SOPAC Member Countries National Capacity Assessments:

Tsunami Warning and Mitigation Systems

Consolidated Regional Report

Prepare • Receive • Communicate • Respond

Australian Government
AusAID

Australian Government
Bureau of Meteorology

Australian Government
Attorney-General's Department

SOPAC

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Consolidated Regional Report

RESULTS SUMMARY

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Document Control

Approved for release:	Dr Ray Canterford (Deputy Director, Services)	Date: 23 February 2011
Corrections & comments:	Cherie Stitz (formally O'Brien) Australian Bureau of Meteorology GPO Box 1289 Melbourne VIC 3001 E-mail: c.stitz@bom.gov.au Phone: +61 (3) 9669 4801 Fax: +61 (3) 9669 8161	
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Acronyms

AGD	Australian Attorney-General's Department
AM	Amplitude Modulated
ATWS	Australian Tsunami Warning System
AusAID	Australian Agency for International Development
Bureau	Australian Bureau of Meteorology Bureau
CEOs	Chief Executive Officers
DFAT	Australian Department of Foreign Affairs and Trade
DM	Disaster Management
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EMA	Emergency Management Australia
EMWIN	Emergency Managers Weather Information Network
FM	Frequency Modulated
FSM	Federated States of Micronesia
GA	Geoscience Australia
GIS	Geographic Information Systems
GPRS	General Packet Radio Services
GTS	Global Telecommunications System
HF	High Frequency
ICG	Intergovernmental Coordination Group
IOC	Intergovernmental Oceanographic Commission
ISDR	International Strategy for Disaster Reduction
ITIC	International Tsunami Information Centre
ITSU	ICG for the Tsunami Warning System in the Pacific
JATWC	Joint Australian Tsunami Warning Centre
Mw	Moment Magnitude
NA	Not Applicable
NAP	National Action Plan (for DRM)
NDMO	National Disaster Management Office
NGOs	Non-Government Organisations
NMHSs	National Metrological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration
PGSP	Pacific Governance Support Programme
PICs	Pacific Island Countries
PNG	Papua New Guinea
PPSLP	Pacific Public Sector Linkages Program
PTWC	Pacific Tsunami Warning Centre
PTWS	Pacific Tsunami Warning and Mitigation System
RA V	World Meteorological Organisation Region V Association
RANET	Radio and Internet for the Communication of Hydro-Meteorological Information for Rural Development
SMS	Short Message Service
SOPAC	Pacific Islands Applied Geoscience Commission
SOPs	Standard Operating Procedures
SPREP	South Pacific Regional Environment Programme
TOR	Terms of Reference
UNESCO	United Nations Educational, Scientific and Cultural Organization
USA	United States of America
VHF	Very High Frequency
VSAT	Very Small Aperture Terminal
WMO	World Meteorological Organisation

1. Summary

1. Summary

1.1. Background

1.1.1. This Report

The Consolidated Regional Report is a collation of results from the 14 Pacific Islands Applied Geoscience Commission (SOPAC) Member countries involved in the Tsunami Capacity Assessment project. The report looks at regional commonalities and the status of current tsunami warning and mitigation systems, as well as common recommendations made to improve these systems.

Further detail on a country level can be obtained from the National Tsunami Capacity Assessment Reports. Details on how to access these reports can be found in Table 3.

Results were accurate at the time the tsunami capacity assessment was undertaken in each country. Since then, some changes to the countries status with regard to particular aspects of their tsunami warning and mitigation system can be expected. As is normally a matter of course when developing projects, it is recommended that each country is consulted to clarify progress since the Tsunami Capacity Assessment as part of project planning. Annexure 4 contains a checklist for development of new projects based on the findings of the Tsunami Capacity Assessments (this Project).

1.1.2. Intended Audience

This report is written primarily for international aid organisations and forums involved in facilitating enhancement of tsunami and multi-hazard early warning systems and Disaster Risk Management (DRM) in the PICs. This includes potential development partners that may have project development and fund allocations to be made in this space. The report can also be used by countries as evidence to underpin and boost submissions to development partners for enhancement in multi-hazard early warning systems and DRM at a country or Regional level.

1.2. Executive Summary

The Tsunami Capacity Assessment project assessed the capacity of individual nations to manage tsunami events to better guide national and donor strategic effort and funding towards achieving targeted system improvements.

The fourteen SOPAC member countries who participated in the project were the Cook Islands, the Federated States of Micronesia (FSM), Fiji, Kiribati, the Marshall Islands, Nauru, Niue, Palau, Papua New Guinea (PNG), Samoa, the Solomon Islands, Tonga, Tuvalu and Vanuatu. The key

deliverable of the project was internationally recognised and detailed National Reports, and this Consolidated Regional Report outlining the next steps needed to enhance tsunami warning and mitigation systems in the region.

The strength of the project was to bring together appropriate professionals, agencies, commercial, non-government and community based organisations from across each country to discuss tsunami warning and mitigation. The project involved some 500 people from 300 organisations across the 14 Pacific Island Countries (PICs) involved. Country level considerations are often not addressed in detail in international forums. However, this project enabled each country to discuss their national needs and issues and map a positive way forward to enhance the country's system. The recommendations made at a country level were ranked in priority and resource intensity. This assisted in identifying the 'low hanging fruit' that could be addressed nationally by countries using existing resources.

Table 1 outlines a summary of the Status of Key System Components for each country involved in the project.

Table 1: Country Summary, Status of Key System Components

	SOPAC Member Countries													
% Per Country	Cook Islands	Federated States of Micronesia	Fiji	Kiribati	Marshall Islands	Nauru	Niue	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Tuvalu	Vanuatu
% Yes	28	28	22	9	38	13	12	16	19	75	25	19	19	28
% No	38	34	3	44	25	44	39	22	38	9	22	28	34	22
% Partially	34	38	75	47	38	44	45	63	44	16	53	53	47	50
% NA	0	0	0	0	0	0	3	0	0	0	0	0	0	0

Table 2 outlines a number of recommendations that were commonly made across the Tsunami Capacity Assessments. The recommendations are sorted by the number of countries to which each recommendation applies.

Five recommendations are common across 13 or more countries. These are:

- Expansion of the current or development of a tsunami community awareness program;
- Upgrade, strengthen and develop international communications systems to enable effective and efficient broadcast and two way information exchange, including timely receipt of international tsunami and other warnings from Pacific Tsunami Warning Centre (PTWC) and others;
- Implementation of effective, efficient and sustainable mechanisms for dissemination of tsunami and multi-hazard warnings to local centres (such as outer island Police stations) and the population with particular consideration given to reaching remote communities and warning the public outside of waking hours;

- Improved in-country coordination of communications systems (existing and new) to enable effective use, interoperability and reliability for tsunami warnings, multi-hazard warnings, emergency response and other functions (for example, education and health); and
- Development or enhancement of Standard Operating Procedures (SOPs) for the operation of the country's tsunami warning and response service.

A number of other recommendations with regard to Tsunami Emergency Response (including evacuation), Tsunami Hazard, Vulnerability, Risk and Mitigation and Governance and Coordination appear quite high on the list in Table 2, reflecting the importance of in-country coordination and greater understanding of the risk of tsunami to individual nations to enable them to interpret the local tsunami threat to their communities.

Each recommendation made by the project provides an opportunity to mitigate the risk of tsunami on PICs through focused projects. Ideally, implementation of a large program of work could be completed to enhance tsunami warning and mitigation systems in PICs using this regional report as an overarching strategic framework. Annexure 4 of this report contains a checklist for development of new projects or programs based on the recommendations of this Tsunami Capacity Assessment Project. It is also recommended that the progress of PICs in improving their tsunami warning and mitigation systems be monitored by revisiting this assessment project in the future.

The Bureau has facilitated the dissemination of National reports and this Regional report to development partners and other stakeholders to ensure maximum exposure of results in the hope of facilitating further capacity development projects being undertaken based on the results of this project. Each national report provides an improvement strategy. PICs involved in the project are encouraged to use their National Tsunami Capacity Assessment report to guide both national projects and projects funded by development partners to achieve targeted improvements of their tsunami warning and mitigation systems. In turn, this will assist in improving systems for other natural hazards.

Table 2: Top recommendations for each aspect of Pacific Island Tsunami Warning and Mitigation Systems. Recommendations are sorted in this table based on the number of countries for which the recommendation was made

Topic	Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Public and Stakeholder Awareness, Education and Training	Awareness Program	Expansion of the current OR development of a tsunami community awareness program. Collaborate between organisations and incorporate the program into a multi-hazard framework supported by work plans and budgets. Build evaluation into this program to review its effectiveness. Include awareness raising of tsunami warnings, action to take on receiving a warning, post event education and natural tsunami warning signs for those countries with local tsunami generation sources	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu	**14**
Communications	International broadcast systems	Upgrade, strengthen and develop international communications systems to enable effective and efficient broadcast and two way information exchange, including timely receipt of international tsunami and other warnings from PTWC and others	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu	**14**

Topic	Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Communications	In-country dissemination	Implementation of effective, efficient and sustainable mechanisms for dissemination of tsunami and multi-hazard warnings to local centres (such as outer island Police stations) and the population with particular consideration given to reaching remote communities and warning the public outside of waking hours Options include: RANET Chatty Beetle, satellite broadcast, national SMS, dedicated HF or VHF radio, GPRS, VSAT, traditional methods such as church bells, sirens (police car or fixed), AM and FM radio, television etc. *(For definitions refer to Acronyms list)*	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu	**14**
Communications	Improved in-country coordination	Improved in-country coordination of communications systems (existing and new) to enable effective use, interoperability and reliability for tsunami warnings, multi-hazard warnings, emergency response and other functions (for example, education and health)	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu	**14**
Governance and Coordination	Standard Operating Procedures	Develop OR enhance SOPs for the operation of the country's tsunami warning and response service	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Solomon Islands, Tonga, Vanuatu	**13**
Tsunami Emergency Response (including evacuation)	Testing & Exercising	Conduct regular multi-stakeholder tests/exercises of the tsunami warning and response arrangements including a post exercise debrief to further enhance procedures and training	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Tonga, Tuvalu, Vanuatu	**12**

Topic	Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Tsunami Emergency Response (including evacuation)	Evacuation Planning	Begin OR continue to make plans for the safe evacuation of communities at risk of tsunami including consideration of evacuation shelters, maps, signage and drills	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Solomon Islands, Tonga, Vanuatu	**12**
Tsunami Hazard, Vulnerability, Risk and Mitigation	Inundation Modelling	Investigate future options for completing tsunami inundation modelling in partnership with regional and international bodies, particularly for population and infrastructure centres	Cook Islands, FSM, Fiji, Kiribati, Niue, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu	**11**
Governance and Coordination	Tsunami Sub-plan	Develop a tsunami specific national plan as a sub-plan to the national DRM plan. This can be implemented for other hazards	Cook Islands, Fiji, Kiribati, Nauru, Niue, Palau, PNG, Solomon Islands, Tonga, Vanuatu	**11**
Governance and Coordination	National DRM Plan	Finalise OR review national level DRM plans and commence implementation	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Niue, Palau, PNG, Tonga, Tuvalu, Vanuatu	**11**
Research Expertise	Proactively Encourage and Cooperate	Proactively encourage and actively cooperate with regional and international organisations that can assist with conducting scientific research and building in-country technical capacity in seismology and tsunami science	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Palau, Samoa, Solomon Islands, Tonga, Vanuatu	**10**
Tsunami Hazard, Vulnerability, Risk and Mitigation	Use Available Studies	Use the tsunami hazard studies completed for the Southwest Pacific Nations to date, historical records, Geographic Information Systems (GIS) data and deep ocean models to identify low-lying communities potentially at tsunami risk	Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Palau, PNG, Samoa, Solomon Islands, Vanuatu	**10**
Tsunami Hazard, Vulnerability, Risk and Mitigation	Acquire Baseline Data	Acquire the necessary high resolution topography and bathymetry data for centres at risk of tsunami as part of a multi-hazard mapping activity. Possible opportunities exist to capitalise on climate change synergies	Cook Islands, Fiji, Kiribati, Marshall Islands, Palau, PNG, Samoa, Solomon Islands, Tonga, Vanuatu	**10**

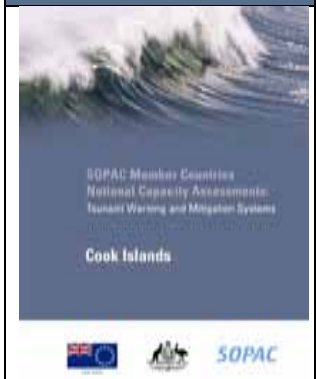
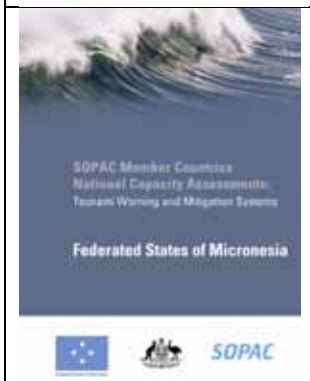
Topic	Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Public and Stakeholder Awareness, Education and Training	Training Program	Develop a tsunami training program, including training for emergency managers, science / warning agencies and others involved in tsunami warning and mitigation within the country. Training should be conducted within a competency-based framework where appropriate (for example, for issuing tsunami warnings)	Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Solomon Islands	**10**
Public and Stakeholder Awareness, Education and Training	Media Education	Develop a tsunami media education program to assist the media to understand the tsunami hazard and warning procedures, therefore passing the correct information onto the community. This should be incorporated into a multi-hazard framework	Cook Islands, FSM, Fiji, Marshall Islands, Nauru, Palau, Tonga, Tuvalu, Vanuatu	**9**
Regional and International Coordination	International Tsunami Working Group	Nominate a representative OR continue to participate in the Intergovernmental Coordination Group Pacific Tsunami Warning and Mitigation System (ICG/PTWS) Southwest Pacific Tsunami Working Group	Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Palau, Samoa, Tonga, Tuvalu	**9**
Regional and International Coordination	Become IOC Member	Become a member of the Intergovernmental Oceanographic Commission (IOC) to ensure the country has a voice in determining IOC programmes and activities of benefit nationally as well as benefiting from IOC capacity building in marine science	FSM, Kiribati, Marshall Islands, Nauru, Niue, Palau, Tonga, Vanuatu	**8**
Tsunami Emergency Response (including evacuation)	NDMO Resources & Profile	Resource the National Disaster Management Office (NDMO) to effectively carry out their DRM coordination role and build their profile throughout the country (for example, through free media)	Cook Islands, Fiji, Kiribati, Marshall Islands, Palau, PNG, Tonga	**7**

