li>• Remittances</li> <li>• plantation</li> </ul>	<ul style="list-style-type: none"> <li>• Know what to do</li> <li>• Not knowing what to do</li> </ul>	<ul style="list-style-type: none"> <li>• Uphill Resettlement</li> <li>• Developing old location/coastal zone for family meeting place and tourists</li> </ul>
<b>Ulutogia</b>	<ul style="list-style-type: none"> <li>• Water, toilet facilities, housing</li> <li>• Electricity to new locations</li> <li>• Tools for farming</li> </ul>	<ul style="list-style-type: none"> <li>• Taro</li> <li>• Fishing</li> <li>• Remittances</li> <li>• Working for central govt</li> <li>• Teachers</li> <li>• Sea foraging to sell (sea cucumber etc)</li> </ul>	<ul style="list-style-type: none"> <li>• Knowing what to do</li> <li>• Not knowing what to do</li> <li>• DMO adverts</li> <li>• Information from ladies telling public</li> <li>• Seeing 2004 tsunami on TV</li> </ul>	<ul style="list-style-type: none"> <li>• Uphill Resettlement</li> <li>• Developing old location/coastal zone for family meeting place and tourists</li> </ul>
<b>Satittoa</b>	<ul style="list-style-type: none"> <li>• Proper homes, water, food, clothes</li> </ul>	<ul style="list-style-type: none"> <li>• Sea foraging and fishing</li> </ul>	<ul style="list-style-type: none"> <li>• Had never heard of tsunamis before and did not know what to do</li> </ul>	<ul style="list-style-type: none"> <li>• Too scared to go near the sea, and thus have now moved far inland</li> <li>• Will live off the land - plantations</li> </ul>

\* field site observations, key informants and Interviews conducted between October 15 – 17, 2009



### 3.6.1.1 Saleapaga

The people of Saleapaga are in the process of relocating to a new settlement, inland. Construction work is in full swing. In some instances, people are already living in their new buildings. In many other cases, this was expected to happen a few days after the research in the field was completed. There are, however, also many areas where construction activities have not yet started or are at the very beginning and people live still in tents provided by various relief and humanitarian agencies. Key informants indicated that the priority should be to ensure that everybody can move out of these tents to a proper house as quickly as possible, as periods of longer and heavier rain are forthcoming. Living in tents for an extended period is seen as a potential health risk, especially when this happens during heavy rain. Many people also expressed discomfort connected to living in tents. Statements such as “we are not used to living in tents” or “the place is just too small for our big family” came up occasionally.

In the immediate need of requiring temporary housing, some people have relocated to inland sites occupying land that may or may not belong to their extended family. Construction in Saleapaga has already begun. People are using old material from the original village in addition to such found in the surroundings and the tarpaulins received from donors. Some households reported that they have received tools for constructions. While a bigger number told us that such tools would be missed dearly. Evidence suggests that permanent buildings are needed. Once this has been achieved families will then move to their (own) land. Construction is on going in many sites. This is considered as a very encouraging aspect as people don't wait until Government or other agencies come for support, but become active themselves. Participants expressed that they will require support from outside, such as the Government, other agencies or in many cases also relatives from other parts of Samoa, and (in a bigger number) such relatives residing overseas.

We cannot overstate the point that the people we interviewed have lost a lot. Illustrations of these losses include: a) loved ones that in cases were the main income earner, b) their home which physically protects everyone from the elements of nature, and provides an emotional and cultural haven; c) clothes, kitchen utensils, agricultural grounds and tools and d) much, much more was lost in many cases. Without exaggerating, we met people who lost everything, but their life.

Road conditions appear to exacerbate survivors' hardships. For example, rainfall created mud on the road which in turn made the upper part of the road almost impassable. Current residents and key informants stated that the road requires structural improvement e.g. to provide a proper foundation for the road or tarring. Dust from the road is a health hazard. In the medium term permanent utilities will be required (electricity, water and sanitation), but as long as temporary toiletry, water and hygiene facilities are required there is an urgent need to closely monitor and regularly service them. For example after 3 weeks, the *Porta-loos* now require pumping, and hygiene needs to be addressed to help stop the spread of sickness and disease.





Equally fast as the road construction, was the construction of electricity poles and power lines. It seems that the provision of electricity to the households was only a matter of a few additional days after the field visit has been completed. Very crucial, however, is the immediate provision of water for drinking and other purposes. Here many people expressed major concerns, both what the amount of water delivered to their settlement as well as what access to water tanks provided. It seems that the green 1000 liter water tanks provided by the Red Cross are seen by some households as given to the households for individual use; and, people expressed concerns that they are excluded from making use of the water as the water tank is not in immediate vicinity of their house or tent.

Key informants told us that equal importance should be given to the installation of sanitation installations. Connected to house construction, people are also constructing facilities, such as septic tanks, for human sewage. Here it is urgently required that experts, from health authorities, supervise the construction of septic tanks and/or sinkholes as these are great potential health risks attached to such installations, especially in times like this where a clear separation of water sources is difficult and a mixture of clean water and waste water can happen easily, e.g. during heavy downpour and flooding of incorrectly installed septic tanks/sinkholes.

The livelihoods of almost every family have been compromised in one way or the other. Looking at individual cases this takes rather mixed form. Farmers have lost their crops (and farmland) in the inundation areas. In some cases, they had not already cultivated lands at higher grounds their subsistence livelihoods; as well, the possible sources of cash income through the sales of agricultural produce have been affected severely. People's food security is directly at risk. Even in those cases where farming households have access to land in higher grounds, key informants told us that food security from subsistence production is not assured, when cultivation of these lands had started only after the tsunami. Depending on the crops planted, it still will take several months before farmers can bring in their first harvest. In a much better position are those farmers that already had plantations at higher ground prior to the tsunami. They might have suffered loss of crops through the event, but many told us that at least they have crops standing in the plantations, which provide food now.

Some families' livelihoods have been affected through the destruction of enterprises they owed or which employed them. Many family businesses, like beach cafes, shops, diving rentals, etc., were destroyed by tsunami. People's livelihoods are affected until the physical structures are reconstructed and tourist confidence is re-established. In addition because most families do not intend to return to the original location of the family home, some families are now planning to build in the coastal area for tourists i.e. increase tourist accommodation.

### **3.6.1.2 Satitooa**

The main village of Satitooa was located at the coast in the beach area. The tsunami totally destroyed houses and belongings of many families. As an illustration of the total destruction, some people could not even salvage any materials such as corrugated iron roofing to be reused. All villagers have moved inland to multiple locations that are widely dispersed over three separate camps.



The scattered nature of relocation has significant implications. The initial distribution of relief aid missed some of the families. Some families still have only tarpaulins for shelter and not even tents two weeks after the tsunami. They were frantically preparing thatch and cutting down trees to build faleo'o. It was noted that the priest with support from the Catholic Church had started building a permanent house far inland. It is likely that all churches except the Assembly of God Church may relocate inland.

### ***3.6.1.3 Ulutogia***

The village of Ulutogia has temporarily been relocated to the school grounds, where some 28 families are based at a camp at the local primary school grounds (with toilet facilities) and tents. Some women plan to stay in evacuation camps until the water infrastructure and roads are developed.

Preliminary inspection suggests that those in evacuation camps appear to have enough water for their needs. Families report that they have almost enough washing and body cleaning water, not enough drinking water, so they need to boil water for drinking.

Key informants told us that the water is running within the village site, but people are worried that the water contains contaminants. This water can be used for washing dishes and clothes.

### ***3.6.1.4 Lepa***

Many family homes were destroyed, especially in Vaigalu. Many of those people wish to permanently relocate the village inland. Some have asked the government to provide electricity and water infrastructure to facilitate this move. Many are staying in the local church or temporary residences inland. The general plan of those interviewed is to use the original site of the family home and develop open fale for family meetings, visitors and family enjoyment. In some cases, small businesses e.g. beach fale, shops, diving rentals, have been destroyed by tsunami, thereby affecting some families' livelihoods. Now many families require funds to erect new physical structures.

### ***3.6.1.5 Lalomanu***

Small family businesses e.g. beach fale, shops, diving rentals, etc were destroyed by the tsunami. Thus most family's livelihoods were directly affected until the physical structures are reconstructed and tourist confidence is reestablished. Interviewees indicate that in addition to the original location of the family home, many families affected by the tsunami are now planning to build for tourists e.g. increase tourist accommodation.

## ***3.6.2 Discussion: natural hazards, disasters and social vulnerability***

During the time of the fieldwork, field observations and survey participants' comments reflected themes also found in the literature on the social and spatial dimensions of vulnerability and resilience. We heard about coping strategies amid social vulnerability (a dual process involving exposure to risk, stress and shocks set against the coping capacity of women, men and children). In future work, international literature should be examined for relevant concepts, themes, and comparative case studies. The focus should be on seeking to



understand how individual women, men and children are ensuring livelihood security. The sorts of questions that should be asked might be: What sorts of crises, stress and shocks have they experienced? After being exposed to a tsunami, how are they adapting? What is the capacity of actors to cope with these events and to recover from them?

Given these points, in general, the tsunami survivor/tsunami disaster awareness research survey we developed, and used during our 3 days of fieldwork, is seen as an effective research instrument (see Appendix 4). The work initiated by the ITST Samoa. Social Impacts Assessment Team's work should continue to be built upon, as well as refined. As mentioned, there is much local capacity to carry on the work initiated. Local expertise can be found in the list of local team members provided in Appendix 1.

The discussion below highlights some of the preliminary analysis of the survey results, which we noted in our thematic analysis: preparedness, livelihood, needs and personal security.

#### **3.6.2.1 Preparedness: *public awareness***

Preliminary assessment of survey results indicates that public awareness of tsunamis, earthquakes and other natural hazards needs to be expanded (see Appendix 6 for relevant programmes). Immediately after the earthquake, some people continued to do what they were doing. Most of the children and tourists knew to run inland when they saw or heard the waves, and others knew when they saw the sea receding. Survey results suggest that there had been knowledge about earthquakes and tsunamis that surely contributed to saving lives in many cases. Future activities can build upon this knowledge, widen it to other forms of hazards; and also make sure that not only knowledge is available, but people have an exact sense of what to do (see below the importance of drill and exercises). Each individual community should very closely look into the aspect of how people's exposure to natural events should be dealt with in order to be even better prepared the next time.

Some participants in the interviews said they knew enough about tsunamis to know what to do. Information on what to do was learnt from the Disaster Management Office (DMO) television advertisement, news on TV of the 2004 Indian Ocean Tsunami and the Solomon Island Tsunami in 2007. Some people mentioned the value of the national tsunami simulation exercise and knew to turn on their radio.

There was some variance in whether people followed the advice or not. In some cases people did not believe anything was going to happen. As a result they did not run inland or uphill until they heard or saw the waves coming or saw others running and followed their example. Others did not understand that earthquakes can generate tsunamis. Awareness into natural disasters of all sorts should also create a sense that people have to act, no matter what they feel will happen realizing that action as early as possible is the best. People must be aware that running twice a year in vain to higher ground when an earthquake happened just to realize an hour later that it was not necessary, if the better thing to do than waiting and run when it is very late, maybe too late. While the Social Impact Assessment Team assumes that through the event of the recent tsunami knowledge and awareness of what to do in such event has been



increased vastly amongst the people of Samoa individual communities should work to better hazard preparedness.

It also is acknowledged that the lessons learnt from the Samoa Tsunami 2009 may assist future programmes that seek to implement disaster awareness in other parts of the Pacific Islands.

Some elderly residents stayed in their houses, as they were unable to run inland due to mobility difficulties. Many others did not heed the warnings because they were complacent and did not believe that a tsunami would impact Samoa. Others believed that God would protect them. On the other hand some believed that the tsunami has been a form of punishment.

One school age key informant told us that school curriculum focuses on science of hazards, but not hazard safety. Some students may know about tsunamis and how they are formed, but not how to respond. Many people expect a tsunami warning will be issued before people react or evacuate. People did not realize that there might not be time for a warning.

One key informant indicated that Emergency response agencies had no way of being prepared for the gravity of the tsunami, in spite of drills and workshops they have had. They did their best to take care of the immediate needs of people affected by the tsunami.

### ***3.6.2.2 Livelihoods***

Our assessment of post disaster livelihoods has made linkages to academic themes such as social and spatial dimensions of vulnerability and resilience, coping strategies, particularly social vulnerability seen as a dual process involving exposure to risk, stress and shocks and the coping capacity of women, men and children. And much analytical work of the survey results remains to be done. The points that are presented below suggest that people's livelihoods in post disaster coastal villages of Lalomanu, Saleapaga, Lepa, Ulutogia and Satitua will continue to change in the short, medium and long term.

#### ***3.6.2.2.1 Short term***

Many people had lost their sources of livelihoods, farmers lost their land, enabling to produce crops for subsistence and for the market, many people employed by the tourism sector lost their jobs and with it their income. Those running beach fales, shops and/or supplying goods and services to the tourism industry also lost their sources of income. While it is difficult to estimate how long it will take to re-build much of the destroyed tourism infrastructure (the issue is rather complex and includes much more than just time for construction. It includes estimation of capital availability for investment as well as people's choices to invest or not), it must also be of concern how long it takes to make the affected region the tourist destination it was.

People relying on fishing to obtain extra income and daily sustenance have been directly affected and will take time for them to feel safe to return to the sea.

Re-settlement in land locations changes a family's livelihood options, priorities and outlook.



Loss of the main income earner results in changes in the role and responsibilities necessary to secure a living for the family.

#### **3.6.2.2.2 *Medium term***

There will be problems of the affordability of new homes if they are required to follow strict building codes.

There is a need to encourage diversification of livelihood choices that are safe and less vulnerable to natural disasters.

#### **3.6.2.2.3 *Long term***

There needs to be a long term approach to diversification of income and going back to the land for livelihoods.