Topic	Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Tsunami Warnings	Warning SOPs - Use of Scientific Information	Use available scientific information to nationalise the tsunami threat (for example, arrival times, forecast points, sea level data, deep ocean models showing energy propagation)	Cook Islands, Marshall Islands, Nauru, Palau, PNG, Tuvalu, Vanuatu	**7**
Research Expertise	Develop Protocol to Receive Studies	Develop a protocol to ensure copies of scientific research reports and data are received and archived by the SOPAC member country as soon as possible post study completion	Cook Islands, Fiji, Kiribati, Samoa, Solomon Islands, Vanuatu	**6**
Tsunami Monitoring Infrastructure	Sea Level Data Access	Investigate access to and training in the interpretation of Pacific Region sea level data to enable integration of this data into tsunami warning procedures. Approach to data access will vary by country (for example, web access, Global Telecommunications System (GTS), restoring real time links for in-country stations)	Fiji, Kiribati, Marshall Islands, Nauru, Samoa, Solomon Islands	**6**
Tsunami Monitoring Infrastructure	International Data Sharing	Ensure any future project agreements with development partners for upgrade or installation of new monitoring equipment includes sharing of seismic and sea level data internationally in real-time and suitable data formats	Cook Islands, Fiji, Marshall Islands, PNG, Tonga, Vanuatu	**6**
Tsunami Warnings	Formalise Responsibility	Formally designate the responsibility and authority for receiving, analysing and interpreting tsunami messages and data and issuing national tsunami warnings (using national plans and legalisation)	Cook Islands, Kiribati, Nauru, Niue, Palau, Vanuatu	**6**
Tsunami Warnings	Warning SOPs - No Threat	Issue a "No Threat" bulletin for tsunami that are not expected to impact the country or felt earthquakes that will not generate tsunami	Fiji, Marshall Islands, Nauru, Samoa, Tonga, Vanuatu	**6**

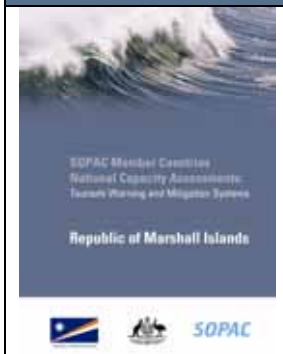
Topic	Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Tsunami Monitoring Infrastructure	Establishment of Seismic Network	Continue establishment of new OR improved seismic network and strengthen the capacity of responsible agencies to fully utilise, maintain and sustain the network (using national funds if required). (Vanuatu - also volcano monitoring)	Fiji, PNG, Samoa, Tonga, Vanuatu	**5**
Regional and International Coordination	Share Tsunami Report Findings & DRM Information	Share the findings of the country's National Tsunami Capacity Assessment Report with international and regional organisations to provide guidance on targeting future capacity development programs and projects. Share DRM information more generally through existing means such as Pacific Disaster Net	Cook Islands, Fiji, Samoa, Tonga	**4**
Research Expertise	Research Past Events	Conduct research into past wave inundation events and paleo-tsunami studies	Fiji, Nauru	**2**

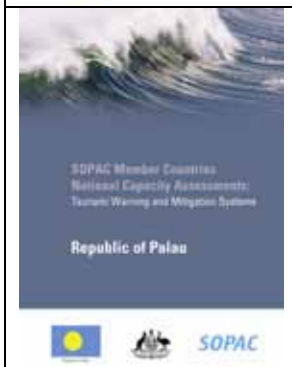
Table 3: Location of country specific reports

In addition to on the following websites, electronic PDF copies (in large and small file sizes) of these National Reports and the Regional Report can be found on the CD in attachment 1.

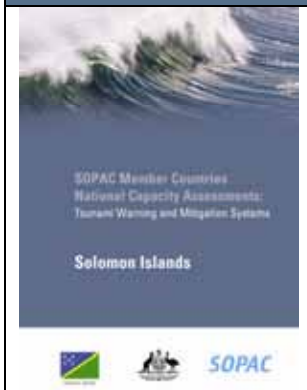
Front Cover	SOPAC Member Country	Bureau Website (www.bom.gov.au)	Pacific Disaster Net Document Identification Number (www.pacificdisaster.net)
	**The Cook Islands**	www.bom.gov.au/tsunami/assessments/cook	3029
	**The Federated States of Micronesia**	www.bom.gov.au/tsunami/assessments/micronesia	6333

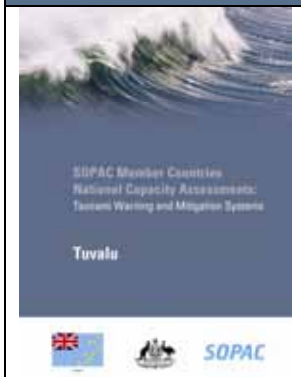
Front Cover	SOPAC Member Country	Bureau Website (www.bom.gov.au)	Pacific Disaster Net Document Identification Number (www.pacificdisaster.net)
	**Fiji**	www.bom.gov.au/tsunami/assessments/fiji	3027
	**Kiribati**	www.bom.gov.au/tsunami/assessments/kiribati	5126

Front Cover	SOPAC Member Country	Bureau Website (www.bom.gov.au)	Pacific Disaster Net Document Identification Number (www.pacificdisaster.net)
	**The Marshall Islands**	www.bom.gov.au/tsunami/assessments/marshall	5127
	**Nauru**	www.bom.gov.au/tsunami/assessments/nauru	5128

Front Cover	SOPAC Member Country	Bureau Website (www.bom.gov.au)	Pacific Disaster Net Document Identification Number (www.pacificdisaster.net)
	**Niue**	www.bom.gov.au/tsunami/assessments/niue	5133
	**Palau**	www.bom.gov.au/tsunami/assessments/palau	5132

Front Cover	SOPAC Member Country	Bureau Website (www.bom.gov.au)	Pacific Disaster Net Document Identification Number (www.pacificdisaster.net)
	**Papua New Guinea**	www.bom.gov.au/tsunami/assessments/papua	5129
	**Samoa**	www.bom.gov.au/tsunami/assessments/samoa	3028

Front Cover	SOPAC Member Country	Bureau Website (www.bom.gov.au)	Pacific Disaster Net Document Identification Number (www.pacificdisaster.net)
	**The Solomon Islands**	www.bom.gov.au/tsunami/assessments/solomon	3030
	**Tonga**	www.bom.gov.au/tsunami/assessments/tonga	3048

Front Cover	SOPAC Member Country	Bureau Website (www.bom.gov.au)	Pacific Disaster Net Document Identification Number (www.pacificdisaster.net)
	**Tuvalu**	www.bom.gov.au/tsunami/assessments/tuvalu	5130
	**Vanuatu**	www.bom.gov.au/tsunami/assessments/vanuatu	5131

2. The Project

2. The Project

2.1. Section Summary

- The Tsunami Capacity Assessment project assessed the capacity of individual nations to manage tsunami events to focus national and donor strategic efforts and funding towards achieving systematic and sustainable improvements.
- The fourteen SOPAC member countries who participated in the project were the Cook Islands, the FSM, Fiji, Kiribati, the Marshall Islands, Nauru, Niue, Palau, PNG, Samoa, the Solomon Islands, Tonga, Tuvalu and Vanuatu.
- The key deliverable of the project was internationally recognised National Reports which then fed into this consolidated Regional Report outlining the next steps needed to enhance tsunami warning and mitigation systems in the region.

2.2. About the Project

The National Capacity Assessment of SOPAC Member Countries: Tsunami Warning and Mitigation Systems project worked in collaboration with the member countries of SOPAC to assess their capacity to receive, communicate and respond effectively to tsunami warnings. The implementation of the project was led by the Australian Bureau of Meteorology (the Bureau), in partnership with the Australian Attorney-General's Department (AGD), (formerly Emergency Management Australia (EMA)), SOPAC, and with the assistance of the IOC a division of the United Nations Educational, Scientific and Cultural Organization (UNESCO). The project was funded by the Australian Agency for International Development (AusAID) under the Pacific Governance Support Programme (PGSP).

The fourteen SOPAC member countries who participated in the Tsunami Capacity Assessment project were the Cook Islands, the Federated States of Micronesia, Fiji, Kiribati, the Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, the Solomon Islands, Tonga, Tuvalu and Vanuatu (refer to Figure 2).

One of the three policy objectives of the recently completed Australian Government *Australian Tsunami Warning System* (ATWS) project was '*To contribute to the facilitation of tsunami warnings for the South West Pacific'*. The Tsunami Capacity Assessment project contributed to the achievement of that policy objective. Also, as part of the implementation of the ATWS, Australia has and will continue to contribute to the facilitation of more effective tsunami advisory

bulletins to PICs through the provision of seismic and sea level observations to the PTWC in Hawaii in real time.

2.3. Project Aim

By undertaking an assessment of the capacity of individual nations to manage tsunami events, the project aimed to better guide national and donor strategic effort and funding towards achieving targeted improvements in the tsunami warning and mitigation systems in each SOPAC member country. The project has assisted in identifying requirements for further capacity building programs and projects that can be implemented by the countries themselves, or through engagement with development partners.

2.4. Key Project Outputs

The key deliverable of the project was an internationally recognised and detailed national set of assessment reports outlining the current state of the tsunami warning and mitigation systems nationally and outlining recommendations for enhancement. These reports include:

- One National Report specific to each country, detailing the strengths and opportunities for improvement and recommendations to address priority issues with regard to tsunami warning and mitigation; and
- A consolidated Regional Report (this report) devised from combining all 14 PIC National Reports with the aim of identifying common issues and opportunities across the Region with regard to tsunami warnings and mitigation.

Other project achievements include:

- Information made readily available to SOPAC Member Countries, SOPAC, AusAID, and potential development partners to facilitate capacity building programs for early warning of and response to tsunami events (and potentially other hazards);
- Development of an enhanced understanding within SOPAC Member Countries of tsunami and the specific requirements for tsunami warning and mitigation;
- Skills within SOPAC Secretariat and SOPAC member countries to complete future assessments and maintain this knowledge, without or with limited external support;
- Understanding within SOPAC Member Countries of the operation and capabilities of the PTWS and the Joint Australian Tsunami Warning Centre (JATWC); and
- Enhanced relationships between Australia, partners and key national government counterparts in SOPAC Member Countries to facilitate ongoing sharing of information, transfer of expertise, and capacity development.

2.5. Project Methodology

Between June 2007 and September 2009 national assessments in each SOPAC member country were conducted by visiting teams including experts in the fields of tsunami warnings, emergency management, DRM and data and warning communications.

The visiting team meets with in-country experts during a workshop of three to four-days. The workshops involved government agencies, the private sector, Non-Government Organisations (NGOs) and regional and international organisations involved in tsunami and DRM within each

country. The dates, location, number of participants, number of agencies involved and organisations involved in the assessment team are outlined in Table 4.

During the workshop, a questionnaire was completed covering all aspects of tsunami warning and mitigation. Visits were made and documents collected (refer to Table 4 for number of supporting documents collected in each country) to gather information to support questionnaire responses. All information provided by the countries of a sensitive nature was treated confidentially. Information collected at the workshops and during in-country visits were then fed into the National Report of each country. These reports were extensively reviewed by project partners and the countries themselves before being signed off. A consolidated Regional Report (this report) was then devised from combining all 14 completed and approved PIC National Reports.

The questionnaire used throughout the Tsunami Capacity Assessment project was a modified version of that used for the Indian Ocean equivalent project. The Indian Ocean questionnaire was jointly developed by UNESCO/IOC, SOPAC, the World Meteorological Organisation (WMO) and the International Strategy for Disaster Reduction (ISDR). Details of the Indian Ocean equivalent project can be found on the Tsunami Program website of the IOC (www.ioc-tsunami.org/)

The Bureau facilitated dissemination of reports to regional and international donors and other stakeholders to ensure maximum exposure of results. This included published report copies and publication of the documents on the Bureau's website (www.bom.gov.au) and Pacific Disaster Net (www.pacificdisaster.net) (refer to Table 3 for details on how to access the published reports).

2.6. Relevant Regional and International Forums and Policies

2.6.1. ICG/PTWS, ITIC and Southwest Pacific Working Group

Under the auspices of the IOC, the ICG/PTWS (formerly known as ICG for the Tsunami Warning System in the Pacific (ITSU)) was first convened in 1968 (IOC, 2009). This is an international cooperative effort involving many IOC Member States of the Pacific Region. The ICG/PTWS meets regularly to review progress and coordinate activities resulting in improvements of the service (IOC, 2009). The International Tsunami Information Centre (ITIC), Honolulu, Hawaii, was established upon the request of IOC and is maintained in partnership with the USA's National Oceanographic and Atmospheric Administration (NOAA). ITIC serves many roles in assisting participating countries in planning for and mitigating the effects of tsunami (www.ioc3.unesco.org/itic).

Under the ICG/PTWS structure, the Working Group on Tsunami Warning and Mitigation in the Southwest Pacific Ocean was formed at the ICG/PTWS-XXI meeting in Melbourne in early May 2006 with the aim of enhancing tsunami warning and mitigation in the Southwest Pacific Ocean. The working group is composed of representatives from IOC Member States and other countries in the region (as members and observers). SOPAC provides secretariat support. The Working Group is currently chaired by a representative of New Zealand, with vice-chairs from Fiji and Samoa. The Working Group has a number of Terms of Reference (TOR) to which this project is directly relevant. One of these TOR is to 'evaluate capabilities of countries in the Southwest Pacific Region for providing end-to-end tsunami warning and mitigation services'.

2.6.2. Regional DRM Framework for Action

National and regional commitment to 'all hazards' disaster risk reduction and disaster management in support of sustainable development is regionally underpinned by "A Framework for Action 2005 – 2015, Building the Resilience of Nations and Communities to Disasters" (RFA 2005-15). This framework is divided into six themes with the aim of accelerating PIC Disaster Risk Reduction (DRR) and Disaster Management (DM) policies, planning and programs to address challenges (RFA 2005-15). The Pacific Regional Framework for Action was endorsed by

the Pacific Forum Leaders decision in Madang 2005. Tsunami Capacity Assessment project topics can be linked to the themes of the Pacific Regional Framework for Action.

2.6.3. Strategy for Enhancing Early Warning for PICs

The Strategy for Enhancing Early Warning for PICs links to the Regional DRM Framework for Action (Theme 5) and aims to bring about a strategic approach to enhancing early warning systems in PICs. Ensuring the delivery of accurate, understandable information in a timely manor is central to the strategy. Key challenges include the need to communicate over vast ocean distances within and between countries. Many of the recommendations made throughout the Tsunami Capacity Assessment project map to this strategy. In particular the project completes a comprehensive inventory and needs analysis of national tsunami early warning systems ensuring inputs from all stakeholders, including traditional knowledge and community needs are addressed.

2.6.4. Pacific Platform for DRM

The Pacific Platform is comprised of a series of Pacific regional meetings of national focal points for DRM; regional development partners and key decision makers of Pacific governments; Chief Executive Officers (CEOs) responsible for Finance and Planning and Disaster Management (SOPAC, 2009). The Pacific Platform is a single forum of exchange and sharing of experiences within the Pacific in relation to policy and operational aspects of DRM (SOPAC, 2009). Meetings include:

- Regional Disaster Managers Meeting - Coordinated by SOPAC involving PIC disaster managers;
- Meeting of the Pacific Disaster Risk Management Partnership Network - Coordinated by SOPAC involving development and technical partners; and
- Pacific Regional Disaster Risk Management Meeting for Pacific CEO's of Finance/Planning and Disaster Management - Coordinated by SOPAC including key PIC government decision makers.

Throughout its duration, the Tsunami Capacity Assessment project has been represented at these forums to inform discussion and promote use of the assessment work.

2.6.5. Regional Meteorological Service Directors Coordination

The Regional Meteorological Services Directors Meeting is held annually and is coordinated by the South Pacific Regional Environment Programme (SPREP) with the aim of providing a forum for information exchange and sharing of experiences within the Pacific meteorological community. Throughout its duration, the Tsunami Capacity Assessment project has been represented at this forum to inform discussion and promote use of the assessment work.

2.6.6. Disaster Risk Management National Action Plans

Some PICs have and are undergoing the process of developing DRM National Action Plans (NAPs). The DRM NAP process provides countries with an opportunity to re-examine existing policy and develop a more coordinated program of action focusing on key vulnerability and risk issues and on priority gaps. The aim is for these plans to be the key national documents highlighting DRM priorities within each country. In those countries with DRM NAPs in place, the Tsunami Capacity Assessment project enabled a comprehensive assessment of that country's tsunami early warning system and linked resulting recommendations to the DRM NAP where possible.

2.6.7. The World Meteorological Organisations RA5

The World Meteorological Organisation (WMO) Region V Association (RA V) is made up of 22 member countries, represented by the 22 National Meteorological and Hydrological Services (NMHSs)[1]. The Regional Association met in Bali in May 2010 to develop its Strategic Plan for 2011-2015, in alignment with and as a contribution to the WMO's new quadrennial Strategic Plan. The RA V Management Group subsequently met during the WMO Executive Council meeting in Geneva in June 2010, and again in September 2010 in Citeko, Indonesia, to refine and finalise the RA V Strategic Plan and strategic priorities for the Southwest Pacific region. The product of this quite rigorous consultation and development process was adopted by the 22 regional members, with the agreed regional priorities being:

- Better climate services;
- Sustainable aviation services;
- Capacity building;
- Improved infrastructure (data and information services) for weather, climate and water; and
- Improved end-to-end multi-hazard early warning systems.

To achieve these priorities by 2013, five working groups have been established consisting of the RA V Tropical Cyclone Committee, a Working Group on Hydrology, a Working Group on Climate Services, a Working Group on Weather Services and a Working Group on Infrastructure.

[1] The WMO Region V Association has the following member countries: Australia, Brunei Darussalam, Cook Islands, Fiji, French Polynesia, Indonesia, Kiribati, Malaysia, Federated States of Micronesia, New Caledonia, New Zealand, Niue, Papua new Guinea, Philippines, Samoa, Singapore, Solomon Islands, Timor-Leste, Tonga, UK, USA and Vanuatu.

Table 4: Date, location, participation and supporting documents collected for the Tsunami Capacity Assessment of SOPAC Member Countries

Country	Workshop date	Location	Participant No.	No. of organisations	Organisations on assessment team	No. of assessment team members	No. of supporting documents collected
Cook Islands	10 – 13 June 08	Catholic Basement, Rarotonga	35	22	BoM, AGD, SOPAC	4	22
Federated States of Micronesia	14 – 17 Sep 09	The Cliff Rainbow Hotel, Pohnpei	38	28	BoM, AGD, SOPAC, NOAA NWS, UOG, USAID	6	14
Fiji	11 – 14 Mar 08	Holiday Inn, Suva	29	11	BoM, AGD, SOPAC	6	19
Kiribati	10 – 18 Sep 08	Otintai Hotel, Tarawa	45	27	BoM, AGD	3	27
Marshall Islands	25 – 28 May 09	Marshall Islands Resort, Majuro	64	33	BoM, IOC, Tas SES, SOPAC	6	17
Nauru	24 – 16 Feb 08	Menen Hotel, Nauru	39	24	BoM, Tas SES, SOPAC	5	23
Niue	25 – 28 May 09	Matavai Resort, Alofi	21	15	BoM, AGD, SOPAC	4	13
Palau	11 – 14 Aug 09	Koror State Assembly Hall, Koror	50	30	BoM, UOG, AGD	5	54
Papua New Guinea	21 – 24 Oct 08 (& Reviewed Nov 09)	Hideaway Hotel, Port Moresby	15	14	BoM, AGD, UOG, SOPAC	4	47

Country	Workshop date	Location	Participant No.	No. of organisations	Organisations on assessment team	No. of assessment team members	No. of supporting documents collected
Samoa	28 Apr – 1 May 08	Development Bank of Samoa Building, Apia	19	10	BoM, AGD, NSW SES, SOPAC	5	40
Solomon Islands	5 – 8 Feb 08	King Solomon Hotel, Honiara	27	10	BoM, AGD, Comms Consultant, SOPAC	4	44
Tonga	29 May – 1 June 07	National Emergency Management Training Room	21	17	BoM, NZ Met Service, SOPAC, AGD, NSW SES	8	27
Tuvalu	26 June – 1 July 09	Government Offices, Funafuti	27	19	BoM, AGD, SOPAC	5	12
Vanuatu	22 – 25 April 08	The Melanesian, Port Vila	53	37	BoM, AGD, NSW SES, NZ Met	4	37
TOTAL			**483**	**297**		**69**	**396**

3. Tsunami in the Context of the Pacific Island Countries

3. Tsunami in the Context of the Pacific Island Countries

3.1. Section Summary:

- The tsunami threat faced by the SOPAC Member Countries consists of a complex mix of tsunami from local, regional and distant sources.
- Tsunami inundation that causes damage and fatalities can vary widely depending on local conditions.
- Several SOPAC Member Countries have a very high tsunami hazard. These nations are usually close to a major subduction zone and are perpendicular to it (Source; Geoscience Australia).
- The nature of the tsunami hazard poses significant management challenges. Tsunami are fast onset, highly destructive, relatively rare and scientifically complex events.
- Even small tsunami can be dangerous to marine activities.
- The most recent example of tsunami devastation causing fatalities in the SOPAC Member Countries occurred in September 2009 when 143 people were killed in Samoa and nine in Tonga due to a tsunami generated on the Tonga trench.
- Components of an end-to-end tsunami warning and mitigation system in a PIC context are outlined graphically in Annexure 4.
- SOPAC Member Countries currently receive tsunami warnings from PTWC and are subsequently responsible for warning their own populations.

3.2. The PIC Tsunami Hazard

The Pacific Ocean covers more than one-third of the earth's surface and is surrounded by a series of mountain chains, deep-ocean trenches and island arcs called the "ring of fire" (refer Figure 1) where most earthquakes occur (off the coasts of Kamchatka, Japan, the Kuril Islands, Alaska and South America) (ITIC, 2010).

A tsunami can be generated by any disturbance that displaces a large water mass from its equilibrium position (Pacific Tsunami Museum, 2007). This includes submarine landslides (that are often the result of earthquakes), marine volcanic eruptions, above water landslides that slump into the ocean and space born objects. Most often, these non-seismic tsunami generation mechanisms affect local coastlines, rather than entire ocean basins (Pacific Tsunami Museum, 2007).

The most common cause of tsunami are large earthquakes occurring under the sea floor, when the sudden movement of large slabs of rock causes the overlying column of water to be misplaced (Thomas and Burbidge, 2009). There are major subduction zones in the west, north and east of the Pacific Ocean basin that either have produced damaging tsunami in the past or could plausibly produce them in the future (Thomas and Burbidge, 2009).

Therefore, the tsunami threat faced by the PICs consists of a complex mix of tsunami from local, regional and distant sources, with tsunami travel times of minutes to greater than 12 hours away. The effect of tsunami at any particular location are highly dependent on variations in the seafloor shape between the source and the affected area (Thomas, Burbidge and Cummins, 2007). Tsunami inundation that causes damage and fatalities can vary widely depending on local bathymetry and topography (Thomas, Burbidge and Cummins, 2007).

Thomas, Burbidge and Cummins (2007) completed *A Preliminary Study into the Tsunami Hazard faced by Southwest Pacific Nations*. Scenarios for two suits of earthquakes (8.5 Moment Magnitude (Mw) and 9.0 Mw) were used to investigate normalised offshore (to a notional depth of 50 metres) wave amplitudes for tsunami caused by earthquakes along subduction zones. In this study, the nations most affected by both suits of earthquakes were in the south and west of the study area, namely Vanuatu, Papua New Guinea, Guam, Solomon Islands and Tonga. Fiji also demonstrated wave amplitudes greater than 250cm from 9.0Mw events. Although not as badly affected, FSM, New Caledonia and Samoa still experienced significant waves in this study (Thomas, Burbidge and Cummins, 2007). Nations in the north and east of the study area were less affected, including Kiribati, Marshall Islands, Nauru, Cook Islands, French Polynesia and Tuvalu. However, without further investigation significant tsunami run-up at some locations from smaller events (for example, 25 – 75 cm amplitudes) cannot be ruled out (Thomas, Burbidge and Cummins, 2007).

A further study completed by Thomas and Burbidge (2009) attempts to answer the question "which Pacific nations might experience offshore amplitudes large enough to potentially result in hazardous inundation, what are the probabilities of experiencing these amplitudes and from which subduction zones might these tsunami originate". The report identifies the countries with the highest hazard for a return period of 1 in 2000 years as being Guam, New Caledonia, Niue, PNG, Tonga and Vanuatu whilst those with the least hazard are Nauru and Tuvalu. The other PICs included in the study are distributed between these two groups. The report also identifies subduction zones that contribute the most to the 1 in 2000 year hazard for that nation.

The two studies outlined above (Thomas, Burbidge and Cummins, 2007 and Thomas and Burbidge, 2009) demonstrate that the proximity of a country to the subduction zones (refer Figure 2 and 3) and the orientation of the fault lines which act to direct the tsunami towards certain nations is the key contributing factor. Typically, when a nation is close to a subduction zone (refer Figure 3), the bulk of the hazard to that nation comes from that zone (Thomas and Burbidge, 2009). In this case there is often limited time for tsunami warning and public awareness of the natural warning signs of the hazard is paramount. When a nation is further away from the

subduction zones, the hazard ordinarily comes from a number of potential sources and the hazard is usually lower because the extra distance reduces the amplitude of the tsunami by the time it reaches the nation concerned (Thomas and Burbidge, 2009). For distant sources (refer Figure 4), time to provide official warnings exists. Some nations are lucky enough to be located so that no zone beams tsunami energy directly towards them. Different parts of countries that cover a large area of ocean can experience tsunami threat from different subduction zones (Thomas and Burbidge, 2009).

On one hand, the lack of any high ground may appear to make some of PICs especially vulnerable to tsunami. On the other hand, atolls can also be somewhat protected as they often have steep drop-offs in which ocean depths increase very rapidly with distance from the fringing reef therefore minimising tsunami shoaling (the process by which tsunami wave heights increase as they approach the shore) and subsequent inundation (Thomas, Burbidge and Cummins, 2007).

Figure 1: The subduction zones (in orange) of the wider Pacific Ocean

Figure 2: The location of PICs involved in the Tsunami Capacity Assessment project as denoted by their capital cities in relation to regional and local subduction zones (in orange)

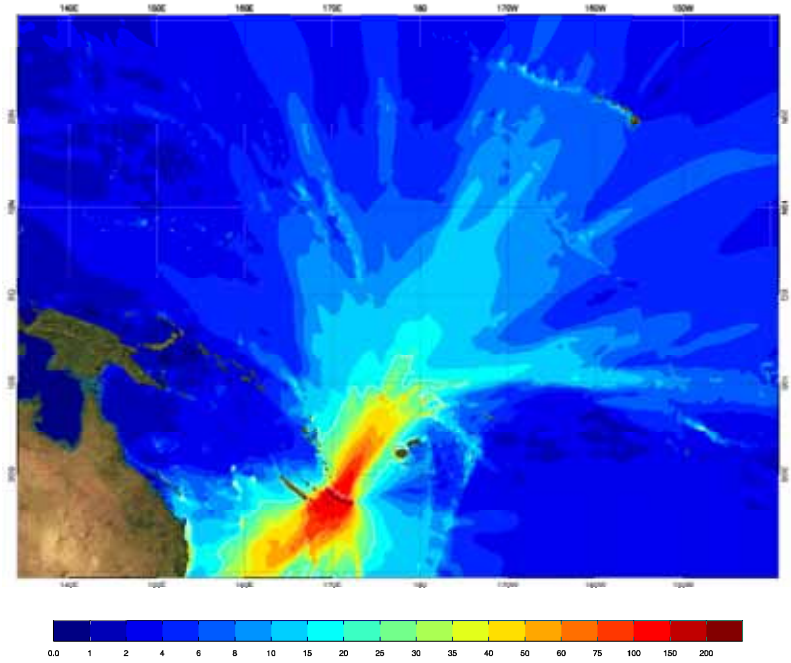


Figure 3: Maximum amplitude tsunami from a magnitude 8.50Mw earthquake on the South Solomons trench. This is an example of a potential locally generated tsunami for the SOPAC Member Countries (Source: Scenario 197c of MOST model from T2 database, Greenslade, Simanjunkak and Allen, 2009).

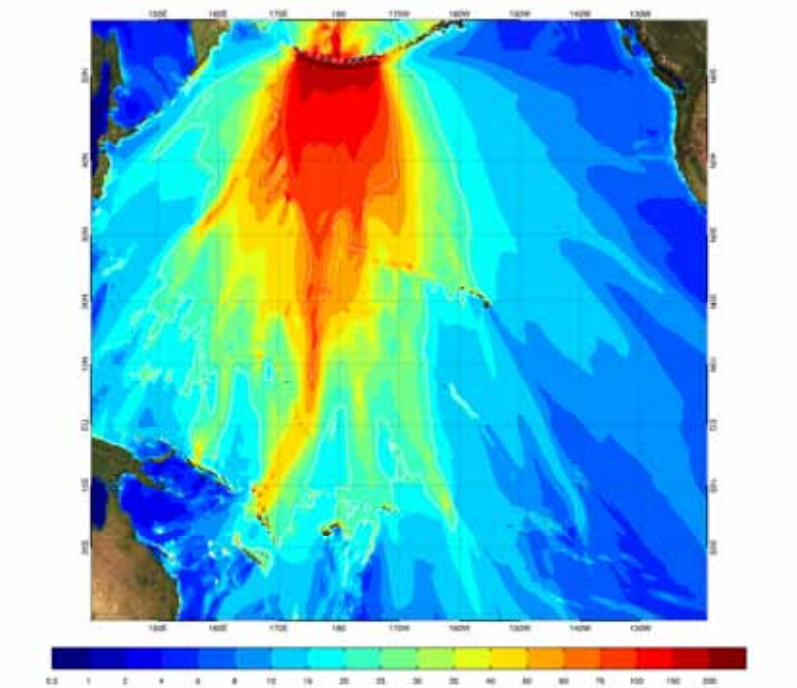


Figure 4: Maximum amplitude tsunami from a magnitude 9.0Mw earthquake worst case scenario on the Aleutian trench. This is an example of a potential distantly generated tsunami for the SOPAC Member Countries (Source: Scenario 347d of MOST model from T2 database, Greenslade, Simanjunkak and Allen, 2009).

3.3. The Challenging Nature of Tsunami

Tsunami, by their very nature, pose significant challenges to hazard preparation and response by PICs. Combined with the pre-existing challenges of providing early warning and disaster relief to remote isolated islands, the characteristics of tsunami that make them particularly difficult to manage include:

Tsunami are a fast onset hazard. Many PICs have potential local tsunami generation sources that could result in a tsunami impacting their coastlines within minutes. Lack of warning time, particularly at night, is a significant issue. By the alternative extreme, PICs can experience tsunami travel times greater than 12 hours from distant sources.