There is a need to encourage a sustainable approach to farming and farming practices in order to support families and/or the tourism sector.

Taken together, all these points suggest that if people have capital to make investments, they will make investment in such infrastructure that depends on local and international tourism. Having lost everything might lead to capital needs of people who are willing to contribute to the economic recovery of the region and also have the skills to do so, but lack the capital to do so. Here the Government (and other agencies) might wish to consider providing subsidized loans for such commercial purposes, especially to people from the affected region (rather than to outsiders and foreigners). It is expected that affected areas, such as sections of Saleapaga and Lalomanu will return to be an important destination for both Samoan as well as international tourists. Through the tsunami and people's decision to move further inland much prime beach land suitable for the construction of beach resort and beach fale has potentially become available. The Government should see this as a chance to promote local initiatives/entrepreneurship/investment as a mean to strengthen locally managed businesses that could even strengthen livelihoods of people from the affected areas. By doing so the Government (with the help of other organizations) has a great chance to assure that aspects of disaster safety are observed when new commercial enterprises in the affected areas are established, something that surely will happen.

More broadly, all of this relates to the broader literature on coping strategies which looks into the action of people to master difficult structural imbalances. Coping in this sense refers to the issue, if people can (or cannot) overcome critical events (like a tsunami) without suffering long-term severe losses to their lives, to their property, to their sources of livelihood or in a more general term "to their well-being". At another layer is the social dimension of coping strategies. Social dimension means that not everybody in a given society is affected by a natural hazards in the same way and to the same extent, but that there are variations that can be explained through social criteria, i.e. poverty (e.g. often poor people are more affected than non-poor), age (often the very young and the elderly are more affected than those in the middle brackets of the population pyramid) and gender (often women are more affected than



men). While such assumptions in many empirical cases turn out to be significant, one has to investigate the nature of social vulnerability, and the question of who is affected most and why in each individual case. The structure of social vulnerability often has been described as multi-dimensional, where local conditions, people's opportunities and disadvantages and the nature of the natural hazard create a rather complex picture.

### **3.6.2.3 Needs**

The needs of the people are categorised into short-term, mid-term and long-term needs. The areas affected by the tsunami will be going through lots of changes. These changes often can be expressed as the cause for immediate needs, which can be met by the people themselves, the government or relief organizations. Here social scientists play a similar role as others who come in direct contact with the people affected. They see, they listen and they compare what they see and what they hear with what they have experienced elsewhere. Not that they are able to look into the future, but their role is surely to compare what they experience right now, with what they might have experienced in entirely different situations.

#### *3.6.2.3.1 Short-term needs (0-6 months)*

The short-term needs include housing, water, toilet facilities, cooking utensils, household items, clothing, food and health.

Currently, families have received relief in terms of tents, tarpaulin and are living in temporary and makeshift shelter. However, many have taken steps to build basic housing using materials salvaged from the ruins. Other families have begun building permanent homes with purchased building materials with the help of family members overseas and church groups. Others are building *faleo'o* with basic traditional materials.

Land was not an issue as all families had customary land inland on which they could resettle. All families interviewed have done so.

Water has been distributed by various organizations including government. Water containers range from water tanks to plastic containers. The government water truck provides water when they can. However, there was still a need for more regular supply of water including the installation of additional water tanks for some families and/or the community. It was also evident that the water tanks were not distributed equally to affected families in all areas.

Shared portable toilets had been provided for most new settlements except for far inland Satitua. Other families had dug pit toilets. Both pose potential health hazards especially given the shortage of water where it is not possible to wash hands after use of the toilets. Portable toilets were not being emptied as often as required.

Families were making do with what was available as cooking utensils. Most cooking was done over open fires or using charcoal stoves. Some families used salvaged household items and basic furniture including Chinese and Samoan mats.





Most families had received donations of clothing through Red Cross, other organizations and containers from relatives overseas. Also noted was that many families had members who had come from overseas to help.

Food had been received by the families. The main concern was the issue of regular supply in the medium term given that livelihoods have been curtailed by the tsunami.

Children and the elderly who had ingested salt water and sand were still being monitored by medical teams and were being encouraged to notify changes of health to the authorities. The issue in the short-term relates to the shortage of water, toilets and general sanitation.

#### *3.6.2.3.2 Medium term needs (6-18 months)*

Infrastructure e.g. proper roads, water supply, electricity and schools are needed. It was noted that at Saleapaga Uta, Lepa and Lalomanu power lines had already been constructed, but not connected to the individual families. Far inland (Satittoa) where some families had relocated, there were no power lines. The families living at the Ulutogia temporary site are waiting for proper facilities to be developed in the inland site before moving.

Some families had land to relocate to due to the customary land system of Samoa. This was noted as a very powerful mechanism in the recovery of the families. The fact that the families had land readily available to them was seen as not only as a relief but also as a means of survival.

The school at Satittoa was destroyed, while the one at Saleapaga is still standing. In both villages, decisions are being made for new locations inland. All people were determined that their children will not go back to school until inland schools are provided.

Some people's livelihoods came from working in the tourism industry, the inland plantation, making handicrafts, remittances from family overseas and family business such as a shop/petrol station/buses. Families who operated businesses, such as shops and petrol stations were waiting to see whether the government would provide any assistance or not.

Some beach fale owners at Saleapaga had no intention of rebuilding preferring instead to lease their land to interested parties; e.g. the owner of Namu'a beach fale was considering reopening next year but will observe Sunday. People who had worked at the beach fale were interested in other employment.

Families who had relied on the sea for their livelihoods are no longer interested in the sea, but will focus instead on development of the land. Those who had relied on the plantation will continue and have sold produce at the market since the tsunami. Furthermore, people now realize that the new settlement inland has made it much easier to cultivate their lands as they now live there. With the new settlement and the people seeking new ways of livelihoods, transport is another medium term consideration.



#### *3.6.2.3.3 Long term needs (18 months onwards)*

The development of the new village sites requires not only infrastructure started in the medium term, but also maintenance and provision of ongoing services. Ongoing services include education, health, transport, water, communication, electricity and churches.

Solutions need to be found that address the severity of individual situations to avoid that the vulnerability level of people increase beyond an exceptional level and leaves them extremely susceptible to further adverse events be it natural or other hazards. Reasons for temporary living arrangement are for relief supply distribution sites, road access, sanitation, medical care access and community. Furthermore, in the immediate need of requiring temporary housing, some people have relocated to inland sites occupying land that may or may not belong to their extended family. Other Pacific island land resource related case studies suggest that are crucial questions with huge implications concerning the cohesion of communities, their ways of how conflicts emerge, are mediated and settled. In the future, community generations these developments need to be observed very sensitively and interventions need to occur with participation of as many stakeholders as possible.

#### *3.6.2.4 Psychological needs*

People were very willing to talk about their experiences only three weeks after the event and this appeared to be quite cathartic for them. It is important that this process continues in the short and medium term where opportunities are provided to share their fears, uncertainties, testimonies, beliefs and stories about their experiences with the tsunami. The survivors who suffered the loss of close relatives and those who sustained long term injuries in the disaster would need opportunities for counseling as well as long term medical treatment.

The roles of the pastors and church ministers, lay preachers, deacons, women fellowship, matai, teachers and schools could be developed to provide the necessary support. Children in particular should be provided with the opportunities to heal from their experiences. It might be necessary that these receive some sort of training to be able to provide their services as efficient as possible. The Red Cross might want to consider to bring in medical personnel that have experience a treating disaster trauma persons from other parts of the world to train local pastors, church ministers and others who can contribute enormously to the psychological well-being of the affected.

Overall, some personal stories highlight people's faith and belief in God, which is now the sustaining factor in their recovery after the tsunami. In spite of the tragedy, people's faith is now providing the motivation to rebuild, recover and move on.

#### **3.6.2.5 Measuring deeper losses, to understand society's deeper needs – loss of personal security**

”The sea is a dragon”

“I am not returning to the sea”



Entire coastal villages – Saleapaga, Satitua, Ulutogia, Lepa, Lalomanu and others, now frightened of future tsunamis, are planning to relocate inland. As noted in various locations, building inland has commenced. However, there are many difficulties associated with relocating to the proposed location. Key informants raise many relevant questions, such as: where are funds to come if the government must put in electricity, water, and plumbing infrastructure in these new settlements? How can we assess the benefits of relocating communities, against the costs incurred? Indeed, in considering the costs and benefits of communities choosing to relocate to new locations, the following points need to be considered: a) the benefits and costs of making these longer term plans to relocate an entire village; b) individual's sense of connectivity to their community and sense of place appears to be altered in the post-disaster short term of recuperation/recovery; and c) steps that might be taken to develop confidence in pre-tsunami livelihood activities in Tsunami affected areas (e.g. fishing, sea-foraging, and tourism).

Building upon the work presented in this social assessment, the next socio-economic impact assessment report utilizes a different methodological framework, hence has very different results, discussion and recommendations.

We began some of the groundwork required to monitor and evaluate human resource recovery alongside developing post disaster economic plans. We provide evidence that many indirect and intangible loss indicators can be found in the field, 1-3 weeks after a disaster. Moreover, the breadth and depth of post disaster coastal people's vulnerability is established by providing an incomplete list of indirect and intangible loss indicators, as seen in the field, which should be monitored in the future. This should be done in two phases: a) short period of recuperation/recovery and b) longer term of recovery.

The following report is significant for five reasons. First, the focus is on human resource recovery, not infrastructure recovery. We are focused on providing empirical evidence to monitor human resource recovery and to develop a process to guide post disaster livelihood options. Our literature review indicates that useful post disaster interventions required by post disaster communities must go beyond: a) building new community infrastructure, b) providing people with farming tools, and c) suggesting new livelihood options. Second, this is the first known study for researchers to seek, identify and list the indirect and intangible loss indicators found onsite, days after a disaster. Third, other research teams may use this list of indirect and intangible loss indicators. Specifically, researchers initiating a socio-economic assessment of the 2009 tsunami impacts, as they document some of the costs incurred by a tsunami. Fourth, the broader significance of listing an array of indirect and intangible loss indicators can be found in the field, a few weeks after a disaster, is to ensure a thematic approach for future data collection and monitoring. Fifth, ideally, an ongoing socio-economic assessment of the 2009 tsunami impacts will allow others to learn from Samoa's socio-economic experience with tsunamis – to hear about some of human, financial, and developmental costs posed by disasters. The financial figures will raise public awareness of the importance of disaster risk reduction in policy circles. However, awareness must be sustained, as disaster risk reduction, disaster education and climate change adaptation programmes needs to be supported in forthcoming years (Appendix 6).



### ***3.6.3 Part B - Establishing post disaster indicators to monitor economic vulnerability and resilience***

Being in the field two to three weeks after tsunami the fieldwork revealed that the research team was collecting disaster loss and damage information from two important periods of the tsunami: a) short period of recuperation and b) the medium to long-term economic recovery. While the Australian Department of Emergency Services suggests that six month point is the earliest starting point for disaster loss assessment process, we suggest that a rapid assessment one to three weeks after the disaster is a worthwhile endeavor. There is a need for a preliminary assessment on the ground by specialist teams to set the indicator framework to evaluate immediate and longer-term losses. Flagging a list of indirect and intangible loss indicators to monitor at the beginning of the medium to long-term economic recovery will allow us to track and monitor the real situation on the ground: e.g. the ability of Samoan communities to tap into existing resilience.

The diversity of pre-disaster coastal people's livelihood options is listed in many Samoan reports (e.g. Early Recovery Report Oct 2009). In the absence of a full 2009 business baseline survey for Samoa, it is difficult to draw conclusions for Samoa on how much employment is created in the tsunami affected area and what the GDP contribution of small businesses in the villages of Lalomanu, Saleapaga, Lepa, Ulutogia and Satitua. This scoping study has address this issue only partly by drawing on comments from key informants, field site visits, observations, and background documents produced by international and national NGOs (non-governmental organizations), the GoS and the media (Tables 15 and 16).

At one level, small businesses are found to be fairly optimistic with respect to the employment, investment and the general performance outlook for 2010. The future performance of small businesses, perceived by business owners, will be positive. At another level, field observations indicate that the breadth and depth of Samoan's sense of loss and personal security has scarcely been articulated. In the flurry of the health, housing and other basic need systems and services responding to the disaster, we must not forget to document if declining productivity is due to poor physical and mental health. Such work would establish the broader impact of the tsunami upon economic development. Such work should be done for two post tsunami phases: a) short period of recuperation and b) longer term of recovery.

**Table 15: Evidence of indirect losses in the short period of recuperation**

Indirect Loss Indicator	Source	Further work Required
Disruption of business	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct)	Collation of original data sets.
Disruption of leisure services	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct)	Collecting information from assessment organizations
Disruption of networks – road	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct)	Collaboration with people with environmental hazard experience interviews
Disruption of networks –other transportation traffic	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct)	Site specific focus groups or surveys  Sector by sector quantitative or qualitative economic analysis of the impact of the event

Disruption of networks –electricity	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct) Key informant – World Bank	
Public utilities – water supply	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct)	
Public utilities – sewage and sewage treatment	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct)	
Public utilities – electricity supply	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct)	
Public utilities – telecommunications	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct)	
Cost of cleaning the debris, rubble, damaged buildings	Key informant – govt official	





Emergency service costs – local government, police, fire brigade, ambulances	Key informant – govt official	
Volunteer labour	Pacific Disaster Net www.pacificdisaster.net OCHA Situation Reports * (30 Sept to 22 Oct)	
Employment – Loss of income (fishing, tourism)	Key informants: fish and vegetable market sales Survey, field work (administering the ITIS social assessment survey, field visit and field observations)	
Cultural activities – church and village contributions – impacts village and church development	Key informants: pastors, village mayors, government officials Survey, field work	
Education – costs of repairs of education buildings used as temporary shelter	Ministry of Education, Sports and Culture Oct 2009 Recovery Report Survey, field work	
Households – additional transport costs from relocated area to essential services	Key informants Survey, field work	



Health – cost of relocating health services	Ministry of Health Oct. 2009 Recovery Report Survey, field work	
Health – costs of treating population affected by disaster after event	Ministry of Health Response Report (Oct 2009) Health Cluster – mental health group Key informants – Red Cross	

\* see websites of Pacific Disaster net contributors such as AusAID, NZAID, Caritas, Red Cross

N.B. Data reliability, damage assessment consistency, institutional memory, and geographic specificity likely will provide challenges in future research work.

**Table 16: Evidence of intangible losses in the short period of recuperation**

Intangible Loss Indicator	Source	Further work Required
Difficulty accessing services and supplies	Survey, field work (administering the ITST social assessment survey, field visit and field observations)	Health and family support services interviewed
Increasing demand on services	Key informants – Red Cross volunteers Survey, field work	Local health and police professional interviewed
Increased dependence on government and non governmental organizations	Key informants – Red Cross volunteers Survey, field work	Monitoring information from assessment organizations
Temporary loss of utilities	Recovery reports Survey, field work	Collaboration with people with environmental hazard experience interviews
Disruption to education	Key informants – two primary school teachers Survey, field work	Site specific focus groups or surveys
Disruption to living, including isolation, and evacuation	Survey, field work	Sector by sector quantitative or qualitative economic analysis of the impact of the event



Disruption generated by the rebuilding and building process	Survey, field work	
Loss of original day-to-day social contact	Survey, field work	
Residents isolated/ generally cut off	Survey, field work	
Loss of community – access to networks, services and assets including recreational areas	Survey, field work	
Diminished community as activity goes to individual recovery	Survey, field work	
Loss of memorabilia	Survey, field work	
Damage to cemeteries	Survey, field work Key informant – Samoan colleague	
Loss of personal security	Survey, field work Key informants: pastors, mental health group, Red Cross	
Tranquility lost	Survey, field work Key informants: pastors, mental health group, Red Cross. Govt representative	



Leisure time affected	Survey, field work	
Physical separation of family members	Survey, field work	
Non-use values of lost heritage and environmental sites and collections	Survey, field work	
Damage to ecological sites – changed habitats and landscape	ITST Ecological Team ITST Biodiversity Team Survey, field work	
Lowered socio-economic status	Survey, field work	
Economic marginalization	Survey, field work Key informant – Govt representative	
Potential long term psychological problems if left destitute	Survey, field work  Key informant – Samoan counterpart	
Long term depression	Survey, field work Key informants: pastors, mental health group, Red Cross. Govt representative	
Stress induced ill health	Survey, field work	

Bereavement	Survey, field work Key informants: pastors, mental health group, Red Cross. Govt representative	
Substance abuse	Survey, field work Key informant – Samoan counterpart	
Problematic to work in fishing industry	Survey, field work	
Lost reputation of tourism industry when known to be tsunami prone	Survey, field work	
Major disruption to day-to-day police work	Survey, field work Key informant – Red Cross	
Major disruption to day-to-day health services and support work	Survey, field work Key informant – member from the health services community	
Sewage entering storm drain system	ITST Ecological Team ITST Biodiversity Team Survey, field work	
Tap water undrinkable	Member from health professional	





Stench in water from sewage, poisons and rubbish	ITST Ecological Team ITST Biodiversity Team Survey, field work	
Changed water regime	ITST Ecological Team ITST Biodiversity Team Survey, field work	



### 3.6.4 Discussion of social sciences analysis

Before discussing the results, we restate the relevant task that was to “*explore the human and community vulnerability and resilience factors at work in different places – i.e., what made a particular community resilient or vulnerable*”.

We are committed to providing Samoa with some recommendations. As a part of this commitment, we refined our economic impact assessment methodology with an eye to improving the ability of communities to withstand the effects of natural hazards. In recent years, there has been an increasing worldwide focus on climate change adaptation and disaster mitigation as a key aspect of environmental disaster management. Generally, it is recognized that the costs of natural disasters to the community, the economy and the environment, can be significantly minimized by reflecting on lessons learnt in other post disaster coastal people’s communities when assessing the damage done to coastal communities and the resulting needs and priorities of these communities. However, in order to assess the benefits of disaster risk reduction and disaster education to the community, we require improved methodologies to measure the costs of natural disasters (Andrew et al 2007, Pelling et al, 2002).

A brief review of the literature reveals three key points. First, immediately after a natural disaster, there is recuperation period. This period is characterized by emergency response and calculation of economic loss and restoration damages. This phase requires quick, accurate and reliable data. An effective information collection system must be developed in order to formulate efficient decisions, particularly in contexts that have scarce resources. In contrast, long-term recovery defined as rebuilding process that brings back the economic activities to the level of pre-disaster as soon as possible. This period tends to be influenced by many factors, some of them are: a) the diversity of coastal people’s livelihood strategies and the sources of their vulnerability, b) the business cycle at national and regional levels and c) the macroeconomic condition of the nation (Okuyama 2005).

Second, natural disasters tend to negatively impact economic activity. In the short term, there tends to be a reduction in income generation, investment, production, consumption, and employment, and transportation and distribution implications. In the longer term, a disaster may affect economic growth and progress, wealth improvement and even local strategies for poverty alleviation. At the same time, as the Overseas Development Institute (ODI 2005) reports, the construction development and infrastructure upgrades can result in positive economic activity after extreme disasters.

Third, many economists suggest that the specific outcome of natural disasters on economic activity depends on sequencing of impacts, the type of hazard experienced, the vulnerability to a particular hazard, other concurrence on economic performance, but most importantly designing interventions that builds on this understanding to guide the selection of promising post-disaster livelihood options (Pelling et al, 2002, Andrew et al 2007).



We sought empirical evidence of some root causes of post disaster vulnerability – economic, social and environmental. We also established a set of indirect and intangible loss indicators (as seen in the field) that could be monitored in two post tsunami phases: a) short period of recuperation and b) longer term of recovery. Moreover, this list of indicators constructed in the first few weeks of recuperation, should be monitored to better understand post disaster coastal people’s sources of vulnerability and how this might narrow the diversity of their post-tsunami livelihood strategies (e.g. fishing, tourism). There is much work to be done collecting original data sets, holding focus groups and interviewing key informants to qualify and even quantify the cost of the tsunami on socio-economic fabric.

Examples of future work are as follows:

- Estimating the cost on cultural activities by examining data sets of pre and post-tsunami church and village contributions and discussing the broader impact of the tsunami upon village and church development.
- Estimating the cost of public and private costs and declining productivity due to poor physical and mental health in two post tsunami phases: a) short period of recuperation and b) longer term of recovery.
- Estimating the cost of medically treating the population affected by the disaster after the event, including the cost of public health and epidemiological interventions such as vaccination campaigns, post-trauma counseling and discussing the broader impact of the tsunami upon economic development in two post tsunami phases: a) short period of recuperation and b) longer term of recovery.

The key reason that such pieces of work need to be done is to allow others to learn from Samoa’s example of some of the human, financial, and developmental costs posed by disasters. The financial figures would raise public awareness of the importance of risk reduction in policy circles. Such a list of costs, used to sustain awareness, in turn could be used to support disaster risk reduction, disaster education and climate change adaptation programmes in forthcoming years (ODI 2005).

In summary, we have provided a specific path forward for several government and non-governmental organizations (NGOs) that are involved in small business promotion in Samoa. The small business sector is a key sector for alleviating poverty and generating economic growth. However, likely families business, such as fishing and renting out beach fales to tourists – is mostly not measured due to the informal nature of small businesses. Many businesses in the Tsunami affected area, such as the villages of Lalomanu, Saleapaga, Lepa, Ulutogia and Satittoa may not be registered with the Samoa Tourism Authority (STA), yet these companies generate income, employ staff and help families to get by.

The path suggested is thus: First and foremost, focus on developing a method to monitor human resource recovery alongside developing post disaster economic plans. Then, develop a process to guide post disaster livelihood options. Taking lessons learnt

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from other post disaster coast communities, we have sought to confront the longer-term challenge of building resilience and sustainability into communities by addressing the root causes of post disaster vulnerability - human resource recovery.



#### 4. SYNTHESIS

Having provided a detailed account of our investigations, the critical question that arises is:

*“how can the interdisciplinary and multisectoral approach taken by the UNESCO-IOC ITST Samoa provide insights that help us improve future tsunami disaster management practice?”*

The answer to this question is embedded in the approach we have taken – humans are *interconnected* with the physical environment in which events like tsunamis occur. To study the effects of a tsunami (e.g., inundation and run-up) without relating them to the spatial distribution of buildings, people and past policies, means we only get a basic understanding of the tsunami event.

A simplified outline of a coupled human-environment system framework for integrating information like that generated by this investigation is shown in Figure 52. This framework provides us with a set of ‘hooks’ that we may grasp so that we can begin to make connections between otherwise apparently disparate elements of the problem we face – namely, how to understand the nature of the effects of the tsunami. The framework simplifies a complex situation and allows us to trace the connections between those ‘things’ that help us understand why the tsunami had the effects that it did. Further, the framework allows us to identify the vulnerability and resilience factors at work in the places affected by the tsunami.

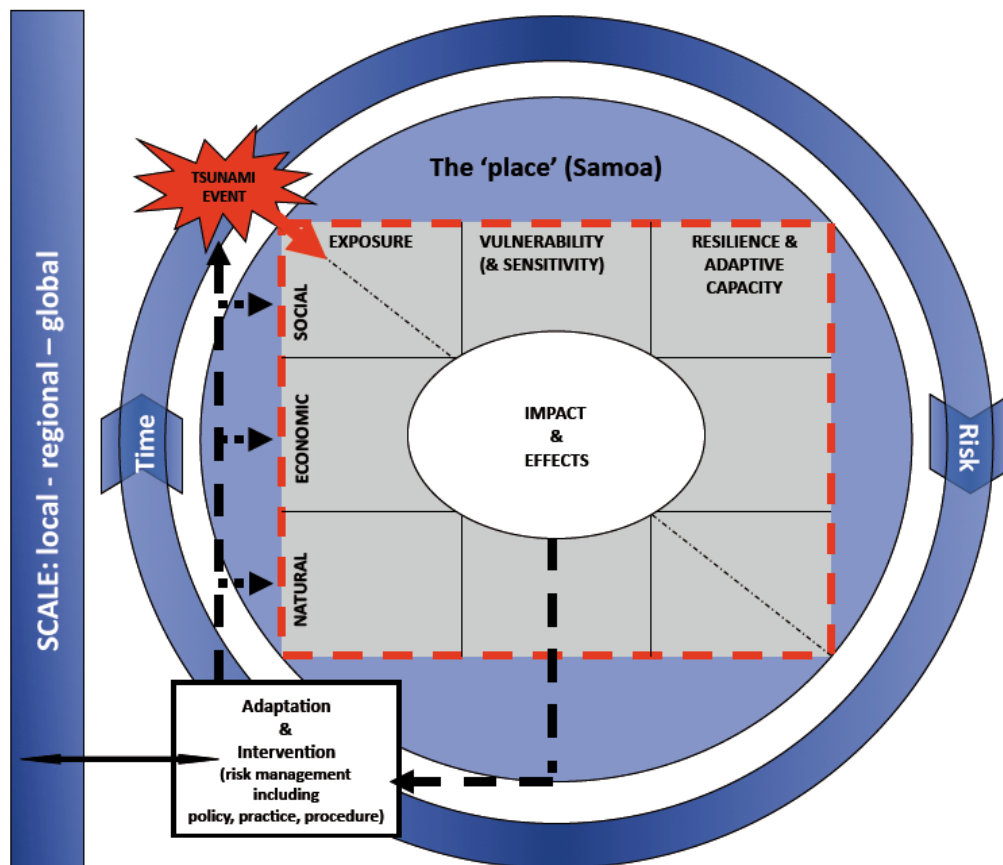
To go through the diagram we start with the event - the Samoa tsunami of September 29<sup>th</sup> 2009 - the tsunami affects a ‘place’. The scale of place depends on who you are and what you want to know. For example, for the Disaster Management Office of the Government of Samoa, the place *is* ‘Samoa’ as a whole. By contrast, for the Head of a village, the ‘place’ is the village. Scale does not matter.

Second, we recognise that the ‘place’ is composed of a ‘natural’, ‘social (socio-political-cultural)’ and ‘economic’ system. These three systems are variously ‘exposed’ to the physical processes of the tsunami, are ‘vulnerable’ (and sensitive) to its effects and will have a certain degree of ‘resilience’ and ‘adaptive capacity’ to be able to withstand its effects. The interactions between exposure, vulnerability and resilience will determine the degree of impact/loss associated with a tsunami of a particular magnitude at the place of interest. Vulnerability and resilience vary according to the range of pre-event risk mitigation strategies that are in effect (e.g., early warning systems, public education campaigns, building codes etc).

Impacts and effects then occur at the place. Once the coupled human-environment systems recover, disaster risk managers must take account of past events and determine new risk management approaches relevant to the natural, social and economic systems. Ideally, appropriate risk management strategies are in place before the occurrence of the



next tsunami. If everyone has done a good job, for an event of the same magnitude, impacts and effects will be less next time around.



**Figure 52: Simplified coupled human-environment system framework (modified from Turner et al., 2003)**

We cannot possibly map all the interconnections between humans and the environment in various places in Samoa affected by the tsunami. Further, each one of us will (because of our own areas of expertise) see certain connections more clearly. We believe that this powerful tool can be used by staff of the ministries of the GoS to identify those processes and connections that have resulted in the degree of damage sustained during this tsunami as relevant to their portfolios. The data contained in this report and in the accompanying data files can be explored by the GoS in the coming weeks and months to assist them make decisions about tsunami disaster risk reduction in a more considered way.