Tsunami are potentially highly destructive. Tsunami are a series of waves that travel at speeds of 800 – 1000 km/hr in the open ocean, have long wave periods (of ten minutes to two hours), long wavelengths of 100 – 500km and involve the movement of the entire water column from surface to the seafloor (PTWC, 2009). Combined, these factors result in a hugely powerful and destructive body of water that continues to flood destructively inland for an extended period.

Tsunami are rare events. Traditional knowledge can be lost through entire generations not experiencing a tsunami and maintenance of public awareness is difficult due to there being a long time between events. Development and maintenance of tsunami warning systems can be hard to justify when in competition with other more frequent human induced and severe weather related hazards. This is where a multi-hazard approach is vital.

Tsunami are scientifically complex. This makes it difficult to complete pre-event tsunami risk assessments and interpretation of international tsunami warnings to determine national impacts. Subsequently this increases the frequency of 'perceived' false alarms by the pacific community. The impact of tsunami on a coastline will be variable and dependant upon the characteristics of the source earthquake, the shape and depth of the seafloor (bathymetry) between the source and the affected area, coastline features (such as fringing reefs), the topography of the coastline (slope, type and density of construction and vegetation) and the orientation and distance of landfall in comparison to the source. Destructive tsunami are normally generated by large (greater than Mw 7.5) and shallow (less than 100m deep) earthquakes with the epicentre or fault line near or on the ocean floor. Other factors such as the length of the rupture zone and the extent of vertical displacement of the seafloor often contribute to tsunami severity. If tsunami waves arrive at high tide, or if there are concurrent storm waves in the area, the effects will be cumulative and the inundation and destruction even greater (ITIC, 2010).

Even relatively small tsunami can be dangerous and are a community awareness challenge. Even seemingly small changes in sea level due to tsunami could adversely impact on activities in communities whose coastal way of life includes daily interaction with the ocean (fishing, fuel unloading, tourism, snorkelling, diving). Even if no inundation occurs, people in the water during a tsunami are at significant risk due to associated high currents which can be two or three times those experienced under normal conditions. The community and media's knowledge on tsunami is largely dictated by footage of destructive walls of water associated with the December 2004 Indian Ocean tsunami. Very few communities have an understanding of the dangers of smaller events or experience of tsunami in the context of their own country.

In comparison to other hazards, tsunami science, planning and response are relatively immature. Scientific knowledge and planning continues to evolve, and countries are at various stages of DRM competency. International best practice continues to evolve.

3.4. Components of an End-to-End Tsunami Warning and Mitigation System

Components of an end-to-end tsunami warning and mitigation system in a PIC context are outlined graphically in Annexure 4. An end-to-end tsunami warning and mitigation system not only refers to tsunami warning system components (detection, data analysis, formulation and dissemination of the warning) but also incorporates several other individual components that operate sequentially to produce an effective system for holistic tsunami DRM from the national to the village community level. These include:

- Consideration of the tsunami hazard in the national DRM governance and planning framework (for example, legislation);
- Assessing the tsunami risk;
- Tsunami specific planning and preparedness at a national, provincial / district and village / island level (for example, evacuation planning, community awareness, staff training);
- Appropriate response by the community during a tsunami event as well as operational emergency response and recovery efforts; and
- Continuous system improvement through completion of lessons learned processes post event which feed into revised training and procedures.

3.5. Examples of Tsunami Impacting on PICs in Recent History

In recent history, examples of key tsunami that have caused considerable destruction and loss of life in the PICs are outlined below. These examples demonstrate the complex mix of tsunami from local, regional and distant sources that PICs can experience.

Fiji (Suva, 1953)

In 1953, a magnitude 6.8 earthquake originating offshore from Suva, Viti Levu, triggered a coral reef platform collapse, which in turn generated a local tsunami. The tsunami killed five people. Another three people died as the consequence of the earthquake. The tsunami wave heights ranged from 0.7 to 5.0 metres above mean sea level. A wave height of 4.3 metres was recorded in Nakasaleka in Kadavu. Eyewitness accounts indicate that the first wave took only three minutes to reach Suva (Pacific Disaster Centre, 2005 and Rahiman, 2006).

Chile (1960)

The 1960 Chile tsunami was generated by a 9.5 magnitude earthquake off the Chilean coast which devastated Chile. The tsunami resulted in major damage and deaths as far away as Hawaii, Japan and the Philippines and minor damage was reported throughout the Pacific (Alport and Blong, 1995). The tsunami waves took approximately 13 hours to reach Suva, Fiji (Pacific Disaster Centre, 2005). The tsunami damaged ships anchored at Fiji's Walu Bay but fortunately, caused no deaths (Pacific Disaster Centre, 2005). The tsunami arrived in PNG 22 hours after the earthquake, causing waves of one to two metres in height and some flooding in the New Guinea Islands and at Wewak (Everingham, 1977).

Papua New Guinea (1998)

The tsunami that hit the coast of west Aitape on the evening of 17 July 1998 was the first damaging tsunami for 68 years in PNG. The tsunami energy was focused on a 14km stretch of coastline west of Aitape. In this area two large villages were completely destroyed, two others were extensively damaged, and an estimated 2200 people lost their lives (UPNG, 2006) and Thomas and Burbidge, 2009). Further to the east and west the damage was less severe (UPNG, 2006). The Port Moresby Geophysical Observatory recorded two strong quakes that Friday evening, one at 6.49pm and the other at 7.09pm local time. Both were recorded to be of 7.0 magnitude with the second one being slightly stronger (Davies, 1998). The earthquakes were strongly felt and continued for several minutes. The tsunami is thought to have been caused by a massive submarine landslide approximately 30km offshore. It arrived 15 to 20 minutes after the first earthquake and was preceded by a fall in sea level (Davies, 1998). The tsunami consisted of a series of three waves with the energy focused towards Arop and Warapu (UPNG, 2006).

Vanuatu (1999)

On the 27 November 1999 at 12:21am local time, central Vanuatu was struck by a large offshore earthquake (Mw 7.5) generated on the New Hebrides trench followed by a tsunami that killed five people and caused significant damage to near shore structures, mainly at Martelli Bay, south Pentecost Island (Ioualalen, M., et al 2006). A maximum tsunami run-up height of seven to eight metres above sea level was measured (using plants killed by salt water) at the mouth of a small river just south of Pamal village (Ioualalen, M., et al 2006). One eyewitness reported a water withdrawal succeeded by three waves, the first of which was smaller than the others and arrived within about ten minutes of the earthquake (Ioualalen, M., et al 2006). In one village the receding water warned residents to move away from the shore line.

Solomon Islands (2007)

The Solomon Islands tsunami of 2 April 2007 impacted upon the Western and Choiseul Provinces (refer Figure 5). Fifty two lives were lost and significant damage was caused. The tsunami was triggered by a magnitude 8.1Mw earthquake which occurred at 7.39am local time along the Solomon Islands subduction zone as a result of under-thrusting of the Australia/Woodlark/Solomon Sea plate beneath the Pacific plate, as part of the broader northeast-directed subduction process (USGS, 2008). There have also been unconfirmed reports of damage in PNG from this event (Thomas and Burbidge, 2009).

More recently, two earthquakes hit the Solomon Islands on the morning of 4 January 2010 local time, the largest being magnitude 7.1 (USGS, 2010). Significant damage from both tsunami and earthquake related landslides occurred in the southern and northern coast of the islands of Rendova and Tetepare (WHO SITREP, 12/01/2010). One day later (5 January), an aftershock measured at magnitude 6.9 struck, damaging houses around the Marovo lagoon (WHO SITREP, 12/01/2010).

Samoa and Tonga (2009)

On the 30 September 2009 a Mw 8.1 (USGS, 2010) earthquake on the Tonga trench generated a tsunami that severely impacted upon Samoa (refer Figure 6), American Samoa and a northern island of Tonga.

The Tongan island of Niuatoputapu was located 190 km from the earthquake epicentre (Wilson et al., 2009). There were nine fatalities on Niuatoputapu, over half of the houses were destroyed and the healthcare and communications facilities were badly damaged (Wilson et al., 2009). Inundation up to 1100m inland occurred at the southeast of Niuatoputapu and 46% of the island was inundated by the tsunami (Wilson et al., 2009). A maximum tsunami run-up of 4.7 m above mean sea level was recorded at the village of Falehau in the northwest of Niuatoputapu (Wilson et al, 2009).

The earthquake epicentre was located 190 km south of Apia. The coastal areas of Samoa sustained damage with extensive destruction mainly to the south-eastern coast of Upolu Island. Damage occurred to resorts, family homes and community buildings, roads, power lines and water supply located along the coastline of the affected areas (NEOC SITREP: 7, 14/10/09). 143 deaths were confirmed (as of 14 October 2009), 5 people missing and 310 injured (NEOC SITREP: 7, 14/10/09). A coordinated international scientific team undertook post tsunami assessments, in cooperation with the Samoan Government.

Figure 5: Coastal shot of tsunami damage around Gizo, Solomon Islands as a result of the 2 April 2007 tsunami (Source: Roger Wheatley, AusAID)

Figure 6: Immediate response efforts to the Samoa / Tonga tsunami of 30 September 2009 in Lalomanu, Samoa (Source: Stuart Chape, SPREP)

3.6. The Current Structure of Tsunami Warnings for Pacific Island Countries

3.6.1. Summary

Under the auspices of the United Nations, the IOC established the ICG/PTWS in 1968 (PTWC, 2009) and the PTWC was renamed to form the operational headquarters for the PTWS (PTWC, 2009).

PTWC works with other international, sub-regional and national centres to monitor seismic stations to locate and establish the parameters of potentially tsunamigenigic earthquakes as well as accessing sea level stations around the Pacific Ocean to verify the generation and evaluate the severity of tsunami (Pacific Tsunami Warning and Mitigation System, 2009). As the primary operational headquarters for the PTWS, PTWC disseminates tsunami information and warning messages to designated national authorities in over 100 locations across the Pacific, including the PICs (Pacific Tsunami Warning and Mitigation System, 2009). Individual countries are then responsible for using this advice to distribute national tsunami warnings to their communities. All PICs, regardless of their real or perceived tsunami hazard level, must have procedures in place to respond to PTWC tsunami information and warning messages and in doing so, help to mitigate the threat to their community.

3.6.2. Warning Process

The following description of the warning process used by PTWC is taken from the brochure Pacific Tsunami Warning and Mitigation System (2009). A full definition of each PTWC product products can be found at http://www.prh.noaa.gov/ptwc/about_messages.php

> When a large earthquake occurs in the Pacific Ocean area, PTWC personnel determine the earthquake's hypocenter (the initial rupture point of the earthquake) and magnitude. If the hypocenter is under or near the ocean and not too deep within the earth, and if the magnitude is sufficiently large, then tsunami generation is possible. On the basis of this seismic evidence, the Center issues a regional tsunami warning to areas located near the epicenter. A regional tsunami watch is also issued to areas located further from the epicenter if the magnitude is so large there is the possibility of a long-range destructive tsunami. All remaining areas are issued an advisory. The initial bulletin tells participants that an earthquake has occurred, where and when it occurred, and that a destructive tsunami is possible.
>
> Because tsunami move through the water in accordance with known physical laws, estimated arrival times are computed and given for key Pacific locations. Additional bulletins are issued at least hourly and the warning and watch areas expanded as needed. The first indication of a tsunami usually comes within an hour or two from the sea level stations located nearest the earthquake. Fortunately, most large earthquakes with tsunamigenic potential do not generate long-range destructive tsunamis and the warning and watch will be cancelled. But if confirmation of a potentially destructive, long-range tsunami is received, the PTWC issues a Pacific wide tsunami warning to advise designated national authorities.

It alerts all warning system participants to the approach of potentially destructive tsunami waves and provides estimated tsunami arrival times for key locations throughout the Pacific. This warning continues, with bulletins containing updated information issued at least hourly, until the tsunami has crossed the entire Pacific or additional evidence is received to indicate there is no further tsunami threat. Messages are disseminated in accordance with procedures outlined in the Users Guide for the Pacific Tsunami Warning and Mitigation System.

Note – Particularly in the Micronesian countries, tsunami warnings from the Japan Meteorological Agency are applicable and sometimes used. Coordination between JMA and PTWC are outlined in the procedures of each centre. For more information refer to

http://www.jma.go.jp/jma/en/Activities/Earthquakes/act_Earthquakes.htm

4. Assessment Results: Status of Key System Components

4. Status of Key System Components

This section analyses the key components of the tsunami warning and mitigation system of each country. Thirty-two key aspects of a best-practice national tsunami warning and mitigation system were chosen to enable each country to be rated in an attempt to summarise the current status of national systems. Each country was rated against these thirty-two aspects with the status of each system aspect being rated as fully realised (yes), partially realised or not realised (no). The ratings were at the discretion of the expert Tsunami Capacity Assessment team, with countries given the chance to review these ratings before the finalisation of each National Report. Table 5 outlines a summary of these results for each country and highlights the most and least comprehensive systems across the region, where Table 6 provides a snap-shot of the status of Key System Components across each of the 14 countries.

4.1. Summary - Status of Key System Components

Table 5 outlines a summary of the status of Key System Components for each country.

Table 5 (same as Table 1): Country Summary, Status of Key System Components

	SOPAC Member Countries													
% Per Country	Cook Islands	Federated States of Micronesia	Fiji	Kiribati	Marshall Islands	Nauru	Niue	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Tuvalu	Vanuatu
% Yes	28	28	22	9	38	13	12	16	19	75	25	19	19	28
% No	38	34	3	44	25	44	39	22	38	9	22	28	34	22
% Partially	34	38	75	47	38	44	45	63	44	16	53	53	47	50
% NA	0	0	0	0	0	0	3	0	0	0	0	0	0	0

4.2. Details by Country - Status of Key System Components

Table 6: Overview of the Status of Key System Components of Tsunami Warning and Mitigation Systems in SOPAC Member Countries

	SOPAC Member Countries													
Key System Component	**Cook Islands**	**Federated States of Micronesia**	**Fiji**	**Kiribati**	**Marshall Islands**	**Nauru**	**Niue**	**Palau**	**Papua New Guinea**	**Samoa**	**Solomon Islands**	**Tonga**	**Tuvalu**	**Vanuatu**
Authority, Coordination and NGO Role														
Legislation in place for tsunami warnings and response	P	Y	P	Y	Y	P	P	N	N	Y	P	P	Y	P
Tsunami coordination committee or effort at a National and local level	P	P	P	P	Y	N	P	N	N	Y	P	P	P	P
Agency responsibilities clearly defined	N	P	P	N	Y	P	N	P	N	Y	P	Y	P	P
NGOs have a defined role in tsunami warning dissemination, preparedness and awareness and emergency response	P	P	Y	N	P	N	NA	P	P	Y	Y	Y	P	Y

	SOPAC Member Countries													
Key System Component	**Cook Islands**	**Federated States of Micronesia**	**Fiji**	**Kiribati**	**Marshall Islands**	**Nauru**	**Niue**	**Palau**	**Papua New Guinea**	**Samoa**	**Solomon Islands**	**Tonga**	**Tuvalu**	**Vanuatu**
Regional and International Cooperation														
Country represented at an international and regional level to aid cooperation in tsunami warning and mitigation efforts	Y	P	Y	P	P	Y	P	P	Y	Y	Y	Y	P	P
Priorities														
Priorities established for implementation of tsunami warning and mitigation system at a National level	Y	Y	P	P	Y	P	N	Y	P	Y	P	N	P	Y
Multi-hazard Approach														
Tsunami warning capabilities are being established within a multi-hazard framework	Y	Y	Y	P	Y	Y	P	Y	Y	Y	Y	P	P	Y
Research Expertise														
Active research is being undertaken within the country for seismology and tsunami to strengthen the tsunami warning and mitigation system	N	N	P	P	N	N	N	N	P	P	N	N	N	P

Key System Component	SOPAC Member Countries													
	Cook Islands	Federated States of Micronesia	Fiji	Kiribati	Marshall Islands	Nauru	Niue	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Tuvalu	Vanuatu
Tsunami monitoring infrastructure														
Existence of seismograph stations and integration of real time data from these stations into the tsunami warning process	P	N	P	P	P	N	P	P	N	Y	P	P	Y	P
Existence of sea level stations and integration of real time data from these stations into the tsunami warning process	P	P	P	P	Y	P	P	P	Y	Y	P	P	Y	Y
Sharing of seismic and sea level data internationally to facilitate improvement of PTWC tsunami messages for the region	Y	Y	P	Y	Y	Y	Y	P	P	Y	Y	P	Y	P
Warnings														
Nation receives PTWC messages	Y	Y	Y	P	Y	P	Y	Y	Y	Y	Y	Y	Y	Y
24/7 operational staff at warning receipt and dissemination location	Y	Y	P	P	Y	P	N	Y	Y	Y	Y	Y	N	P
Disseminate national tsunami warnings as guided by a Standard Operating Procedure	N	P	P	N	P	P	N	P	P	Y	N	Y	P	Y

Key System Component	SOPAC Member Countries													
	Cook Islands	Federated States of Micronesia	Fiji	Kiribati	Marshall Islands	Nauru	Niue	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Tuvalu	Vanuatu
System redundancies in place for receipt of PTWC messages and dissemination of National warnings	P	Y	P	N	P	N	N	P	N	P	P	P	N	Y
Redundant 24/7 methods available for dissemination of warnings to community (e.g. public radio, sirens etc.)	N	Y	P	P	N	P	P	P	N	Y	N	N	N	P
Effective warning dissemination to remote communities	N	N	P	N	P	P	P	P	N	Y	P	P	P	P
Communications coverage of whole country that is effectively utilised for the dissemination of tsunami warning messages	N	P	P	N	P	P	P	P	P	P	P	P	P	N
Issue of marine tsunami warnings and guidance for vessels, harbours and ports	P	N	P	N	N	N	P	P	P	Y	P	P	P	N
Emergency Response and Evacuation														
Disaster preparedness and emergency response system has been reviewed and opportunities for improvement and training identified	Y	P	P	N	Y	P	N	P	P	Y	P	N	P	Y
Tsunami emergency response, evacuation and recovery plan exists	N	N	P	N	P	N	P	N	N	Y	P	P	P	P

Key System Component	SOPAC Member Countries													
	Cook Islands	Federated States of Micronesia	Fiji	Kiribati	Marshall Islands	Nauru	Niue	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Tuvalu	Vanuatu
The designated agency for evacuation is identified and have authority by law	Y	Y	Y	Y	Y	Y	Y	P	N	Y	Y	P	Y	Y
Plans have been made for safe evacuation of population centres including aspects such as maps, routes and signage	N	N	P	N	N	N	P	N	P	P	N	P	N	N
Procedures are tested and exercised to improve the response through better planning and preparedness	P	P	Y	N	P	N	N	P	P	Y	P	P	N	P
Land use policies and building codes are in place to mitigate against the tsunami hazard	P	N	P	P	P	P	Y	P	N	N	P	P	P	N
Tsunami hazard, vulnerability and risk														
Completion of studies to assess the tsunami hazard in the country or Region	Y	P	P	P	P	P	P	Y	P	Y	P	P	N	P
Local risk assessments have been completed for at risk communities	N	P	P	N	N	N	N	N	P	N	N	N	N	N
Adequate data exists and local inundation modelling has been completed for population centres	N	P	P	P	Y	P	N	P	N	N	P	P	N	P

Key System Component	SOPAC Member Countries													
	Cook Islands	Federated States of Micronesia	Fiji	Kiribati	Marshall Islands	Nauru	Niue	Palau	Papua New Guinea	Samoa	Solomon Islands	Tonga	Tuvalu	Vanuatu
Public and stakeholder awareness and education														
Measures have been taken to ensure the public understand and take action in the event of a tsunami warning being issued	P	N	P	N	N	N	P	P	Y	Y	N	N	P	P
Community level education and preparedness programs exist tsunami	P	N	Y	P	N	N	P	P	P	Y	P	N	P	P
Training programs for the National media exist for natural hazard and tsunami	N	N	P	N	N	N	N	N	P	Y	Y	N	N	N
Training programs exist for officials involved in tsunami warning and response	N	N	N	P	P	N	N	P	N	P	N	N	N	N
% Per Country														
% Yes	**28**	**28**	**22**	**9**	**38**	**13**	**12**	**16**	**19**	**75**	**25**	**19**	**19**	**28**
% No	**38**	**34**	**3**	**44**	**25**	**44**	**39**	**22**	**38**	**9**	**22**	**28**	**34**	**22**
% Partially	**34**	**38**	**75**	**47**	**38**	**44**	**45**	**63**	**44**	**16**	**53**	**53**	**47**	**50**
% NA	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

5. Assessment Results: Results by Topic

5. Results by Topic

This section takes a Regional view of the key areas of tsunami warning and mitigation systems across PICs. It provides a consolidated picture of the status of progress towards competency in each of the key areas and outlines recommendations, common across countries, needed for system enhancement.

Under each topic, the status of Key System Components relevant to that topic has been graphed outlining some important points regarding the status of warning systems across the region.

Key recommendations to address priority issues are then outlined. These recommendations are ranked by Regional importance which has been calculated by counting the number of countries to which the recommendation relates.

5.1. Governance and Coordination

As outlined in the DRR and DM Framework for Action 2005-2015, in each of the 14 counties involved in the assessment process, national governments hold the responsibility for DRM, including tsunami warning and mitigation systems. A whole of country approach requires integration of tsunami warning and mitigation considerations into legislation, policies and plans. Coordination mechanisms need to exist across the national government but must also integrate NGOs, private industry and the public at all levels. In recent years preparedness planning for DRM has improved through the preparation of DRM NAPs. This process has encompassed a review of current arrangements and development of strategic plans to enhance DRM capability into the future. Governance and coordination sections of the Tsunami Capacity Assessment process looked at the adequacy of these organisational structures for tsunami.

Whilst the understanding of responsibility for tsunami mitigation and warning within each country is to some degree informally recognised, formal recognition of roles and responsibilities through national legislation, policies and plans requires significant improvement in many countries. In many countries, legislation is in place to designate responsibilities for DRM, early warning and establishment of plans, in some cases plans are incomplete, out of date or do not include tsunami leading to a lack of definition of agency roles and responsibilities (refer Figure 7a and 7b). In some cases, agencies are not provided with the authority under legislation to issue tsunami warnings to the community without the approval of Government officials. Particularly for tsunami generated by local sources, this requirement can lead to the loss of precious warning time. Many countries have a disaster coordination committee at the national level but may need a more focused effort on tsunami in the short term to ensure tsunami plans are progressed (refer Figure 7c). The NGO role in most countries is one of community awareness, preparedness, emergency response and recovery. In many countries these roles could be better integrated into the national arrangements (refer Figure 7d).

5.1.1. Status of Key System Components

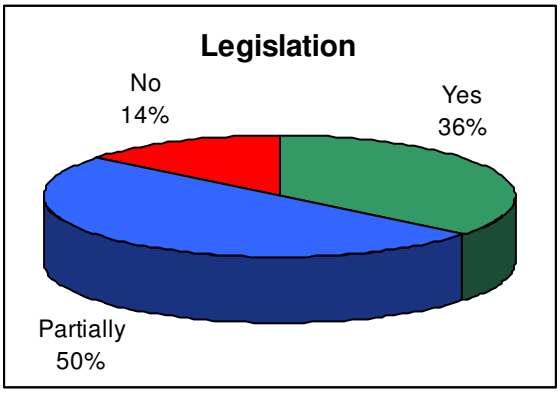


Figure 7a: Legislation in place for tsunami warnings and response

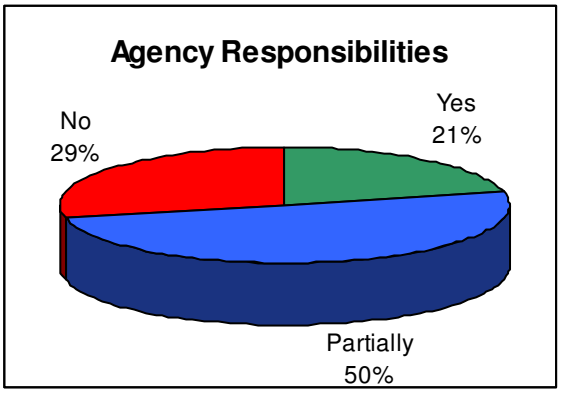


Figure 7b: Agency responsibilities clearly defined

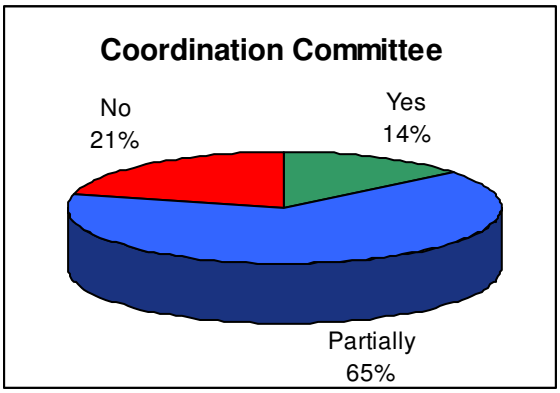


Figure 7c: Tsunami coordination committee or effort at a national and local level

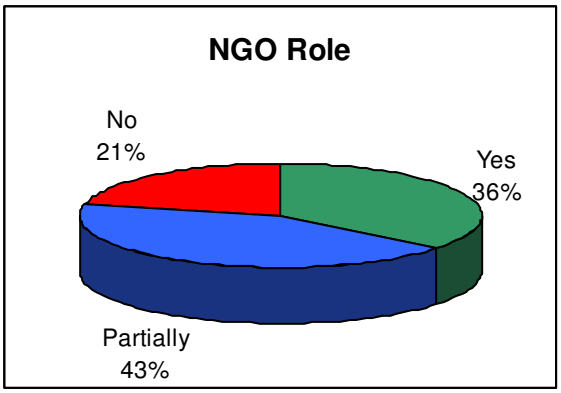


Figure 7d: NGOs have a defined role in tsunami warning dissemination, preparedness and awareness and emergency response

5.1.2. Key Regional Recommendations to Address Priority Issues

Key recommendations to address priority issues in governance and coordination for tsunami warning and mitigation systems are outlined in Table 7. Key recommendations across the region include development or enhancement of SOPs, tsunami specific national plans and national DRM plans.

Table 7: Key Regional Recommendations: Governance and Coordination

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Standard Operating Procedures	Develop OR enhance SOPs for the operation of the country's tsunami warning and response service	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Solomon Islands, Tonga, Vanuatu	**13**
Tsunami Sub-plan	Develop a tsunami specific national plan as a sub-plan to the national DRM plan. This can be implemented for other hazards	Cook Islands, Fiji, Kiribati, Nauru, Niue, Palau, PNG, Solomon Islands, Tonga, Vanuatu	**11**
National DRM Plan	Finalise OR review national level DRM plans and commence implementation	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Niue, Palau, PNG, Tonga, Tuvalu, Vanuatu	**11**
Local Level DRM (tsunami) Plans	Develop OR continue to develop DRM plans (including tsunami plans) at the local level (local government, district, island, village)	FSM, Kiribati, Marshall Islands, Niue, Palau, Samoa, Tonga, Tuvalu, Vanuatu	**9**
Legislation	Review, adopt AND/OR commence implementation of DRM legislation	Cook Islands, Fiji, Nauru, PNG, Tonga, Vanuatu	**6**
National DRM Council / Committee	Formalise OR enhance disaster councils or committees at the national level	Kiribati, Nauru, Palau, PNG, Tonga	**5**
Working Groups	Incorporate tsunami warning and mitigation considerations into existing national working group structures OR enhance the Tsunami Working Group	Cook Islands, Fiji, Solomon Islands, Tonga, Vanuatu	**5**
DRM NAP	Implement OR continue work towards development of DRM NAP	Cook Islands, Marshall Islands, PNG, Vanuatu	**4**
Organisation DRM (tsunami) Plans	Develop DRM plans (including tsunami plans) for government agencies, NGOs, community based organisations and the private sector	Kiribati, Marshall Islands, Palau, Tuvalu	**4**

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Resource Agencies	Resource key agencies involved in tsunami warning and mitigation systems to enable them to carry out their nominated functions under national governance arrangements	Palau, Samoa, Tuvalu, Vanuatu	**4**
Strengthen NGOs & Community Based Organisations	Implement actions to strengthen the capacity of key NGOs and Community Based Organisations involved in DRM and response (particularly with regard to using these groups to deliver community awareness)	FSM, Marshall Islands	**2**
Sharing National Plans	Ensure that the distribution of the country's national DRM plan to all key stakeholders	Niue, Tuvalu	**2**
Advocacy for DRM	Advocacy to support DRM at the government decision making level	Nauru, Tonga	**2**
Local Level DRM Structures	Develop DRM structures at the local level (local government, district, island, village)	Kiribati, Tonga	**2**
Co-location of Technical Agencies	Develop institutional arrangements that allow technical agencies involved in early warning systems and disaster risk management to be located together	Fiji	**1**

5.2. Regional and International Coordination

Figure 8 is a simple representation of the extent of regional and international engagement in tsunami warning and mitigation throughout the 14 PICs involved in the project.

Most countries participate in the ICG/PTWS Southwest Pacific Tsunami Working Group and are linked to the PTWC and other international providers for the provision of tsunami advice. Due to the vulnerability of the PICs there is a strong presence of development partners in the region running many programs, which in some cases could be further expanded to include tsunami. Some countries are working regionally to enhance systems (such as seismic infrastructure in Fiji and Tonga) with the aim of sharing information with their near neighbours as well as internationally for the improvement of tsunami warnings in the Pacific.

A consistent challenge is to ensure continued representation of PICs in forums such as the PTWS, without compromising national stability by removing key in-country experts from their day jobs on a regular basis. Funding for involvement in key international meetings is challenging, as is interpretation of meeting outcomes to form in-country action. A number of countries are not members of the IOC. Becoming a member is important to ensure the country has a voice in determining IOC programs and activities of benefit nationally as well as benefiting from IOC capacity building in marine science. However, with limited financial and human resources, PICs are often overwhelmed by imperatives to join and be represented on international bodies. The material benefit to the countries of these memberships is at times not measurable, resulting in decreased priority in national budgets.

Development partner coordination to ensure focused outcomes of programs is challenging. With limited in-country human resources, PICs can struggle to make the most of donor funding opportunities and the responsibility for being the in-country focal point for a number of externally driven projects can fall to just a few.