To provide an example of the power of this tool, here is an example:



Maximum run-up was recorded at over 14 metres (see work of inundation and run-up group). Run-up was extreme because wave energy was focused towards the SE tip of the island (see modelling by inundation and run-up group). However, run-up was surprisingly high at Siafaga in the SW of the island. This observation can be explained by our knowledge of bathymetry and coastal geomorphology (including reef structure) (see work of geology and marine ecology groups). Tsunami flow depth across the landscape varied highly but even in areas where flow depth was the same, the degree of damage sustained by buildings varied significantly (see work of the building damage group). The observed damage to buildings can be explained by a combination of hydrodynamics (see inundation and run-up group), geology (see geology and marine ecology group), building materials, codes and standards (see building damage group) and policy and practice of code enforcement (see social sciences group). The number of lives lost and their spatial distribution varies significantly. There are many reasons, but we can say that flow depth and velocity were important in some areas (see inundation and run-up and geology groups). We can also say that poor building standards and materials contributed to human casualties in other places (see building damage group). In some locations, communities were well prepared and had practiced their tsunami evacuation procedures but in others, had not (see social sciences group). At a broad level, the resilience of survivors is high (even when their coastal property has been destroyed) because of land ownership arrangements and the capacity to move further inland (see social sciences group). In other ways however, coastal agriculturalists are vulnerable because of changes in cropping types and the susceptibility of those crops to damage from seawater (see ecology and biodiversity group)..... and so it goes on.

It is true that scientists can make reasonable guesses about the reasons for differential impacts and effects. However, our interdisciplinary, multisectoral and collaborative approach with GoS and local scientists has ensured we can easily make connections between these otherwise complex systems that individually, we do not have skill in and knowledge of. The sum of the whole is much greater than of its individual parts.

#### **4.1 Identifying factors affecting vulnerability and resilience to the tsunami in Samoa**

Table 17 provides a rapid ‘quick-look summary’ of the factors that we have identified as relevant to our areas of investigation (and related to the Terms of Reference).



Table 17: Factors identified that appear to have played (or continue to play) a role in ‘vulnerability’ and ‘resilience’ before, during and after the tsunami

BEFORE THE TSUNAMI		
Sub-group	Vulnerability factors	Resilience factors
<b>Inundation and Run-up</b>	Not applicable	Not applicable
<b>Building Damage</b>	<ul style="list-style-type: none"> <li>• Poor building standards</li> <li>• Poor construction materials</li> <li>• Poor quality workmanship</li> <li>• Lack of knowledge about tsunami effects on buildings</li> </ul>	<ul style="list-style-type: none"> <li>• Good building codes when enforced</li> </ul>
<b>Geology</b>	<ul style="list-style-type: none"> <li>• Low lying coastal landscape</li> <li>• Narrow width of fringing reef</li> </ul>	<ul style="list-style-type: none"> <li>• Wide reef without breaks</li> </ul>
<b>Ecology and Biodiversity</b>	<ul style="list-style-type: none"> <li>• Loss of native species</li> <li>• Loss of cultural knowledge of species types and values</li> </ul>	<ul style="list-style-type: none"> <li>• Large trees still present at coast</li> <li>• Mangroves and wetlands etc in original condition</li> </ul>
<b>Video Interviews</b>	Not applicable	Not applicable
<b>Social Sciences</b>	<ul style="list-style-type: none"> <li>• Not understanding previous hazard education materials/efforts</li> <li>• Disbelieving possibility of tsunami occurrence</li> <li>• No cultural memory of past events as reference point</li> </ul>	<ul style="list-style-type: none"> <li>• Community had practiced tsunami evacuation</li> <li>• Land tenure structure</li> <li>• Policy and planning of government</li> </ul>



DURING THE TSUNAMI		
Sub-group	Vulnerability factors	Resilience factors
<b>Inundation and Run-up</b>	<ul style="list-style-type: none"> <li>• Where coastal landscape steep, run-up was high</li> <li>• Where coastal landscape flat, inundation was extensive</li> <li>• Narrow reefs with breaks broken fringing reefs 'focused' tsunami inundation/energy</li> <li>• Presence of off-shore islands may have focused inundation at the coast</li> </ul>	<ul style="list-style-type: none"> <li>• Wide, unbroken reefs 'lessened' inundation and run-up</li> <li>• Intact coastal vegetation reduced flow velocity and depth</li> </ul>
<b>Building Damage</b>	<ul style="list-style-type: none"> <li>• Large flow depth and high velocity increased vulnerability</li> <li>• Debris in water caused 'impact' damage to buildings</li> <li>• Poor construction style and material and workmanship</li> </ul>	<ul style="list-style-type: none"> <li>• Good construction design, workmanship and materials</li> <li>• Buildings raised even just 1 metre above surrounding land surface reduced damage levels</li> <li>• Vegetation (e.g., trees and mangroves) between the shore and the buildings, on average, increased resilience of buildings</li> </ul>
<b>Geology</b>	<ul style="list-style-type: none"> <li>• Large volumes of soft sediment that may easily be eroded by tsunami</li> <li>• Large quantities of blocky material that may be easily transported (e.g. sea wall)</li> <li>• Wide, unbroken reefs</li> </ul>	<ul style="list-style-type: none"> <li>• Extensive coastal vegetation that holds sediment and soil together reducing erosion</li> </ul>

<p><b>Ecology and Biodiversity</b></p>	<ul style="list-style-type: none"> <li>• As noted in pre-tsunami situation</li> <li>• Debris in backwash of tsunami flow increased damage to corals in shallower water</li> </ul>	<ul style="list-style-type: none"> <li>• As noted in pre-tsunami situation</li> <li>• Ecosystem is adjusted to absorb effects of high energy waves associate with tropical cyclones – so generally resistant</li> </ul>
<p><b>Video Interviews</b></p>	<p>Not applicable</p>	<p>Not applicable</p>
<p><b>Social Sciences</b></p>	<ul style="list-style-type: none"> <li>• Dependence of some people on hearing a warning message/siren (that may not have occurred), rather than reacting when feeling ground shake</li> <li>• Confusion about how to react</li> <li>• Low mobility of some people to move away from the coast and dependence on others to help</li> <li>• Vulnerability of buildings to damage during tsunami</li> <li>• Short period between earthquake event and tsunami arriving at shore</li> </ul>	<ul style="list-style-type: none"> <li>• Did not wait for a tsunami warning message – just reacted after the tsunami</li> <li>• Had practiced an evacuation</li> <li>• Community warning/helping each other</li> </ul>



AFTER THE TSUNAMI		
Sub-group	Vulnerability factors	Resilience factors
<b>Inundation and Run-up</b>	Not applicable	Not applicable
<b>Building Damage</b>	<ul style="list-style-type: none"> <li>Buildings are being quickly rebuilt in same areas to same standards as before the tsunami</li> <li>No chance to implement new design codes/standards</li> </ul>	<ul style="list-style-type: none"> <li>Many people have capacity to rebuild further inland at higher elevations – outside of likely inundation zone</li> </ul>
<b>Geology</b>	Not applicable	<ul style="list-style-type: none"> <li>Coastal geological deposits will remain, meaning we can use deposits as an analogue to examine longer-term records of past tsunamis improving risk assessment</li> <li>Where erosion occurred (e.g., at beaches), ecosystem is already recovering</li> </ul>
<b>Ecology and Biodiversity</b>	<ul style="list-style-type: none"> <li>As identified previously</li> <li>Not recognising the value of plant (especially, tree) species in providing protection from tsunami inundation</li> <li>Planting agricultural crop plants that are vulnerable to salt water damage at the coast</li> </ul>	<ul style="list-style-type: none"> <li>Moving inland to higher ground and replanting coastal areas with trees and other plants</li> <li>Selecting agricultural plant species that are more tolerant of salt conditions</li> </ul>
<b>Video Interviews</b>	<ul style="list-style-type: none"> <li>Not be able to talk about experiences</li> </ul>	<ul style="list-style-type: none"> <li>Talking about experiences helped reduce stress</li> <li>Knowing that their experiences were</li> </ul>

		being valued so as to provide educational material to other Samoans (and international people)
<b>Social Sciences</b>	<ul style="list-style-type: none"> <li>• Disbelief and shock</li> <li>• Loss of possessions and lack of resources</li> <li>• Interruption to livelihood income</li> <li>• Limited savings</li> <li>• Dependence on aid</li> <li>• Uncertainty about the future</li> <li>• Fear of the ocean and ghosts</li> <li>• Time it will take government to complete reconstruction of critical services</li> <li>• Potential impacts of poor health whilst living in temporary accommodation</li> <li>• Lack of knowledge about how to rebuild safely at the coast to protect structures</li> </ul>	<ul style="list-style-type: none"> <li>• Capability to move further inland</li> <li>• Remittances from family overseas</li> <li>• Strong government support</li> <li>• Close family ties and support</li> <li>• Faith in God and the church</li> <li>• Good work of Red Cross (and other agencies)</li> <li>• Willingness of some businesses to reopen as soon as possible and employ staff again</li> </ul>

NOTE: The identification of these factors is rapid and must be repeated when a more detailed post-process analysis of the data has been undertaken. However, use of the integrated framework shown in Figure 52 allows GoS officials and scientists (as well as UNESCO-IOC ITST members) to identify these factors easily



## 5. RECOMMENDATIONS

Appendix 7 contains the full list of recommendations provided by the six sub-groups. They are unedited. However, we recognise that such an extensive list of recommendations is unhelpful at this time. Therefore, we list below the top three recommendations from each of the six sub-groups as key take home messages.

Our number one recommendation is:

**“Retain and *enhance* community based tsunami education activities” – these saved lives on 29<sup>th</sup> September 2009**

### 5.1 Recommendations of the Inundation and Run-up Team

We recommend the following:

**RECOMMENDATION 1: Collection and compilation of a detailed near shore bathymetric and coastal topographic datasets to help with future tsunami modelling for risk assessment**

**RECOMMENDATION 2: Train Government of Samoa staff/officials on how to measure inundation and run-up to avoid the need to work with international scientists**

There are only two key recommendations from this sub-group.

### 5.2 Recommendations of the Building Damage Team

We recommend the following:

**RECOMMENDATION 3: New buildings should be built on raised ‘platform’s approximately 1 metre higher than surrounding landscape and on solid foundations**

**RECOMMENDATION 4: New buildings should be of reinforced concrete (or at the very least, with concrete foundations, floors and support columns)**

**RECOMMENDATION 5: The building code should be enhanced as soon as possible, enforced (as far as possible), and communicated to the people as part of a wider hazards education campaign**

### 5.3 Recommendations of the Geology Team

We recommend the following:

**RECOMMENDATION 6: Using aerial photographs and satellite images, map carefully the maximum inundation level to fully understand spatial extent of tsunami flooding**

**RECOMMENDATION 7: increase in-country training and capacity building for all-**



## hazards management

**RECOMMENDATION 8:** Complete a national (and regional) palaeotsunami study to identify long-term frequency-magnitudes of tsunamis

### 5.4 Recommendations of the Ecology and Biodiversity Team

We recommend the following:

**RECOMMENDATION 9:** Replant damaged coastal areas and protect pristine coastal areas with species shown to increase resilience to tsunami (and extreme wave) inundation

**RECOMMENDATION 10:** Undertake community education activities to raise awareness of the value of plants and vegetation to protect from tsunamis

**RECOMMENDATION 11:** Establish a longitudinal study to monitor vulnerability and resilience of ecosystems and biodiversity

### 5.5 Recommendations of the Video Interview Team

We recommend the following:

**RECOMMENDATION 12:** Establish a procedure and train Samoan people to collect video accounts from survivors

**RECOMMENDATION 13:** Continue to collect survivor stories. This helps with the healing process and provides valuable material to help with future awareness raising activities

**RECOMMENDATION 14:** Conduct survivor interviews in 6 and 12 months time to provide an assessment of survivor experiences through time

### 5.6 Recommendations of the Social Sciences Team

We recommend the following:

**RECOMMENDATION 15:** Maintain and enhance the community based tsunami education activities for early warning and response

**RECOMMENDATION 16:** Work with communities to identify ways to facilitate reestablishment of post-event livelihood opportunities

**RECOMMENDATION 17:** Establish an annual Tsunami Memorial Day to honour the lives lost and practice tsunami evacuation exercises





## 6. CONCLUSIONS

The tsunami of 29<sup>th</sup> September 2009 was regionally significant within the SW Pacific, a physical disaster for some communities in Samoa and a psychological trauma for the whole country. Sadly, the earthquake that triggered the tsunami occurred so close to the south coast of Upolu that whilst warning messages were issued, insufficient time existed for low-lying exposed communities to fully evacuate. Further, for a variety of complicated reasons, people within communities claim that either they did not receive a warning message or, that if they did, it came too late. Coupled with the confusion over warnings and their timing in relation to the earthquake, a confused picture is emerging about people's stated reaction to the earthquake and warning messages, and the arrival of the tsunami at the coast. Many people state that for whatever reason, they did not know how to react.

Not-with-standing the previous points, the excellent tsunami awareness campaigns of the Disaster Management Office (DMO) of the Government of Samoa in recent years means that far fewer people died than would have been the case. From this perspective, some comfort can be gained from prior government activities. The 'take home message' from the limited research we have been able to undertake in the last week is that the Government of Samoa should:

***“retain and enhance its community based tsunami education activities because they do save lives”***

This simple recommendation is underpinned by many more detailed recommendations that the Government of Samoa may consider for immediate and future implementation to increase resilience to future hazard events.

Having negotiated a set of Terms of Reference (ToR) for our UNESCO-IOC International Tsunami Survey Team, we set out to address the following key activities on behalf of the Government of Samoa:

1. Measure maximum inundation and maximum flood run-up. Such measurements are important inputs for running and validating tsunami inundation models;
2. Collect geological samples of sediments left by the tsunami. This is so that we may characterise the deposits left by the 2009 tsunami. Once completed, we should at a later date, explore the geological record of the coast of Samoa to explore records of older tsunamis in the recent historic (e.g., the 1917 tsunami) and prehistoric (or palaeotsunami) past. Such work enables scientists to establish longer-term tsunami risk;
3. Collect and measure information about environmental and biophysical system impacts of the tsunami on the terrestrial and marine environment in selected locations;



4. Measure the type and severity of damage to different types of buildings and record what factors appeared to control damage levels;
5. Collect information about survivor experiences and stories through interviews (including for the first time ever in a UNESCO-IOC ITST, video interviews of survivors);
6. Collect information on human and community vulnerability and resilience factors at work in different places: i.e., what made a particular community resilient or vulnerable?; and
7. Where possible, to map the above information.

To this end, we divided our large UNESCO-IOC ITST in to six sub-groups to tackle each of these tasks. Each sub-group team was composed of a representative from an associate relevant Government of Samoa ministry, a local scientist from a partner research institution (e.g., USP) and a local Samoan speaker. Each sub-group was required to clarify its research methods and techniques for gathering data (detailed in Section 2 of this report).

The six sub-groups comprising Inundation and Run-up, Building Damage, Geology, Ecosystems and Biodiversity, Video Interviewing and Social Sciences then set about gathering data to address each of the Government’s ToR’s. The research findings are detailed in Section 3 of the report. Wherever possible, we have mapped the data we have collected to give the government an idea of where we have worked.

We have attempted an interpretation of the data but we caution that this is preliminary since we have not had time to ‘post-process’ the data – a process that is critical if we are to come to concrete conclusions.

The data we have collected has been made available to the Government of Samoa in raw form in a series of electronic folders. Once data has been properly processed, each sub-group will provide a final report back to government. Further, as the international scientist work to publish their findings collaboratively with GoS ministry staff and partner investigators, we will forward copies of these publications to the government as ‘final statements’.

Our approach to collaboration, partnership and horizontal skills sharing, is a global first for a UNESCO-IOC ITST assessment and is testament to the good will and professionalism of all involved.

Key findings (unprocessed) are shown below:

KEY FINDINGS
<p><b>Inundation and Run-up:</b></p> <ul style="list-style-type: none"> <li>• Maximum run-up exceeded 14 metres above sea level</li> </ul>



- Maximum inundation (at right angles to the shore) was approximately 400 metres
- Maximum inundation with the waves running inland and parallel to the shore, exceeded 700 metres

### **Building Damage:**

- Buildings sustained varying degrees of damage
- Damage is correlated with depth of tsunami flow, velocity, condition of foundations, quality of building materials used, quality of workmanship, adherence to the building code and so on
- Buildings raised even one metre above the surrounding land surface suffered much less damage
- Plants, trees and mangroves reduced flow velocity and flow depth – leading to greater chances of human survival and lower building damage levels

### **Geology:**

- The tsunami has left a clear and distinguishable geological record in terms of sediments deposited in the coastal landscape
- The clear sediment layer associated with this tsunami suggests that older (and prehistoric) tsunamis can be identified helping to answer questions about frequency and magnitude of tsunamis
- The tsunami caused widespread erosion of the coastal and beach zones but this damage will repair itself naturally quickly

### **Ecosystem and Biodiversity:**

- The tsunami has had clear impacts on ecosystems and these are highly variable
- Ecosystems will repair themselves naturally and are unlikely to preserve long-term impacts
- It is clear that some plant (tree) species are highly resilient and provided immediate places for safety during the tsunami and resources post-tsunami
- People of Samoa are forgetting their knowledge of the value and uses of indigenous plant and animal species and efforts are needed to increase the understanding of the value of these plants and animals (thus increasing community resilience)

### **Video Interviews:**

- Video recording survivor stories is important
- Sadly, there is no cultural story telling or memory of past tsunamis so capturing survivor accounts means such stories can be retained
- Survivors telling their stories are important to allow these people to emotionally heal and as evidence useful for future education and community outreach



## **Social Sciences:**

- The people of Samoa are hurting after the tsunami
- Impacts and effects are highly variable socially and spatially
- Where lives have been lost, the impacts and associated fear are much higher
- Communities require practical and longer-term emotional care
- A complex picture is emerging about community experiences of warning and response behaviour that presents challenges to the Government in terms of education and outreach for hazard reduction

We have been able to identify a series of factors that appear to influence/control vulnerability and resilience. Not all factors operate at all scales and in all places. We have provided a tool - the coupled human-environment systems framework - to the Government of Samoa to enable its staff to continue this process in coming months as time permits.

From the work of our sub-groups, we have identified a series of recommendations. From these, the three most important have been selected for each sub-group.



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**UNSW**



## **APPENDICES**



## Appendix 1

### List of members of the UNESCO-IOC International Tsunami Survey Team, Samoa

#	Name	Organisation	Contact details	Key skills, interests
1	Dale Dominey-Howes	Australian Tsunami Research Centre (ATRC), UNSW	<a href="mailto:Dale.dh@unsw.edu.au">Dale.dh@unsw.edu.au</a>	Tsunami scientist and disaster risk manager
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3	James Goff	ATRC, UNSW	<a href="mailto:j.goff@unsw.edu.au">j.goff@unsw.edu.au</a>	Tsunami scientist
4	Luke Strotz	ATRC, UNSW	<a href="mailto:lukestrotz@gmail.com">lukestrotz@gmail.com</a>	Coastal geologist,
5	Catherine Chague-Goff	ATRC, UNSW	<a href="mailto:c.chague-goff@unsw.edu.au">c.chague-goff@unsw.edu.au</a>	Tsunami sedimentologist, environmental change
6	Samuel Etienne	University of French Polynesia	<a href="mailto:Samuel.etienne@upf.pf">Samuel.etienne@upf.pf</a>	Coastal geologist
7	Randy Thaman	USP (USP team leader)	<a href="mailto:Thaman_r@usp.ac.fj">Thaman_r@usp.ac.fj</a>	Terrestrial ecology
8	Eberhard Weber	USP	<a href="mailto:Weber_e@usp.ac.fj">Weber_e@usp.ac.fj</a>	Community livelihoods, vulnerability
9	Gabriel Gravelle	USP	<a href="mailto:Gravelle_g@usp.ac.fj">Gravelle_g@usp.ac.fj</a>	GIS, coastal vulnerability mapping
10	Ed Lovell	USP	<a href="mailto:Lovell_e@usp.ac.fj">Lovell_e@usp.ac.fj</a>	Coral reefs
11	Posa Skelton	USP	<a href="mailto:Skelton_p@usp.ac.fj">Skelton_p@usp.ac.fj</a>	Marine peology
12	William Power	GNS	<a href="mailto:w.power@gns.cri.nz">w.power@gns.cri.nz</a>	Tsunami modeller
13	Kate Wilson	GNS	<a href="mailto:k.wilson@gns.cri.nz">k.wilson@gns.cri.nz</a>	Geologist
14	Gegar Prasetya	GNS	<a href="mailto:g.prasetya@gns.cri.nz">g.prasetya@gns.cri.nz</a>	Tsunami modeller
15	Jochen Bind	NIWA	<a href="mailto:j.bind@niwa.co.nz">j.bind@niwa.co.nz</a>	GIS, RTK GPS



16	Stefan Reese	NIWA	<a href="mailto:s.reese@niwa.co.nz">s.reese@niwa.co.nz</a>	Risk/hazard analyst
17	Shona van Zijl de Jong	NIWA	<a href="mailto:s.vanzijldejong@niwa.co.nz">s.vanzijldejong@niwa.co.nz</a>	Social scientist
18	Guy Urban	West Coast/Alaska Tsunami Warning Centre	<a href="mailto:Guy.urban@noaa.gov">Guy.urban@noaa.gov</a>	Tsunami warning
19	Yoshitaka Matsuzaki	Port and Airport Research Institute Japan	<a href="mailto:Matsuzaki-y@pari.go.jp">Matsuzaki-y@pari.go.jp</a>	Multiphase flow research
20	Koji Fujima	Japan Society of Civil Engineers (National Defense Academy)	<a href="mailto:fujima@nda.ac.jp">fujima@nda.ac.jp</a> +81-46-841-3810	Run-up measurements
21	Tutomu Sakakiyama	Central Research Institute of Electric Power Industry	<a href="mailto:sakaki@criepi.denken.or.jp">sakaki@criepi.denken.or.jp</a>	Run-up measurements
22	Taro Arikawa	Port and Airport Research Institute, Japan	<a href="mailto:arikawa@pari.go.jp">arikawa@pari.go.jp</a>	Damage assessment
23	Yoshinobu Tsuji	Japan Society of Civil Engineers (Earthquake Research Institute, Tokyo University)	<a href="mailto:tsuji@eri.u-tokyo.ac.jp">tsuji@eri.u-tokyo.ac.jp</a>	Run-up measurements
22	Daisuke Tatsumi	Port and Airport Research Institute, Japan	<a href="mailto:tatsumi@pari.go.jp">tatsumi@pari.go.jp</a>	Damage assessment
25	Bruce Richmond	USGS	<a href="mailto:brichmond@usgs.gov">brichmond@usgs.gov</a>	Geologist
26	Mark Buckley	USGS		Geologist
27	Walter Dudley	Uni Hawaii	<a href="mailto:dudley@hawaii.edu">dudley@hawaii.edu</a>	Interview survivors
28	Brian McAdoo	Earth Science and Geography Vassar College, NY	<a href="mailto:brmcadoo@vassar.edu">brmcadoo@vassar.edu</a> 845.249.9561 m 845.437.7703 w	Tsunami geologists
29	Beatriz Brizuela	INGV, Italy	<a href="mailto:Beatriz.brizuela@ingv.it">Beatriz.brizuela@ingv.it</a>	Inundation and run-up
30	Roberto Tonini	University of Bologna, Italy	<a href="mailto:roberto.tonini2@unibo.it">roberto.tonini2@unibo.it</a>	Inundation and run-up



31	Gianluca Pagnoni	University of Bologna, Italy	<a href="mailto:gianluca.pagnoni3@unibo.it">gianluca.pagnoni3@unibo.it</a>	Inundation and run-up
32	Litea Biukoto	SOPAC	<a href="mailto:litea@sopac.org">litea@sopac.org</a>	Disaster risk management
33	Dr Fonoti Iupati Fuatai	Director of Samoan Studies, NUS	<a href="mailto:l.fuatai@nus.edu.ws">l.fuatai@nus.edu.ws</a>	
34	Faleafaga Toni Tipamaa	ACEO Division of Environment and Conservation, MNRE	<a href="mailto:toni.tipamaa@mnre.gov.ws">toni.tipamaa@mnre.gov.ws</a>	
35	Malamaalii Aokuso Leavasa	MNRE	aokuso,leavasa@mnre.gov.ws	Principal Forestry Officer
36	Bill Cable		bllcbl@gmail.com	Consultancy for FAO
37	Taupau Maturu Paniani	ACEO, Forestry		Forestry
38	Tautalaaso Taulealo-Seru	Avele College, MESC	<a href="mailto:taulealoseru@yahoo.co.nz">taulealoseru@yahoo.co.nz</a>	Biodiversity
39	Anita Latai	NUS	<a href="mailto:sataoa@hotmail.com">sataoa@hotmail.com</a>	Geography
40	Suemalo Tumutalie Foliga	MNRE	talie.foliga@mnre.gov.ws	Principal National Reserve
41	Leatuavao Ioane Malaki	USP	<a href="mailto:malaki_i@samoa.usp.ac.fj">malaki_i@samoa.usp.ac.fj</a>	Biodiversity
42	Moafanua Tolo Iosefa	USP	<a href="mailto:iosefa_t@samoa.usp.ac.fj">iosefa_t@samoa.usp.ac.fj</a>	Biodiversity
43	Eiko Fuimaono	Scientific Research Organisation of Samoa		Biodiversity
44	Czarina Iese	MNRE		Biodiversity
45	Faigame "Me" Sale	Ministry of Natural Resources and Environment, Meteorology Division, PO Box 3020, Mulinu`u, Apia, Samoa	Phone: 20855	Geology
46	Tolu Muliaina	USP		Social science
47	Jackie Faasisila	USP		Social science



48	Angela Jowitt	USP		Social science
49	Dr Sonny Lameta	USP		Social science
50	Tili Afamasaga	NUS		Social science
51	Maima Koro	NUS		Social science
52	Dawn Tuiloma-Sua	MNRE-DMO		Social science
53	Latu Afioga	MWCSD		Social science
54	Francisco Fidow	Samoa Red Cross Society		Social science
55	Daisy Bedford	Samoa Red Cross Society		Social science
56	Rodney Fu	Samoa Red Cross Society		Social science
57	Francisco Fidow	Samoa Red Cross Society		Social science
58	Adam Jowitt	Consultant		Engineer
59	Faafeti Tevaga			Building damage, engineering
60	Steven Percival	Paradigm Documentaries	<a href="mailto:Steven.percival@gmail.com">Steven.percival@gmail.com</a>	Film maker
61	Siosina	MNRE		Damage and inundation

NOTE: we do not yet have the full details of many of our GoS ministry colleagues or participants from the other partner organisations. These will be properly collected and integrated in the coming weeks

## Appendix 2

### UNESCO-IOC ITST Samoa ‘Terms of Reference’ (ToR’s)

We were asked to undertake the following key tasks:

1. Measure maximum inundation and maximum flood run-up. Such measurements are important inputs for running tsunami inundation models;
2. Collect geological samples of sediments left by the tsunami. This is so that we may characterise the deposits left by the 2009 tsunami. Once completed, we might at a later date, explore the geological record at the coast of Samoa to explore records of older tsunamis in the recent historical past (e.g., the 1917 tsunami) or prehistoric (or palaeotsunamis). Such work enables geologists to establish longer-term tsunami risk;
3. Collect and measure information about environmental and biophysical system impacts of the tsunami on the terrestrial and marine environment in selected locations;
4. Measure the type and severity of damage to different types of buildings and record what factors appeared to control damage levels;
5. Collect information about survivor experiences and stories through interviews (including for the first time ever in a UNESCO-IOC ITST, video interviews of survivors);
6. Collect information on human and community vulnerability and resilience factors at work in different places: i.e., what made a particular community resilient or vulnerable?; and to
7. Where possible, map the above information.