5.2.1. Status of Key System Components

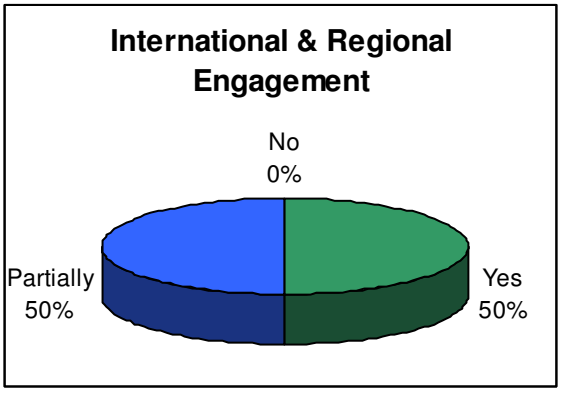


Figure 8: Country represented at an international and regional level to aid cooperation in tsunami warning and mitigation efforts

5.2.2. Key Regional Recommendations to Address Priority Issues

Key recommendations to address priority issues in regional and international coordination for tsunami warning and mitigation systems are outlined in Table 8. Key recommendations across the region include involvement in the ICG/PTWS Southwest Pacific Tsunami Working Group, becoming an IOC member and sharing the findings of this tsunami capacity assessment and DRM information more generally through existing means such as Pacific Disaster Net.

Table 8: Key Regional Recommendations: Regional and International Coordination

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
International Tsunami Working Group	Nominate a representative OR continue to participate in the ICG/PTWS Southwest Pacific Tsunami Working Group	Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Palau, Samoa, Tonga, Tuvalu	**9**
Become IOC Member	Become a member of the IOC to ensure the country has a voice in determining IOC programmes and activities of benefit nationally as well as benefiting from IOC capacity building in marine science	FSM, Kiribati, Marshall Islands, Nauru, Niue, Palau, Tonga, Vanuatu	**8**
Share Tsunami Report Findings & DRM Information	Share the findings of the country's National Tsunami Capacity Assessment Report with international and regional organisations to provide guidance on targeting future capacity development programs and projects. Share DRM information more generally through existing means such as Pacific Disaster Net	Cook Islands, Fiji, Samoa, Tonga	**4**
Capitalise on Existing Relationships	Maximise the opportunities provided through international and regional partnerships to strengthen monitoring, warning, preparedness and response capabilities in relation to tsunami AND/OR DRM capabilities more generally	FSM, Tuvalu	**2**

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Communicate with Neighbouring Countries	Communicate with near neighbours, both at an operational and planning level, to assist in capacity development to better manage and respond to a range of hazards. This includes consideration of 'twinning' arrangements with an international agency with an operational tsunami warning system	Palau, PNG	**2**

5.3. Research Expertise

Figure 9 provides a simple representation of seismology and tsunami research being undertaken within the 14 PICs to strengthen tsunami warning and mitigation systems. In-country research into the tsunami hazard is minimal. In-country capacity for such research to occur is variable generally limited. Regional and international technical assistance is required to address this area.

The projects recommendations focused on proactively encouraging and actively cooperating with regional and international organisations that can assist with conducting scientific research and building in-country technical capacity in seismology and tsunami science. Key to understanding the tsunami hazard is understanding tsunami history. Some countries were therefore recommended to form partnerships to conduct research into past wave inundation events and paleo-tsunami studies. Some countries have potential volcanic (Vanuatu) and submarine landslide (Fiji, PNG) sources that could generate local tsunami. In some instances, these hazards require further research.

Whilst some studies are completed by international scientists into various hazards throughout the region, countries expressed concern regarding the feedback provided to them on these studies. Countries were therefore encouraged to develop a protocol agreement to ensure copies of scientific research reports and data are received and archived by the SOPAC Member Country as soon as possible post study completion.

5.3.1. Status of Key System Components

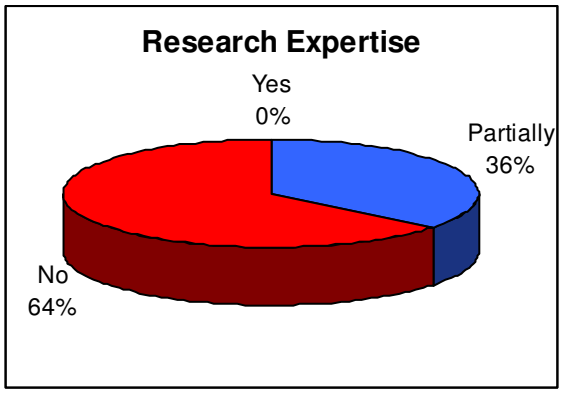


Figure 9: Active research is being undertaken within the country for seismology and tsunami to strengthen the tsunami warning and mitigation system

5.3.2. Key Regional Recommendations to Address Priority Issues

Key recommendations to address priority issues in research expertise for tsunami warning and mitigation systems are outlined in Table 9. Key recommendations across the region include proactively encourage and actively cooperate with regional and international organisations that can assist with conducting scientific research and building in-country technical capacity in seismology and tsunami science, develop a protocol to ensure copies of scientific research reports and data are received and archived and conduct past event and paleo-tsunami studies.

Table 9: Key Regional Recommendations: Research Expertise

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Proactively Encourage and Cooperate	Proactively encourage and actively cooperate with regional and international organisations that can assist with conducting scientific research and building in-country technical capacity in seismology and tsunami science	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Palau, Samoa, Solomon Islands, Tonga, Vanuatu	**10**
Develop Protocol to Receive Studies	Develop a protocol to ensure copies of scientific research reports and data are received and archived by the SOPAC member country as soon as possible post study completion	Cook Islands, Fiji, Kiribati, Samoa, Solomon Islands, Vanuatu	**6**
Research Past Events	Conduct research into past wave inundation events and paleo-tsunami studies	Fiji, Nauru	**2**
Develop Protocols for Post Impact Scientific Assessments	Develop and enforce protocols for the reception of international technical experts for post impact scientific assessments for tsunami and other disasters	PNG	**1**
Body to Coordinate Research	Establish a national scientific body/committee to co-ordinate, prioritises and facilitate tsunami research, including the exchange of existing research	PNG	**1**
Capitalise on Climate Change Initiatives	Build on existing climate change adaptation relationships and initiatives with international and regional bodies to incorporate consideration of DRM where possible	Kiribati	**1**

5.4. Tsunami Monitoring Infrastructure

Seismic and sea level observations are critical to ensure accuracy and efficiency of tsunami warning information.

There are a number of sea level coastal stations located throughout the 14 PICs. Most of these stations are third party owned, operated and maintained in agreement (formal or otherwise) and with the assistance of PICs (refer Figure 10a). The majority of these stations report to international tsunami warning providers such as the PTWC in real-time and therefore contribute to the accuracy and efficiency of tsunami warning information (refer Figure 10b). However, countries expressed a desire to have improved comprehensive access to sea-level data in real-time from the Pacific network of gauges. Countries were encouraged to investigate access to and training in the interpretation of Pacific region sea level data to enable integration of this data into national tsunami warning procedures. Approach to data access channels and use will vary by country (for example, web access, GTS, restoring real time links for in-country stations).

The number of operational seismographs (refer to Figure 10c) throughout the 14 PICs is less than that of the sea-level gauges. In-country operational seismic stations existed in five countries (Fiji, PNG, Samoa, Tonga and Vanuatu). These in-country networks were at varied stages of their lifecycles, with some earmarked to be revamped. A number of research seismic stations also existed throughout the Pacific. The information from these stations is largely used for research purposes and is not accessible in real time for operations. The degree to which operational seismic stations are used in tsunami warnings was minimal, either due to limited scientific and technical capacity of staff or lack of 24/7 operations and integration into warning infrastructure and procedures.

5.4.1. Status of Key System Components

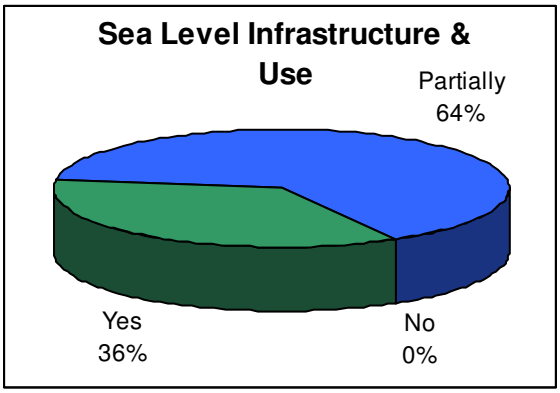


Figure 10a: Existence of sea level stations and integration of real time data from these stations into the tsunami warning process

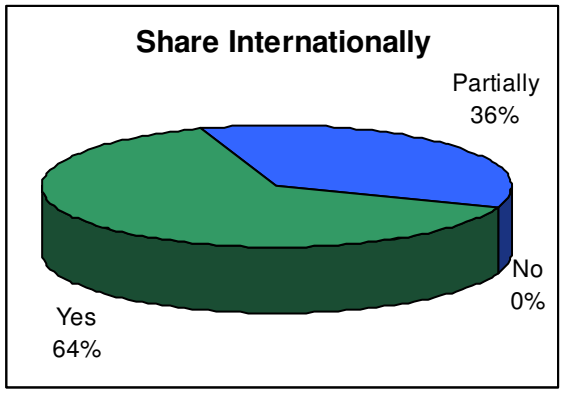


Figure 10b: Sharing of seismic and sea level data internationally to facilitate improvement of PTWC tsunami messages for the region

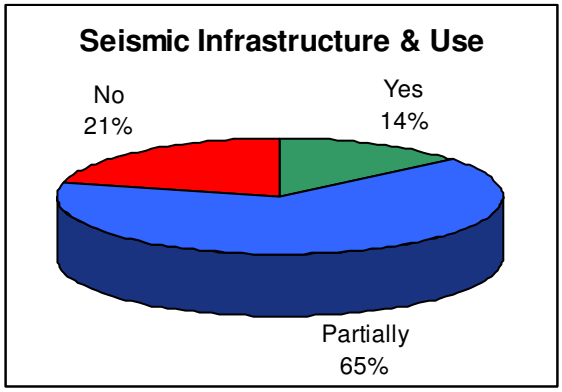


Figure 10c: Existence of seismograph stations and integration of real time data from these stations into the tsunami warning process

5.4.2. Key Regional Recommendations to Address Priority Issues

Key recommendations to address priority issues in tsunami monitoring infrastructure for tsunami warning and mitigation systems are outlined in Table 10. Key recommendations across the region include improved access to sea level data, international data sharing and reestablishment of seismic networks.

Table 10: Key Regional Recommendations: Tsunami Monitoring Infrastructure

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Sea Level Data Access	Investigate access to and training in the interpretation of pacific region sea level data to enable integration of this data into tsunami warning procedures. Approach to data access will vary by country (for example, web access, GTS, restoring real time links for in-country stations)	Fiji, Kiribati, Marshall Islands, Nauru, Samoa, Solomon Islands	**6**
International Data Sharing	Ensure any future project agreements with development partners for upgrade or installation of new monitoring equipment includes sharing of seismic and sea level data internationally in real-time and suitable data formats	Cook Islands, Fiji, Marshall Islands, PNG, Tonga, Vanuatu	**6**
Establishment of Seismic Network	Continue establishment of new OR improved seismic network and strengthen the capacity of responsible agencies to fully utilise, maintain and sustain the network (using national funds if required). (Vanuatu - also volcano monitoring)	Fiji, PNG, Samoa, Tonga, Vanuatu	**5**
Equipment Maintenance	Take part in maintaining existing sea level and seismic infrastructure, including receiving appropriate training for this role	Cook Islands, Niue	**2**
Upgrades & Further Installations	Seek upgrade to existing third party owned equipment and infrastructure for seismic stations and sea level gauges AND / OR encourage installation of new equipment	FSM, Tuvalu	**2**

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Sea Level Network	Scope options for installation of the country's own multi-purpose sea level observation network, including outside assistance where required	Palau	**1**

5.5. Tsunami Warnings

The short lead time of local tsunami events for many PICs means that a robust 24/7 agency for warning receipt and dissemination is required. This responsibility must be formally and clearly designated. The vast majority of PICs are able to receive tsunami warning messages from international providers, primarily PTWC (refer Figure 11a). In some countries enhancement is required in the 24/7 staffing arrangements at the offices responsible for receiving and acting on international advice (refer Figure 11b). The importance of the National Meteorological Services as a 24/7 operational agency, capable of receiving and disseminating tsunami warnings, is vital in the majority of countries. The communications systems, 24/7 staffing arrangements and operational expertise and capacity to interpret scientific information is, for many countries, not replicated in any other agency. Some countries expressed the desire for their seismic agencies to become the primary tsunami warning receipt and dissemination organisation. This is possible only with the realisation of the resources required to establish a 24/7 operation. If countries commit to this goal, interim arrangements through the National Meteorological Service, or other appropriate agency, should be put in place whilst capacity is built elsewhere. Co-locating operational agencies is also a valid way forward.

Many PICs require improvement in processes for the issuing of tsunami warnings nationally both within and between responsible agencies. This could be achieved by completion of a comprehensive set of SOPs (refer Figure 11c) at a government scale (for example, a National Tsunami Response Plan that also includes the roles of private sector and NGOs active in each country) and SOPs for each institution involved in tsunami warning and response.

Redundancy for both the receipt (refer Figure 11d) and dissemination of tsunami warnings within national boundaries requires improvement across the majority of countries. This may include, for example, adequate back-up power to ensure the agency that receives tsunami warnings is reliably on line, or a second agency to provide back-up to the primary warning agency. For warning dissemination, the majority of countries need to closely analyse their current communications mechanisms (both technical and otherwise) and adapt use of these mechanisms for national warning dissemination (see communications for more details).

The capacity of the PICs to use international scientific tools to nationalise the tsunami threat is limited and requires further enhancement through development of further PIC specific easy to use tools (for example, sea-level visualisation displays, displays of tsunami model scenarios etc.) accompanied by appropriate training. Tsunami warning decision support tools are freely available from ITIC including sea level monitoring tools supported by PTWC, tsunami travel time software, real-time earthquake displays and heads-up SMS text alerts from the PTWS (through RANET). Unfortunately the uptake of such tools appeared lower than expected across the PICs and integration of these tools into SOPs is required to enhance use. By better understaning the tsunami threat to their nation, PICs can make informed decisions about the action they take when mentioned in an international tsunami warning. At present, most countries have no choice but to evacuate the entire coastal population of a nation. This is a disruptive and expensive action that impacts on public confidence in the system and the agencies themselves.

Tailoring of tsunami warning messages to ensure receipt by specific user groups such as marine users (refer Figure 11e) was largely ad-hoc across the PICs. Closer warning user consultation is required when developing tsunami warning SOPs to ensure effective communication with important community and industry sectors.