These core tasks were derived from a more detailed ‘Terms of Reference’ document circulated prior to arrival in Samoa.

#### UNESCO-IOC International Tsunami Survey Team (ITST) Samoa – 14<sup>th</sup> to 26<sup>th</sup> (approx) October 2009

#### Terms of Reference and Survey Protocols – DRAFT

**Team leaders:** Dale Dominey-Howes, Australian Tsunami Research Centre (ATRC), Sydney, Australia

Randolph (Randy) Thaman, University of the South Pacific and SOPAC

As Team Leaders for this UNESCO-IOC ITST Survey, we have been asked to develop a Terms of Reference (ToR) and Protocol to guide the work of the survey team. The purpose is to provide a framework to guide our work in Samoa, to ensure we all understand what is required of us as scientists, to foster a shared and collective ownership of the research and survey work and to provide details of data sharing mechanisms and consider collaborative team publication. The purpose is to reduce stress,





improve group dynamics, to show respect for each other and to ensure our work is focused and delivers results appropriate for enhancing community resilience to future tsunamis in Samoa and elsewhere.

An apology – there is NO template for us to follow so this ToR and Protocol is being established from limited available documentation. Invariably, the final details will vary from that listed here, but this is a start. As valued members of the Samoa ITST survey team, you are invited to provide feedback and suggestions for improvement. Thanks ☺

### **1. Framework for the Samoa UNESCO-IOC ITST Survey - why is it needed, what will it accomplish, and what will be the outcomes?**

The Samoa tsunami of Sept 29<sup>th</sup> 2009 was regionally significant and locally catastrophic. It has resulted in close to 200 deaths and caused enormous damage to infrastructure. Whilst the Pacific Tsunami Warning System (PTWC) was able to follow standard operating procedures and issue a warning message, lives have still been lost. The government of Samoa, other governments in the region and the wider scientific community are asking many questions about what, why, how and what can be done to reduce future losses for similar events. Our team has an important role to play in addressing these (and other) important questions.

The final composition, skills, interests and resources available to our team will determine exactly what tasks we undertake as part of the survey. Further, we will be advised by the Samoa government of specific knowledge gaps they wish us to explore once we are on site in Apia. However, at present, the core research tasks/questions to be addressed by this UNESCO-IOC ITST survey include:

- (1) *take measurements of maximum inundation and maximum flood run-up and flow depth above ground surface* at as many sites as possible – such measurements are useful for many reasons including improving forecast inundation models and understanding impacts of tsunami inundation on building damage;
- (2) *take geological samples of sediments left by the tsunami* – such samples help with the characterization of tsunami deposits providing highly valuable analogues to compare with suspected palaeotsunami deposits;
- (3) *measure the type and severity of damage to different types of buildings* and record what factors appeared to control damage levels – such data are valuable for helping revise building codes and design standards and for informing land use zoning and planning decision making;
- (4) *collect and measure information about the environmental and biophysical system impacts* of the tsunami in different places – such work is helpful for exploring many aspects of conservation, ecosystem function analysis and environmental change and management;
- (5) *collect information about survivor experiences* and stories through interviews (if deemed appropriate);
- (6) *explore the human and community vulnerability and resilience factors* at work in different places - what made a particular community resilient or vulnerable, what are the differential experiences of different types of people who experienced the tsunami? – such data are critical for understanding how to develop appropriate education and hazard awareness programs, for revising early warning approaches and alike;
- (7) use the results from tasks 1 to 6 to draw up recommendations to assist local and national government authorities to increase community resilience, improve disaster preparedness and planning and increase community awareness and education.



The ‘outputs’ of the research will include an immediate (end of survey) report; a later more detailed report of our findings and numerous scientific publications in discipline specific journals dealing with various aspects of our survey research findings. Further, a single summative paper that deals with our immediate findings is planned for submission to a very high impact journal at the end of the survey. Details of this planned paper will be discussed at our planning meeting in Apia on the 14<sup>th</sup> October. This high impact journal paper will include EVERY survey team member in recognition of their skills, efforts and contributions.

Outcomes from the planned work of our team are harder to define but essentially – safer regional communities. If we do our job well, we can provide information useful for planners and risk managers who work with, and serve regional communities. They can use the results of our work to refine existing risk management strategies.

## **2. ITST Team Conduct and Ground Rules - daily agenda (briefings, data collection (how, with what, questions), data repository (mandatory data sharing by all possible?), data sharing (available to all who participated, but respecting rights of further distribution if they need to publish), etc....**

At this moment in time, we anticipate that small work teams will go out on a daily basis around the island to do their survey research, returning each evening to HQ at the Alafua Campus Centre at USP, Apia. If it becomes necessary, teams may be provided with local accommodation to stay away in the field.

At the start of our work, we will have a large team meeting at 10am on Wednesday 14<sup>th</sup>. At this meeting, final team composition will be determined, presentations made by Samoan government officials and the final research tasks will be decided collaboratively. Small teams will be established, a “Team Leader” for each team identified and a research approach and techniques to be used will be determined for respective tasks set.

At the start of each day – we think a short (circa 15 min) meeting will take place – perhaps informally during breakfast – where the work program for the day will be set. At the end of each day, each team will nominate one person to transfer data collected that day to a shared repository. We will make an external hard drive available in which survey results (task by task) are to be uploaded. All team members will have access to this to ensure we all have all data at the end of the survey. These data will also be made available to ITIC/UNESCO-IOC according to their usual data acquisition protocols. We do understand that each of you have specific things that you wish to learn and as volunteers, your right to publish data you have collected is respected and honoured. We hope that we can all share data and collaboratively publish.

We will discuss the mechanics of data storage and sharing on site in Apia. We will also seek advice from Laura Kong (UNESCO-IOC) on data repository with her organisation. Comments and feedback much appreciated.

## **3. Survey Forms - to be used by teams to collect data**

Attached to this email are data recording sheets for inundation/run-up and building damage assessment. Thank you to colleagues who have made these available. Also attached is a draft UNESCO social survey questionnaire. Lastly, a UNESCO Field Guide provides basic guidance notes that our

# UNSW



team can use to collect data. What we will finally use can evolve from these documents. Please take time to look at these prior to us meeting on the 14<sup>th</sup> and be willing to provide comments and feedback on amendments for better data collection.

#### **4. Caring for each other and professional conduct**

Working in post-disaster situations is stressful and can be upsetting. We must take care of each other, take time to ask if we are ok, take time to sit and listen to each other at the end of each day – formally if needed but definitely informally.

We must also respect each other professionally and understand our roles and responsibilities as researchers.

Attached are some papers that describe the need for supporting one another and also professional ethics in post disaster research. Happy reading!

Thank you all for your willingness to be part of this team.

Looking forward to meeting and working with you all next week.

Warm wishes

Dale and Randy

Road

## Appendix 3

### Inventory of plant status

Tree species, with selected associated information, assessed in coastal littoral zone, coastal plain, mangrove, swamp and residential and garden areas in the tsunami-affected areas on the east and southeast coasts of Upolu. With a special focus on trees showing high resilience to, and providing protection from coastal and inland erosion, tsunamis, storm waves and king tides, loss of property and life. (Notes: under abundance, V = very abundant, A = abundant, C = common, O = occasional, U = uncommon, R = rare; Under origin, I = indigenous or native tree to Samoa, A = early aboriginal introduction by Samoans, R = recent non-indigenous post-European contact introduction into Samoa).

Samoa Name	Common name	Scientific Name	Abundance	Origin	Est. Mortality	Estimated Damage/defoliation	Life saving	Comments
Talie	Tropical almond	<i>Terminalia catappa</i>	V	I	< 5%	10%	Saved lives of 7 people	Very resistant to both wave-fall and saltwater damage; a few trees uprooted or felled by debris in the worst affected areas
fetau	Beach mahogany	<i>Calophyllum inophyllum</i>	C	I	<5%	<5%	Saved lives of 3 people	Maximum mortality seem to be on the immediate coastal zone due to wave undercutting
Pu'a	Chinese lantern tree	<i>Hernandia nymphaeifolia</i>	O	I	<5%	<5%		cases of severe undercutting and evacuation of sand from the roots in the Lefaga area of Lalomanu
Tau'anave	Beach trumpet	<i>Cordia subcordata</i>	R	I	Nil	<5%		Number of individual trees seen in the coastal zone of Vaovai and Vavau



Fao	No common name	<i>Neisosperma oppositifolium</i>	R	I	Nil	Nil	Saved one life	Assessment biased as only 1 individual seen at the area behind the small mangroves at the Ilili Peninsula at the Ilili Beach resort
Fau	Beach hibiscus	<i>Hibiscus Tiliaceus</i>	C	I	<10%	30%		
Milo	Pacific rosewood	<i>Thespisian poupeneia</i>	U	I	<5%	Nil		
pani	<i>manilkara</i>	<i>Manilkara dissecta</i>	R	I	Nil	Nil		Single large grove of ten trees seen at Satitua 70 mtrs from the coastline. Clear damage of the trunk up to about 3 mtrs. National native trees reported to be present on Nuutele Island and possibly on Namua Is. Mentioned by a number of respondents from Satitua and Lalomanu as trees that should be planted for protection.
Ulu	breadfruit	<i>Artocarpus altilis</i>	V	A	40- 100%	95%	Saved 5 lives	
poumuli	No common name	<i>Plaggea flexuosa</i>	V	R	<5%	100%	2 lives	Greatly affected by the tsunami in terms of saltspray. Many removed but evident that it was abundant before the event
mago	mango	<i>Mangifera indica</i>	O	R	50%?	100%		Unable to assess how many were lost Percentage recovery uncertain with mangoes in some of the more protected areas surviving particularly the larger mature trees.
vineka	Carambola	<i>Averrhoa carambola</i>	U	R	Nil	<5%		
ifi	Tahitian chestnut	<i>Inocarpus fagifer</i>	O	I	Nil	<5%	4 lives	
tamaligi	Raintree	<i>Albicia samanea/ saman</i>	O	R	Nil	<5%	1 life	
Tamaligi	Flametree Poinciana	<i>delonix regia</i>	O	R	Nil	<5%		
togo	oriental mangrove	<i>Bruguiera/ gymnorrhiza</i>	Locall		Nil	<5%	4 lives	Little or no impact on tall trees but



	American mangrove	<i>Rhizophora samoensis</i>	y common U					some breaking and damage to branches due to vehicles and debris
lopa	Red bead tree/ Red sandalwood/ Samoan peanut	<i>Adania nanthera</i> <i>bavonina</i>	U		<5%	<10%?	1 life	Seen on a number of backbeach ridges and inner areas of the coastal plain. Extent of planting on highly devastated unknown.
koko	Cacao	<i>Theobroma Cacao</i>	O		50%?	90%	1 life	
Niu	coconut	<i>Cocos nucifera</i>	V		<5%	Nil		
Lautotolo/ fasa	Wild swamp pandanus sp	<i>pandanus sp/ var</i>	O		30%	Nil [very resilient to salt spray though defoliation evident when the trees were uprooted]		Most of the mortality would have occurred in the highly impacted areas where there was little vegetation remaining. Occassionally found in swampy areas bordering villages and extensive at Fusipu Swamp near Utulaelae
Laulala	No common name	<i>Dendrolobium umbrellatum</i>	C		<5%	20-30%		
Aloalo, aloalo tai		<i>Premna serratifolia</i>	O		<10?	?		Found in manrove margins, in inner undisturbed coastal forest and occasionally in houseyard gardens because of its medicinal importance
Toitoti	Half flower/ beach salt bush	<i>Scaevola taccada</i>	R		?	?		Seen only in a planted garden at Vavau Beach resort AND as an uprooted plant on coastal seawall at Saleaumua - possibly uprooted from Namua or Nuutele islands offshore



namulega	No common name	<i>Vitex trifolia</i>	U		20%?	50%		
Pua Hawaii	Frangipani	<i>Plumeria Rubra</i>	O-C		Nil	Nil		Very resilient to salt spray though some damaged possibly by clean up crew
Pua solomona	Frangipani	<i>Plumeria obtusa</i>	C- V		Nil	Nil		Some partly uprooted at Saleaumua though still alive
Moso'oi	Perfume tree, ylangylang	<i>Cananga odorata</i>	O?					
	Coral bush	<i>Jatropha interrigima</i>	O		Less than 10%?	?		We don't really know the levels of damage at Lalomanu
Niu kuma	Sago palm	<i>Metroxylon warburgii</i>	C		20-30%	<5%		
Masame	No common name	<i>Glochidion ramiflorum</i>	O		<5%	<5%		
Lautalotalo samasama	Golden grinum	<i>Grinum zanthophyllum</i>	V		50-60%?	Nil		Very resilient to salt spray and water. Loss due to uprooting by wave erosion or by subsequent removal by clean up crews.
Lautalotalo meamata	Grinum sp	<i>Grinum asiaticum</i>	U		<5%	<5%		Mainly found at Sinalei and Salani and low damage
Ifilele	Beach mahogany/ fetau beach mahogany/ ipil	<i>Intsia bijuga</i>	R					Only 1 individual seen in Vaovai on the small point opposite Nuusafee Is.
Toa	Casuarina, ironwoon	<i>Casuarina equisetifolia</i>	O		Nil	10%		
Leva	Beach mango	<i>Cerpera mangbas</i>	O		Nil	Nil		
Tausuni	Heliotrope	<i>Tournefortia argentea</i>	U		Nil	Nil		
Futu	Fish poisontree	<i>Barringtonia asiatica</i>	U		<5%*	Nil		*One fallen tree seen on the raised coast/ cliff undercut by the tsunami just north of the quarry at Tuiolemu
Saato	Swamp fern	<i>Acrostichum aureum</i>	U		100%	100%		