5.5.1. *Status of Key System Components*

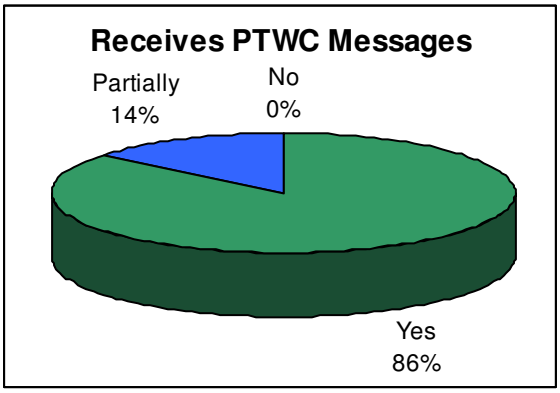


Figure 11a: Nation receives PTWC messages

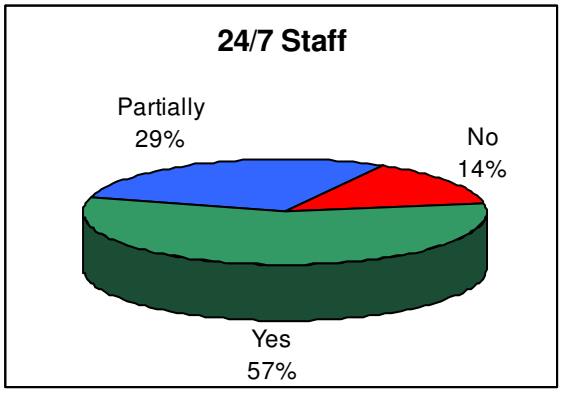


Figure 11b: 24/7 operational staff at warning receipt and dissemination location

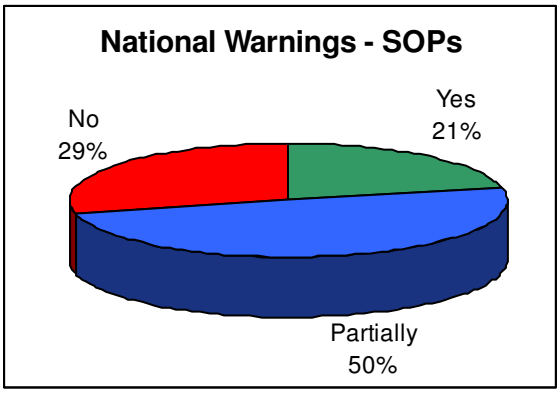


Figure 11c: Disseminate national tsunami warnings as guided by a Standard Operating Procedure

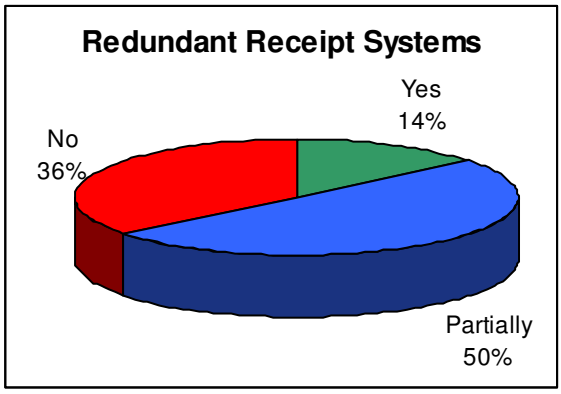


Figure 11d: System redundancies (back-up) in place for receipt of PTWC messages and dissemination of National warnings

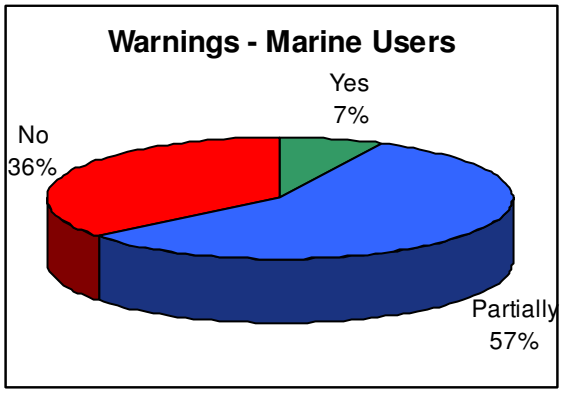


Figure 11e: Issue of marine tsunami warnings and guidance for vessels, harbours and ports

5.5.2. Key Regional Recommendations to Address Priority Issues

Key recommendations to address priority issues for tsunami warnings are outlined in Table 11. Key recommendations across the region include development of warning SOPs, formalising responsibility for warnings and building back-up or redundancy into the national warning systems.

Table 11: Key Regional Recommendations: Tsunami Warnings

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Warning SOPs - Use of Scientific Information	Use available scientific information to nationalise the tsunami threat (for example, arrival times, forecast points, sea level data, deep ocean models showing energy propagation)	Cook Islands, Marshall Islands, Nauru, Palau, PNG, Tuvalu, Vanuatu	**7**
Formalise Responsibility	Formally designate the responsibility and authority for receiving, analysing and interpreting tsunami messages and data and issuing national tsunami warnings (using national plans and legalisation)	Cook Islands, Kiribati, Nauru, Niue, Palau, Vanuatu	**6**
Warning SOPs - No Threat	Issue a "No Threat" bulletin for tsunami that are not expected to impact the country or felt earthquakes that will not generate tsunami	Fiji, Marshall Islands, Nauru, Samoa, Tonga, Vanuatu	**6**
Back-up Agency	Establish formal arrangements and procedures for a second 24/7 back-up agency in-country to receive PTWC messages and disseminate national warnings. This agency must have robust communications systems	Cook Islands, Kiribati, Nauru, Niue, Palau, Samoa	**6**
Resource Geoscience Agency for 24/7 Operation	Formally review the resource requirements of the Geoscience agency in-country that would enable it to maintain (or be involved in) a 24/7 tsunami watch and advice service	Fiji, PNG, Solomon Islands, Vanuatu	**4**
Warning SOPs - Action Matrix	Develop and approve an action matrix that outlines what national action will be taken for each PTWC message received	Cook Islands, Marshall Islands, Palau	**3**

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Warning SOPs - Templates	Develop tsunami warning templates (including interpretation into local languages and action prompts advising the community on action to take)	Cook Islands, Fiji, Palau	**3**
Warning SOPs - Distribution List	Develop and maintain a tsunami warning distribution list	Fiji, Palau, Tuvalu	**3**
Deep Ocean Model Access	Investigate gaining access to a deep ocean tsunami model scenario database to enable further determination of more specific national threat. Appropriate training must be included	Cook Islands, Palau, Samoa	**3**
Warning SOPs - Improve Receipt Process	Review current process for the receipt of tsunami warnings from PTWC to contribute to improved timeliness of national dissemination	PNG, Solomon Islands, Tuvalu	**3**
Adequate Staffing	Review / maintain staffing levels to effectively run 24/7 operations at responsible agency (multi-hazard benefits)	Kiribati, Niue, Tonga	**3**
Warning SOPs - Communicate with PTWC	Confirm the receipt of warnings from PTWC by the tsunami warning focal point and confirm the arrival (or otherwise) of a tsunami with PTWC	FSM, Solomon Islands	**2**
Back-up Country	Investigate the development of contingency plans that allow the issue of public warnings for tsunami and other hazards from another country	Samoa, Vanuatu	**2**
Determining Threat Levels	Consider how the country can move towards determination of different threat levels in their tsunami warnings (for example, marine only or land inundation)	Cook Islands, Samoa	**2**
Ports & Marine Users	Improving tsunami warning processes for ports and marine users such as vessels	Palau	**1**

5.6. Communications

Many of the communications recommendations made throughout the Tsunami Capacity Assessment project are technical and specific to the existing communication system in a particular country. It is therefore recommended that for further detail, the reader refers to individual country reports (refer Table 3).

The Tsunami Capacity Assessment project represents perhaps the most comprehensive review of in-country communications systems for some time with the inclusion of a communications expert on the Assessment Team for each country. A number of general recommendations are discussed below that address key challenges shared by many, if not all countries involved in this project.

Telecommunications underpin almost all in-country programs in the Southwest Pacific region including the development of all hazard warning networks as well as everyday weather forecasting, health and education services. The vast ocean expanses and isolation of many PIC communities make telecommunications vital to create links back to population centres for the delivery of basic services, early warning and emergency response.

The lack of reliable telecommunications infrastructure in the region, along with the technical challenges in delivering to remote sites, leads to many in-country programs being constantly compromised by poor connectivity and availability. Poor telecommunications impacts upon the send and receipt of warnings and observational data for both weather and climate networks. Figures 12a to 12b demonstrate that although telecommunications systems in the PICs are improving over time (for example, improvement mobile telephone networks) these systems are very rarely effectively used for receipt and dissemination of tsunami warnings. Communicating with remote communities (refer Figure 12c), system redundancies and 24/7 operations are three key challenges.

Any consolidated approach to enhancing the capacity of PICs in the telecommunications area needs a supported and purposely dimensioned strategy that encompasses a range of long standing communications issues. Aside from this project, these issues have been identified through various mechanisms, including the informal Pacific Telecommunications Working Group which involves a number of key technical experts from developed countries surrounding the Pacific Rim.

To improve the reliability and sustainability of telecommunications infrastructure in the 14 PICs there are three broad groups of recommendations:

1. Upgrade, strengthen and develop international communications systems to enable effective and efficient broadcast and two way information exchange, including timely receipt of international tsunami and other warnings from PTWC and others. For example, rollout of a VSAT multi-hazard two-way satellite system;
2. Implementation of effective, efficient and sustainable mechanisms for dissemination of tsunami and multi-hazard warnings to local centres (such as outer island Police stations) and the population with particular consideration given to reaching remote communities and warning the public outside of waking hours. For example, the RANET Chatty Beetle has been specifically designed for this purpose. Non-technological, community centric communication mechanisms such as church bells can also be considered here; and
3. Improved in-country coordination of communications systems (existing and new) to enable effective use, interoperability and reliability for tsunami warnings, multi-hazard warnings, emergency response and other functions (for example, education and health).

Long-term support, serviceability and sustainability (including on-going service costs, maintenance and technical training) must be incorporated as part of the overall scope of any future projects in

this field. Further examples of recommendations under these three broad groups can be found in Table 12.

5.6.1. Status of Key System Components

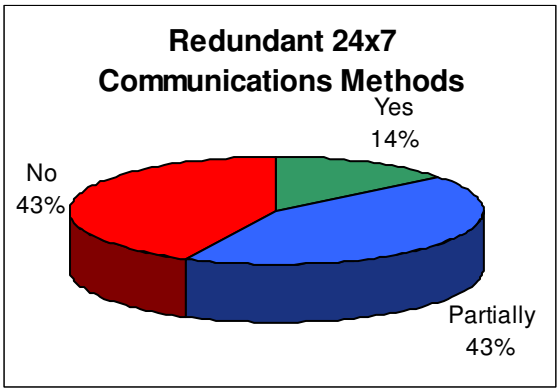


Figure 12a: Redundant 24/7 methods available for dissemination of warnings to community (e.g. public radio, sirens etc.)

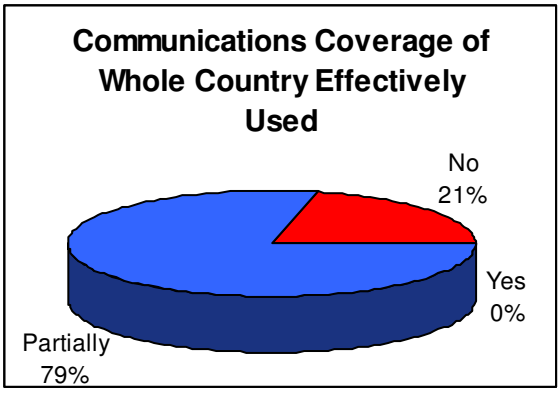


Figure 12b: Communications coverage of whole country that is effectively utilised for the dissemination of tsunami warning messages

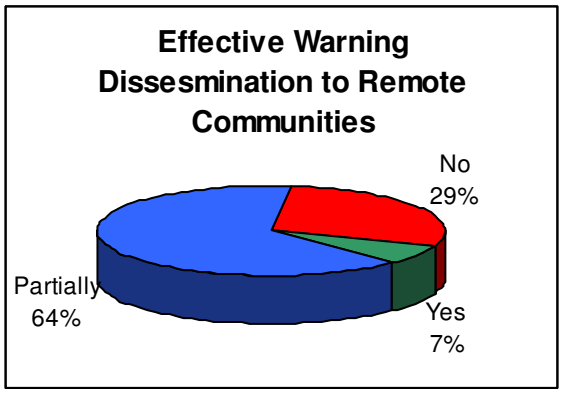


Figure 12c: Effective warning dissemination to remote communities

5.6.2. Key Regional Recommendations to Address Priority Issues

Key recommendations to address priority issues in telecommunications for tsunami warning and mitigation systems are outlined in Table 12. Key recommendations across the region include improved two way international communication, improved in-country communication (particularly out of hours and to remote communities) and improved planning and coordination throughout the country for use of current and new communication mechanisms for early warning and other communication needs.

Table 12: Key Regional Recommendations: Communications

KEY COMMUNICATIONS RECOMMENDATION 1	Upgrade, strengthen and develop international communications systems to enable effective and efficient broadcast and two way information exchange, including timely receipt of international tsunami and other warnings from PTWC and others.	**All**

Country Specific Examples

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Iridium Satellite Phones	Each key agency obtains OR upgrades Iridium phones for international and national voice and SMS backup capability. Update and share a national satellite phone number database	Cook Islands, FSM, Fiji, Niue, Palau, Samoa, Tonga	**7**
Redundant Comms at Key Agencies	Improvement of redundant 24/7 communications mechanisms at all agencies responsible for tsunami warning and response	Fiji, Palau, PNG, Solomon Islands, Vanuatu	**5**
RANET SMS	Ensure relevant in-country contacts are receiving RANET SMS from PTWC on dedicated mobiles as a means for back-up of receiving tsunami warning information	Samoa, Solomon Islands, Samoa, Vanuatu	**4**
EMWIN upgrade	Upgrade national Emergency Managers Weather Information Network (EMWIN) systems and / or install additional systems at key agencies and back-up agencies	Cook Islands, Samoa, Tuvalu	**3**
Power supply	Ensure the provision of an external reliable non-break mains power supply to all tsunami warning agencies / back-up power	FSM, Niue, Samoa	**3**

KEY COMMUNICATIONS RECOMMENDATION 2	Implementation of effective, efficient and sustainable mechanisms for dissemination of tsunami and multi-hazard warnings to local centres (such as outer island Police stations) and the population with particular consideration given to reaching remote communities and warning the public outside of waking hours Options include: RANET Chatty Beetle, satellite broadcast, national SMS, dedicated HF or VHF radio, GPRS, VSAT, traditional methods such as church bells, sirens (police car or fixed), AM and FM radio, television etc. *(For definitions refer to Acronyms list)*	**All**

Country Specific Examples

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Mobile network use	Plan for the use of new or expanding national mobile telephone networks as one mode for warning dissemination (for example, National SMS)	FSM, Nauru, Vanuatu	**3**
Sirens	Install sirens with radio frequency or cellular triggers (with manual back up) around all major population centres	FSM, Palau	**2**
Radio outside hours	Set-up radio station to disseminate information outside normal hours of operation	Kiribati	**1**
GPRS	Utilise Cellular GPRS for telemetry and also as a potential communications mechanism between its regional offices that have coverage	Fiji	**1**
VHF	Maintain and upgrade the VHF two-way radio network and consider upgrading to a linked repeater system with full interagency interoperability	FSM, Palau	**1**

KEY COMMUNICATIONS RECOMMENDATION 3	Improved in-country coordination of communications systems (existing and new) to enable effective use, interoperability and reliability for tsunami warnings, multi-hazard warnings, emergency response and other functions (for example, education and health)	All

Country Specific Examples

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Integrated Messaging System	Consider running an integrated messaging system that manages SMS, e-mail fax and voice messaging to serve as the database and alert system for national emergency contacts	Cook Islands, Fiji, Samoa	**3**
Fund for Maintenance	Establish a fund / funding plan to maintain all emergency communication systems	FSM, PNG	**2**
Inventory and Integration of Systems	Complete an inventory of agency and national communication systems and investigate options for integration with a view to develop a disaster communications plan. Consider training, 24/7 contact, system checks, back-up options, ongoing costs, maintenance	Fiji, Marshall Islands, PNG	**3**
Comms Technicians	Review / maintain staffing skills that will enable operation of all available communications systems to ensure redundant capability	Kiribati	**1**
Formalise media agreements	Formalise agreement with media providers to provide warnings through the media (including outside of normal hours of operation)	Kiribati, Tuvalu, Vanuatu	**2**

5.7. Tsunami Emergency Response (including evacuation)

Emergency response and evacuation planning is largely reliant on solid in-country DRM planning, governance frameworks and coordination. These aspects are discussed in section 5.1 of this report.