Ututu	Water chestnut	<i>Eleocharis dulcis</i>	U		100%	100%		
Mutia palagi	Bermuda grass		C		<5%	<10%		
Fue sina	Beach pea	<i>Vigna marina</i>	C		100%	100%		
Fuemoa	Beach morning glory	<i>Ipomoea pes-caprae</i>	C		100%	100%		
Pulu	India rubber tree	<i>Ficus elastica</i>	O		Nil	10%		
Pulu		<i>Ficus benghalensis</i>	O		Nil	<5%		
Gatae	Coral tree	<i>Erythrina variegata</i>	U		<5%	10%		
Nonu a togi	Indian mulberry	<i>Morinda citrifolia</i>	V		Nil	Nil		
Nonu fiafia	Malay apple	<i>Sisigium Malaccense</i>	R		Nil	Nil		Only one seen at a Vaovai garden
Laupata	Macaranga	<i>Macaranga harveyana</i>	O*		Nil	<5%		*occasional in backyard gardens and on margins just below the trimline
Paina	Norfolk island pine	<i>Araucaria heterophylla</i>	O		Nil	<10%		Near houses particularly at Saleapaga
Pama	No common name	<i>Cycas circinalis</i>	O		90%	100%		



## Appendix 4

### Tsunami survivor/disaster awareness research survey

#### Research Survey Instrument

Name of Village\_\_\_\_\_

Name of Household\_\_\_\_\_

Name of person interviewed\_\_\_\_\_ Age\_\_\_\_\_

Gender\_\_\_\_\_

1. How are you after the tsunami? What are your worries and concerns?  
**O a mai lo outou aiga talu mai le sunami? E iai ni mea o popole ai?**
2. What are your needs now?  
**O a ni mea o manaomia?**
3. How do you see these needs being met?  
**E faapefea ona maua mea oloo manaomia? O a ni auala e maua ai?**
4. What help have you received?  
**Ua maua ni fesoasoani e le tou aiga talu ai le sunami?**
5. What were your sources of income before the tsunami?  
**O a ni tou alagatupe/'oa sa iai a'o le sau le sunami?**
6. How has this been affected?  
**Na faapefea ona aafia nei alaga'oa o le soifua laulelei i le sunami?**
7. Are you planning on rebuilding your homes and where?  
**O iai se fuafuaga e toe fausia o tou fale a'o fea fo'i?**

The following questions should help us to better understand tsunamis. Please help us in that by given your experience with the recent tsunami as best as you can remember.

#### Where were you when you felt the earthquake?

<input type="checkbox"/>	Inside own house	
<input type="checkbox"/>	Inside other people's house	
<input type="checkbox"/>	Inside school	
<input type="checkbox"/>	Inside other:	
<input type="checkbox"/>	Outside own house	
<input type="checkbox"/>	Outside other people's house	
<input type="checkbox"/>	On the street	
<input type="checkbox"/>	Outside other:	

#### What did you do after you felt the earthquake?

<input type="checkbox"/>	I continued with what I was doing
<input type="checkbox"/>	I rushed out of the house to see what was happening
<input type="checkbox"/>	I rushed out of the house to get myself to safety



<input type="checkbox"/>		Other	
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**When were you first aware of the tsunami?**

<input type="checkbox"/>	When I saw the water receding		
<input type="checkbox"/>	When I heard the water coming		
<input type="checkbox"/>	When someone warned me		
<input type="checkbox"/>	When I saw the water coming		
<input type="checkbox"/>		Other	

**How soon after the earthquake did you notice the tsunami?**

<input type="checkbox"/>	Immediately, i.e. I felt the earthquake and then the tsunami came straight away
<input type="checkbox"/>	Less than 5 minutes after the earthquake
<input type="checkbox"/>	Between 5 – 10 minutes after the earthquake
<input type="checkbox"/>	More than 10 minutes after the earthquake
<input type="checkbox"/>	I really don't know



**How many waves did you experience?**

<input type="checkbox"/>	Only one wave	<input type="checkbox"/>	More than three waves
<input type="checkbox"/>	Two waves	<input type="checkbox"/>	I really don't know
<input type="checkbox"/>	Three waves	<input type="checkbox"/>	

**Which waves was the largest?**

<input type="checkbox"/>	The first wave	<input type="checkbox"/>	The fourth wave
<input type="checkbox"/>	The second wave	<input type="checkbox"/>	The fifth wave or after that
<input type="checkbox"/>	The third wave	<input type="checkbox"/>	I really don't know

**How much time was there between the waves? ..... mins**

**From what direction did the water come and where did it go to?**

**When and how did you start to run away from the tsunami?**

<input type="checkbox"/>	Ran away _____ minutes before the tsunami arrival
<input type="checkbox"/>	Ran away just after seeing the tsunami coming
<input type="checkbox"/>	Did not run away, but stayed in the house
<input type="checkbox"/>	Did not run away, but stayed outside

**Were you caught in the tsunami water?**

<input type="checkbox"/>	Yes on the road
<input type="checkbox"/>	yes in the house
<input type="checkbox"/>	No, I was in a safe place

**How could you escape from the tsunami?**

<input type="checkbox"/>	I was able to swim
<input type="checkbox"/>	I held to floating materials
<input type="checkbox"/>	I could climb onto house / tree
<input type="checkbox"/>	Other reasons

**What did you know about tsunamis before your village was affected?**

<input type="checkbox"/>	Nothing, I never before had heard anything about tsunamis
<input type="checkbox"/>	I had heard about tsunamis before, but was not sure what it is exactly
<input type="checkbox"/>	I knew something about tsunamis, but I was not sure what to do



<input type="checkbox"/>	I knew enough about tsunamis that I was able to know what to do
<input type="checkbox"/>	

**How much is your home affected by the tsunami**

<input type="checkbox"/>	Home not affected by tsunami	
<input type="checkbox"/>	Home partly damaged, still living there	
<input type="checkbox"/>	Home partly damaged, moved out to	
<input type="checkbox"/>	Home fully damaged, moved out to	

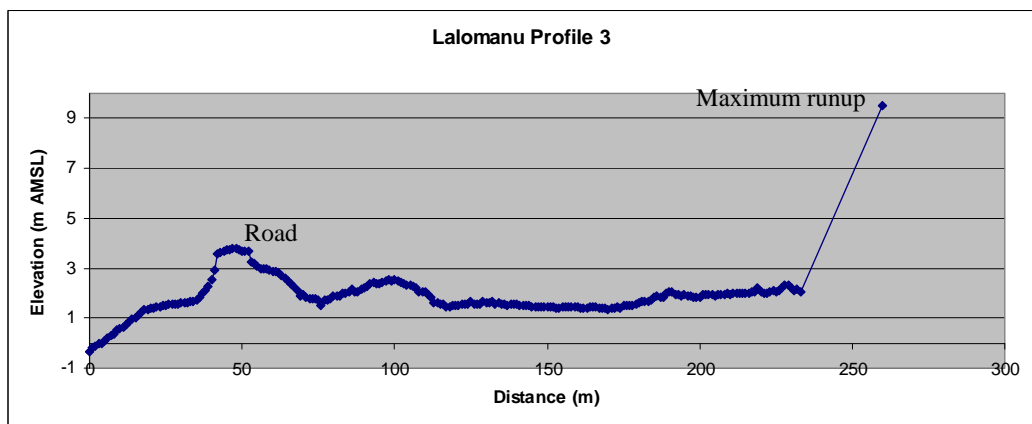
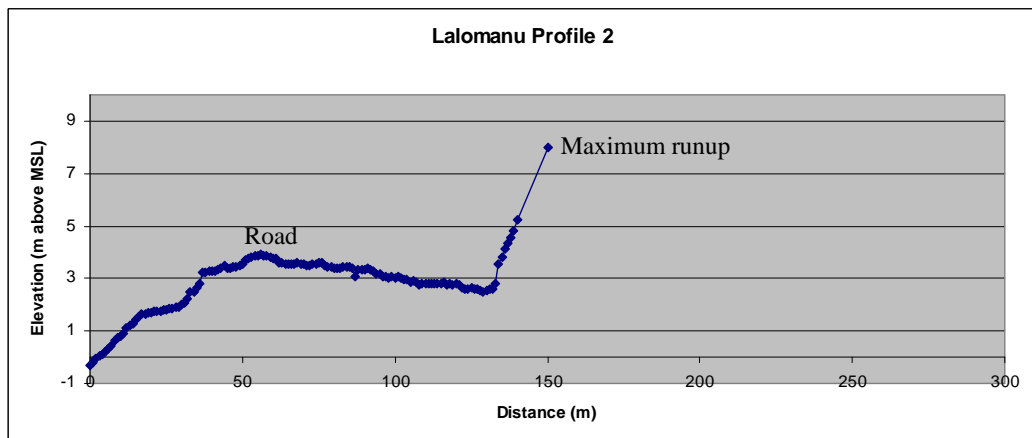
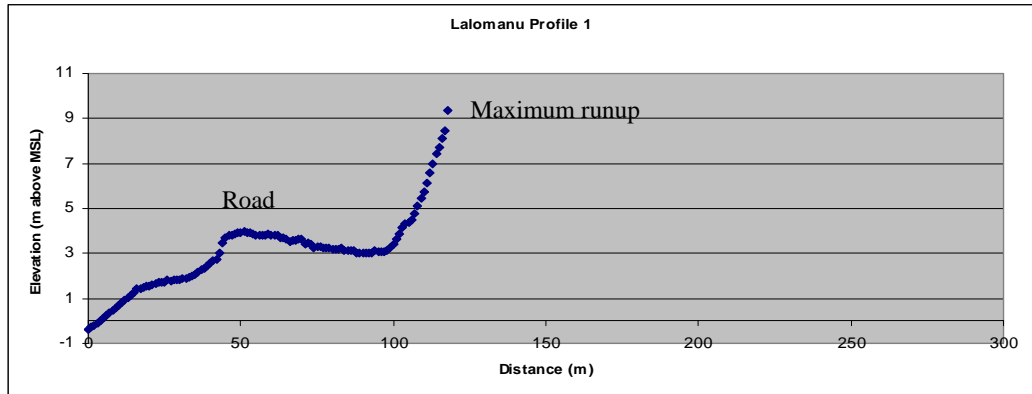
**How were people of your household affected by the tsunami?**

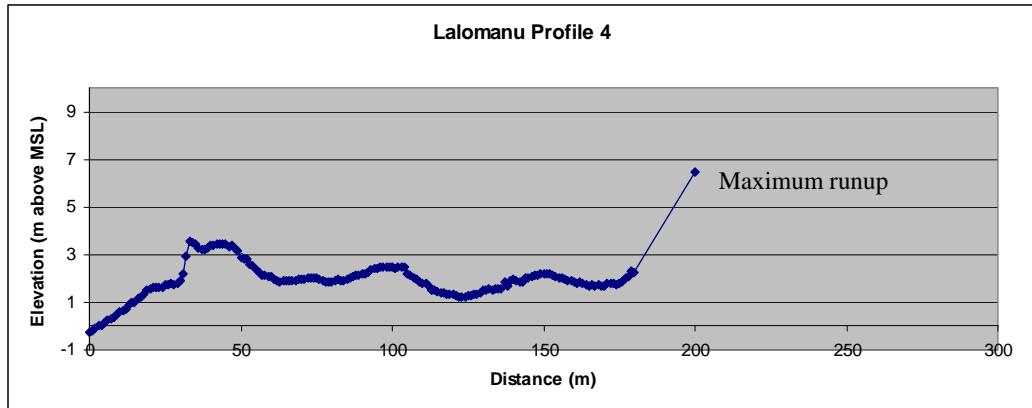
<input type="checkbox"/>	People from your household died in the tsunami
<input type="checkbox"/>	People from your household got injured
<input type="checkbox"/>	People from your household are still missing



## Appendix 5

### Some Topographic Profiles









## Appendix 6

### Current National Disaster Risk Management Programmes in Samoa

Implementing Organisation	Project Name	Donor	Reach	Duration
Ministry of Natural Resources and Environment (MNRE)	SIAM – 2 Project Component C4.0101A: School Curriculum Review to Include Disaster Management	World Bank	Community	July 9 2009– April 30 2010
Ministry of Natural Resources and Environment (MNRE)	SIAM – 2 Project Component C4.0101B: National Tsunami Awareness Workshops (including Early Warning Systems)	World Bank	Community	July 9 – Dec 31 2009
Ministry of Natural Resources and Environment (MNRE)	SIAM – 2 Project Component C4.0101C: Environment Impact Assessment Regulations Workshops	SOPAC, World Bank	Industries	July – Dec 31 2009
Ministry of Natural Resources and Environment (MNRE)	Disaster Awareness Village Workshops	SOPAC/EU/ACP Natural Disaster Facility	Community	
Women in Business Development Incorporation (WIBDI)	WIBDI/Oxfam Disaster Preparedness and Mitigation Programme		Community	On-going
Women in Business Development Incorporation (WIBDI)	Climate Change and Food Security	FAO	Community	
Samoa Red Cross Society and govt partner ministries	Community Based Health and First Aid (CBHFA) Program		Community	
Caritas Samoa	Building Disaster Response and Preparedness in the Pacific	AusAID	Community (Catholic Dioceses)	



## Appendix 7

### PRELIMINARY RECOMMENDATIONS

Since the UNESCO-IOC ITST Samoa has presented its findings group-by-group, we present our preliminary recommendations in a similar way. We must stress that given we have had insufficient time to post process the data, the recommendations are only preliminary. However, they should still be useful to decision makers.

#### **Inundation and Run-up Recommendations**

The tsunami inundation distances, flow depths and runup heights along the east, southeast and west coast of Upolo Island were variable and site specific. The variability is largely attributed to the complex nearshore bathymetry; the existence of offshore reefs as well as the offshore islands influenced tsunami energy and directionality. This situation led to different types of damage to buildings and infrastructure, as well as to varying impacts on the coastal environment and human casualties.

To reduce and mitigate the hazard of future tsunamis within the region we make the following recommendation:

Recommendation 1: Collection and compilation of a detailed nearshore bathymetric and coastal topographic dataset

We highly recommend the collection of LIDAR data for this purpose. Coverage of the offshore reefs and islands is vital as they have a strong influence on the nearshore tsunami wave propagations and inundation distances. Such a dataset could be used to model other tsunami sources and help the Samoan communities better prepare for future events.

#### **Building Damage Recommendations**

The reconnaissance mission achieved all of its objectives. The surveying equipment, though cumbersome to transport, worked well in the field and has given data that we believe is unique and will prove invaluable for calibrating tsunami inundation and loss models. Analysis of the data is ongoing and further results will be published in due course. Hence, this data is preliminary and subject to uncertainties.

The following recommendations are based on the data we have collected and the observations made.

#### **Building material, building code and workmanship**

We've seen a huge variation in the quality and resistance of buildings not only because of the different types of construction but also due to poor quality of



building material, poor workmanship and buildings built not according to the building code. Our impression was that a lot of people are not aware of the benefits building to the standard.

Recommendation 2: People should be educated and informed about the building code but more importantly also about the importance and benefits of following the building code. This applies not only to tsunami but to all hazards

Recommendation 3: The education process should take place at village level to ensure that local authorities are involved. Oral and visual presentations will be more efficient than simply distributing information

Recommendation 4: The education also needs to involve technical staff because they have to be familiar with it and should act as advocates for the building code

Recommendation 5: It is suggested that there will be more rigorous controls that people follow the building code. This will ensure more resilient buildings and also applies to other hazards

Recommendation 6: It is extremely important that these improvements will be implemented as soon as possible as the recovery process has already begun. People are starting to re-build or relocate

Recommendation 7: It should be ensured that high quality material is being used

### **Construction type**

The importance of reinforcement was very clear, buildings with reinforcement sustained significantly less damage than light structures such as timber framed buildings. It was surprising that critical facilities such as schools for instance are constructed the same way as ordinary houses.

Recommendation 8: In high risk areas reinforced buildings should be recommended. This also applies to all hazards

Recommendation 9: Reinforcement for critical facilities such as schools or hospitals should be mandatory

Recommendation 10: In high risk areas reinforced buildings should be recommended. This also applies to all hazards

Recommendation 11: If using natural products it should be ensured that it is well built

Recommendation 12: Traditional rockfill foundations need to be sufficiently



armoured otherwise there is a very high risk of undermining which can ultimately cause the building to collapse

The survey showed numerous buildings with foundations only a few centimetres thick. These foundations sustained severe damage and often caused subsequent wall damage.

Recommendation 13: Foundations should be sound and solid

### **Debris**

Clear evidence was found that debris increased the damage manifold. Often the debris was manmade such as moving watertanks.

Recommendation 14: Man-made objects in the vicinity to the coast should be anchored. This also applies to cyclones and earthquakes

Recommendation 15: Seawall coastal protections have to be well made or rocks of big enough size not to minimize debris

### **Natural environment**

Nature often provides natural protection against coastal flooding or tsunamis such as mangroves or reefs if intact. However, a lot of people are not aware that protecting the environment has numerous benefits, one of them being tourism and coastal protection.

Recommendation 16: Educate the population about how to protect the environment and the benefits of it

Recommendation 17: Protect the reef as well as other natural vegetation in the coastal zone as it reduces the energy of the storm surge or tsunami waves

Recommendation 18: Introducing Integrated Coastal Zone Management could reduce conflicts of interest (Multi-Hazard approach)

### **Preparedness**

There is an obviously lack of information about both the risk of natural hazards and associated consequences as well as to how to prepare for such an event. There has also been some confusion about the warning system, about who activates the sirens and when.

Recommendation 19: People should be informed and educated about the risk of natural hazards and how to prepare for them

Recommendation 20: Identify and sign evacuation routes and assembly areas as



there seems to have been confusion about where to go

Recommendation 21: Establish an effective warning system and have clear protocols in place

Recommendation 22: People also need to be educated that they should not rely on warnings but self-evacuate whenever they feel a strong earthquake

## Geology recommendations

Recommendation 23: The written record of historical tsunamis in Samoa is limited yet it is clear from the tectonic setting of the islands and field evidence from exploratory trenches that Samoa is vulnerable to tsunami impact. A paleotsunami investigation would extend the record of known tsunami impacts back in time and could likely provide useful information on the recurrence interval and magnitude of past tsunamis. This information is critical to tsunami mitigation and planning efforts for developing more disaster resistant communities

Recommendation 24: Our measurements and observations show highly variable local tsunami impacts as a result of small-scale variations in tsunami flow characteristics. Local topography and bathymetry is a critical element in detailed modelling studies that predict tsunami inundation. High-resolution topographic and bathymetric, such as that derived by airborne lidar, multibeam mapping, or dense ground surveys, would greatly facilitate improved inundation models. Inundation models are an effective means of identifying hazardous areas as a step to improve public safety and infrastructure security

Recommendation 25: In terms of risk management, the maximum debris wrack line (vegetation rampart) is an important feature to map as marks the limit of greater damage due to pushing and lifting forces of the carried load (mainly trunks and branches, sometimes cars or boats). The maximum debris line is always closer to the coastline than the inundation limit, beyond which inundation can occur but no strong structural damages are expected. In many areas this feature can be mapped remotely by high-resolution aerial imagery

Recommendation 26: Developing in-country expertise in hazard identification and mapping could improve Samoa's ability to plan, mitigate, and respond to future hazards. Technical training should be encouraged and supported wherever possible

## Ecology and biodiversity recommendations

Recommendation 27: Indigenous coastal, mangrove, swamp and inner coastal plain trees, shrubs and other vegetation should be systematically protected,



rehabilitated and replanted as a basis for future mitigation and adaptation to tsunamis and other extreme events and to assist in the rehabilitation of affected areas

Recommendation 28: There should be an active program of rehabilitation and replanting of those plants, including resistant and culturally important varieties (e.g., selected breadfruit varieties, such as puou and ma'afala, and banana and plantain cultivars, such as misiluki and paka)

Recommendation 29: There is a need for extensive programs for the propagation, multiplication and distribution, and relevant technical assistance of appropriate planting materials

Recommendation 30: There should be an extensive effort at community-based protection, propagation, replanting and enrichment of coastal and mangrove forests, with special emphasis on the re-establishment of rare coastal and mangrove associated species

Recommendation 31: There is a need for a comprehensive education and public awareness programme related to the critical link between culture and environment as a basis for community survival, and that knowledgeable older persons, with extensive traditional knowledge be intimately involved

Recommendation 32: There is a need to identify the locations of threatened or endangered plants and develop a GIS showing the locations of these species

Recommendation 33: Because there are a number of extremely durable rare or uncommon culturally important, trees and shrubs that have survived, almost unaffected by the tsunami (e.g., pani, milo, ifilele, fao, tausuni, leva, tau'anave, futu, to'ito'i, etc.), there should be an active program in promoting the propagation and planting of these underutilized and often ignored and "forgotten species" as a basis for mitigation and adaptation

Recommendation 34: There is a need for seawalls and natural barriers to be better consolidated and combined with extensive tree, shrub and groundcover plantings to enhance their protective role

Recommendation 35: Because the current study was conducted over a very brief period of time, appropriate Samoan agencies should be supported to carry out continued studies of the recovery of the natural, cultural and agricultural plants and vegetation, at least over the year following the tsunami, with a concerted efforts being made to involve local Samoan students and local communities in applied research and monitoring projects that build local capacity

Recommendation 36: Care must be taken to immediately establish quarantine and



phytosanitary procedures to monitor and prevent the possible introduction of new, and the spread of existing, invasive species

Recommendation 37: Initiate a clean-up of beach and subtidal areas at locations such as Lalomanu

Recommendation 38: Survey the fore-reef area to assess the impact on the reef front and determine impact from material removed and assess damage created by material falling down the reef front

Recommendation 39: Develop a monitoring program to assess the medium and long-term effects of the tsunami on the coral reef benthos and fish populations

Recommendation 40: Compare the resilience of the MPA and non MPA locations to assess to see if there is a protection benefit

Recommendation 41: Reconsider the locations of the no-take zone with regard to the tsunami hazard

Recommendation 42: Assess the foraging and nesting areas for the turtles at Aleipata

Recommendation 43: Assess the state of food-fish population

### **Video interviewing sub-group recommendations: Building local capacity**

Recommendation 44: It is essential to have local people available to assist the team, provide easier access to communities and ensure protocols are followed

Recommendation 45: A local student or government employee should be involved in the process of recording survivor stories in order to integrate and utilise information for disaster preparedness. They can also learn skills necessary to conduct studies and undertake follow up

Recommendation 46: Skills in collecting life stories should be developed or expanded locally at institutions such as USP Alafua and NUS in order to continue this work

### **Improving the process**

Recommendation 47: Future teams could include one interviewer and one or two interview assistants to collect the biographical, additional and interview data





Recommendation 48: The physical setting and movement of items could also be recorded by asking survivors to describe and show where items had been and where they moved to during the tsunami. This information would then complement the geology and structural teams and provide local knowledge to verify the course of events

Recommendation 49: Interviews could also be conducted with members of the medical, police, fire teams and employees from the funeral homes to identify challenges experienced and how these could better addressed

Recommendation 50: Survivors' impressions of assistance from the medical, police, fire teams and aid organisations could also be documented

### **Suggestions for the future/follow up activities**

Recommendation 51: Resource and support for translations of video interviews into English and/or Samoan could be sought so that materials may be accessed by a broader audience both locally and internationally

Recommendation 52: Interview and video materials should be analysed to improve tsunami mitigation

Recommendation 53: Stories from this project should be used for educational purposes including the preparation of public service announcements for both radio and television to be made using sound bytes and survivor stories

Recommendation 54: Some form of debrief/counselling for team members to assist in dealing with the information they hear should be provided

Recommendation 55: Follow up interviews should be conducted with the survivors interviewed in this project six months to one year later to document their progress and the process of recovery. Other survivors not part of this project could also be included

Recommendation 56: It may also be useful to document long term medical treatment from a survivor perspective

Recommendation 57: The recommendations of the Social Impacts group with regard to the welfare and well being of the people are also endorsed by this group

### **Social Science Recommendations**

#### **Rebuilding homes and villages**

Recommendation 58: Government to address the short term needs identified as



soon as possible within the next 6 months

Recommendation 59: Building houses and providing clean water are priorities. Working in cooperation with other organizations, the affected people, the Government should present an initiative within the next two weeks. Although it is understood that implementation will take much longer it is considered as crucial to involve the affected population as early as possible, as the need for housing and water supply is urgent, and as activities to build houses have started in many places already

Recommendation 60: Government should consider how to make loans available to people for building projects or re-establishment of small businesses. It should follow a strategy, where people can contribute as much as they are able to do, but get support whenever damages have exceeded their capacities to respond adequately. The reconstruction effort should be seen as a chance to provide better infrastructure, better housing, etc. compared to the situation prior to the tsunami. Make the tsunami a new beginning, a tragic event, about people in many years into the future can say that it was the beginning of positive changes to their lives

Recommendation 61: Government should ensure that no people have been neglected, especially those living far inland. They too should be provided assistance and have access to support

Recommendation 62: New developments need to include building codes, disaster plans, and training for local people. Here the Government (and other organizations) have a chance to recommend / initiate / support improvements as much as has been destroyed and it rebuilt from scratch. This however requires timely initiative and close co-operation with affected people and providing incentives to the people

Recommendation 63: The government should address the short term needs identified as soon as possible within the next 12 months

Recommendation 64: The government should consider the medium term needs and allocate resources appropriately within the next year

## **Health and well-being (physical and psychological)**

Recommendation 65: Intangible losses to Samoan people as well as their emotional, spiritual and psychological needs must be considered (see following report)

Recommendation 66: Traditional roles of the pastors, lay preachers, deacons, women fellowships, matai, teachers and schools be acknowledged and their capacities improved / developed to provide opportunities to survivors of the



tsunami to discuss, share testimonies for therapeutic purposes. Be pro-active in this important field and not re-active, i.e. take up initiatives before sign of trauma really becomes visible

Recommendation 67: The impact of the tsunami on children and their psyche must be addressed. Children should be encouraged to heal, in school, church and family forums. How this can be accomplished needs reflection together with experts in disaster psychology for children. Capacities in this field need to be created as quickly as possible

Recommendation 68: Community support teams with expertise in psychological issues should be coordinated in order to avoid duplication of effort

Recommendation 69: Some form of debrief/counseling for team members to assist in dealing with the information they hear is needed

## **Public awareness and disaster preparedness**

Recommendation 70: Educational awareness and knowledge of tsunami and disasters, targeting all levels of the community, should be continued and strengthened

Recommendation 71: Disaster risk reduction initiatives should be strengthened at the local level, seeking to build on existing capacity and capability

Recommendation 72: An annual event to commemorate 29<sup>th</sup> September 2009 and use it for Tsunami Awareness and educational purposes should be instituted

Recommendation 73: Adopt a process to guide the selection of the promising post disaster livelihood options for those affected men, women and children (e.g. adaptation of the SBEC – Small Business Enterprise Centre)

Recommendation 74: Build resilience and sustainability in communities by addressing the root causes of vulnerability

Recommendation 75: Build on existing reports to: a) identify existing local resilience and capability and b) develop innovative local solutions