The Tsunami Capacity Assessment project looked specifically at capacity for emergency response and evacuation of the 14 PICs involved. Many countries had completed or partially completed a review of their DRM arrangements (refer Figure 13a) through reviews of national disaster plans or completion of DRM NAP processes (refer to Section 5.1). Very few countries had completed specific tsunami planning (refer Figure 13b). Although most countries had an agency that was designated as responsible for leading community evacuation (refer Figure 13c), very little emergency evacuation planning for tsunami had been completed across the Region (refer Figure 13d). The lack of evacuation planning (refer Figure 13e) was very clearly linked to uncertainty about which coastal communities are at tsunami risk (refer Section 5.8). Most of the 14 PICs completed testing and exercising of procedures for better known hazards. However, aside from varying levels of involvement in international tsunami exercises (such as Pacific Wave), many countries had not completed testing and exercising specific to tsunami (Samoa was a standout exception to this generalisation) (refer Figure 13e). The lack of testing and exercising was evident in those countries without specific tsunami plans at the time of the assessment.

The National Disaster or Emergency Management Offices (NDMOs) in each country are small, with a small number of staff and relatively few resources. These agencies have large DRM planning, education and coordination responsibilities that often exceed their capacity to deliver with limited resources.

5.7.1. Status of Key System Components

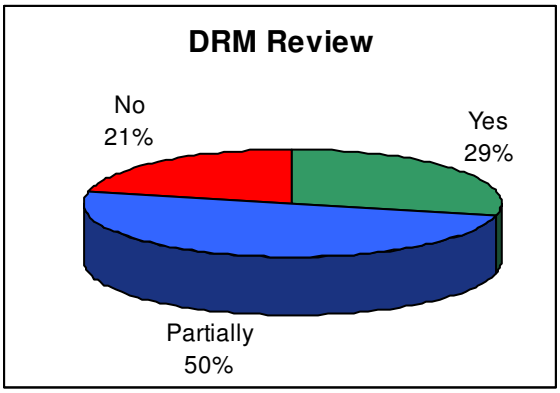


Figure 13a: Disaster preparedness and emergency response system has been reviewed and opportunities for improvement and training identified

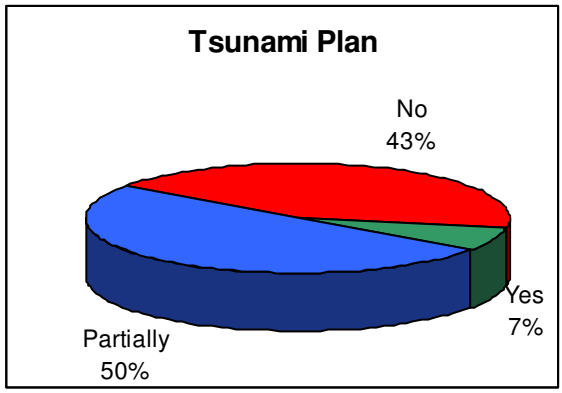


Figure 13b: Tsunami emergency response, evacuation and recovery plan exists

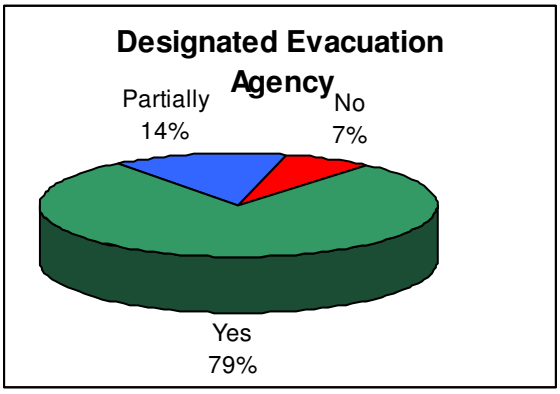


Figure 13c: The designated agency for evacuation is identified and have authority by law

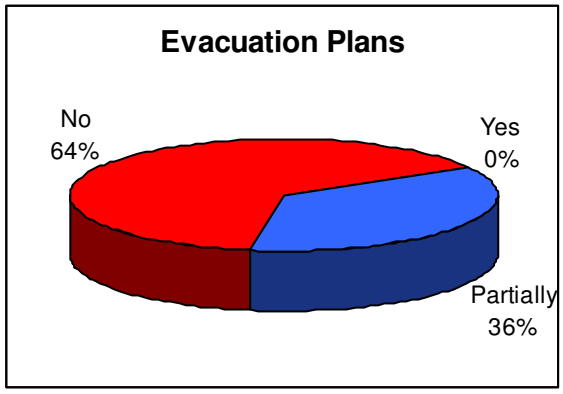


Figure 13d: Plans have been made for safe evacuation of population centres including aspects such as maps, routes and signage

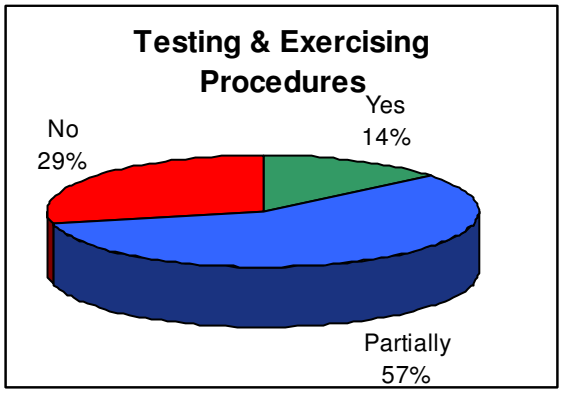


Figure 13e: Procedures are tested and exercised to improve the response through better planning and preparedness

5.7.2. Key Regional Recommendations to Address Priority Issues

Key recommendations to address priority issues in emergency response and evacuation for tsunami warning and mitigation systems are outlined in Table 13. Key recommendations across the region include improved testing and exercising, improved evacuation planning and improved resourcing and profile building of NDMOs.

Table 13: Key Regional Recommendations: Tsunami Emergency Response (including evacuation)

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Testing & Exercising	Conduct regular multi-stakeholder tests/exercises of the tsunami warning and response arrangements including a post exercise debrief to further enhance procedures and training	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Tonga, Tuvalu, Vanuatu	**12**
Evacuation Planning	Begin OR continue to make plans for the safe evacuation of communities at risk of tsunami including consideration of evacuation shelters, maps, signage and drills	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Solomon Islands, Tonga, Vanuatu	**12**
NDMO Resources & Profile	Resource the NDMO to effectively carry out their DRM coordination role and build their profile throughout the country (e.g. through free media)	Cook Islands, Fiji, Kiribati, Marshall Islands, Palau, PNG, Tonga	**7**
Database for DRM Data	Develop an information management system/database to act as a central depository to ensure all national DRM data is available for use during an event	Cook Islands, Fiji, Nauru, Palau, Tonga, Vanuatu	**6**
Critical Infrastructure & Lifeline Support Facilities	Identify critical infrastructure and lifeline support facilities and develop plans to ensure the availability of minimal services after a destructive tsunami, or other natural disaster	Nauru, Palau, Samoa, Solomon Islands, Vanuatu	**5**
NEOC Location & Resources	Review and consider needs for appropriately located and resourced National Emergency Operations Centre AND/OR other key warning and response agencies that are in disaster prone locations	Cook Islands, Kiribati, Samoa, Vanuatu	**4**

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Post Event Reviews	Ensure comprehensive formal event reviews are undertaken for each tsunami that occurs and that these reviews are used to enhance procedures and training as well as being fed into international improvement processes	Nauru, Solomon Islands, Tonga, Vanuatu	**4**
Equipment	Audit, procure and register emergency response equipment needed AND/ OR managed by each response organisation	Marshall Islands, Nauru	**2**
Remote Sensing Data	Use remote sensing data (such as high resolution satellite images) for post disaster damage assessments	Samoa	**1**

5.8. Tsunami Hazard, Vulnerability, Risk and Mitigation

Section 3.2 outlines the tsunami hazard faced by PICs. Much of this current knowledge is based on historical tsunami records. Some preliminary studies have been completed by GA and a select few countries have had inundation studies completed for sections of their coastline (refer Figure 14a). These inundation studies vary in quality, primarily reflecting the quality of topography and bathymetry data available to underpin the work. A country specific example of work that has been completed to better understand the tsunami threat includes the Suva tsunami hazard map completed under the Suva Earthquake Risk Management Scenario Pilot Project. Paleo-tsunami work is also limited across the 14 PICs.

Some high resolution bathymetry and topography data exists across the region, however large gaps in the quality (resolution) and geographical coverage of this data exists (refer Figure 14b). This data is vital for completion of detailed tsunami hazard studies at the country scale. There has been reluctance from the development partner community to fund the significant cost and multi-year commitment to collect this data. Good quality bathymetry and topography data is also useful for other applications such as storm surge and climate change inundation modelling. An inventory of available geospatial data has been completed for Tonga, Niue, Kiribati, the Solomon Islands, Fiji and Tuvalu. A PIC summary draft of the results of these inventories is also available. This information can be found at www.pacificdisaster.net/

There are also a number of Pacific Rim countries that have developed deep ocean tsunami models for local and distant tsunami sources throughout the Pacific (refer Figure 14c). These models could be made available to PICs to enable them to better plan tsunami warning scenarios and better understand communities at risk. These scenarios are intended as an indication of potential broad scale impacts for individual earthquakes. The scenarios end offshore and can therefore not be relied upon as a useful indication of precise tsunami behaviour and impacts on the land. Only further detailed inundation modelling (using high resolution near shore bathymetry data) would describe the potential for localised impacts of tsunami on land.

There are minimal studies at the community level that have been completed to assess the vulnerabilities of communities at risk from tsunami (refer Figure 14b). Samoa is an exception to this generalisation, where a multi-hazard community program is being rolled out across the country to assess community vulnerability to hazards and put plans in place to address areas of need.

Limited mitigation for tsunami can be seen across the PICs, largely due to uncertainties with regard to high risk areas. Existing environmental measures to maintain natural coastal features may assist in mitigating tsunami impacts.

5.8.1. Status of Key System Components

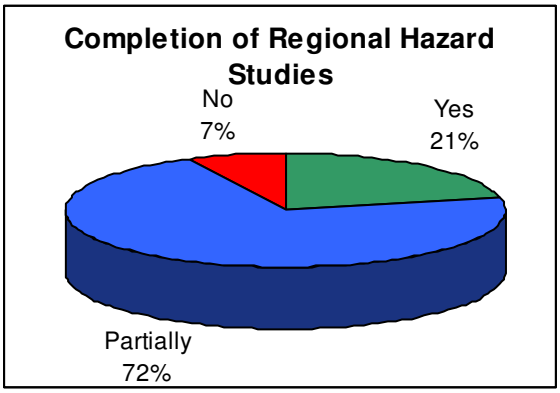


Figure 14a: Completion of studies to assess the tsunami hazard in the country or Region

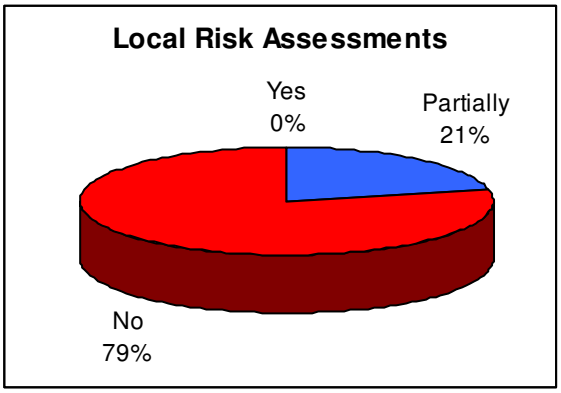


Figure 14b: Local risk assessments have been completed for at risk communities

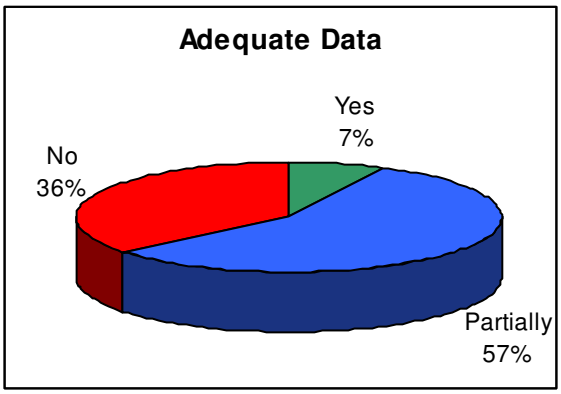


Figure 14c: Adequate data exists and local inundation modelling has been completed for population centres

5.8.2. Key Regional Recommendations to Address Priority Issues

Key recommendations to address priority issues in tsunami hazard, vulnerability, risk and mitigation for tsunami are outlined in Table 14. Key recommendations across the region include completion of inundation modelling, using available studies and deep ocean models to better understand national risk and acquiring the baseline geospatial data required to complete more detailed tsunami inundation modelling.

Table 14: Key Regional Recommendations: Tsunami Hazard, Vulnerability, Risk and Mitigation

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Inundation Modelling	Investigate future options for completing tsunami inundation modelling in partnership with regional and international bodies, particularly for population and infrastructure centres	Cook Islands, FSM, Fiji, Kiribati, Niue, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu	**11**
Use Available Studies	Use the tsunami hazard studies completed for the Southwest Pacific Nations to date, historical records, GIS data and deep ocean models to identify low-lying communities potentially at tsunami risk	Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Palau, PNG, Samoa, Solomon Islands, Vanuatu	**10**
Acquire Baseline Data	Acquire the necessary high resolution topography and bathymetry data for centres at risk of tsunami as part of a multi-hazard mapping activity. Possible opportunities exist to capitalise on climate change synergies	Cook Islands, Fiji, Kiribati, Marshall Islands, Palau, PNG, Samoa, Solomon Islands, Tonga, Vanuatu	**10**
Building Code & Assessing Risks to Development	Develop a strategy for adherence to OR improvement of the current building code AND/OR land zoning requirements. Evaluate the natural hazard risk for potential new developments	FSM, Marshall Islands, Nauru, PNG, Solomon Islands, Tonga, Tuvalu, Vanuatu	**8**
Traditional Knowledge	Investigate and archive past stories, tsunami history and traditional warning signs and tsunami records OR continue to widely disseminate already known traditional knowledge for community awareness benefits	Cook Islands, FSM, Marshall Islands, Nauru, Niue, Samoa, Solomon Islands	**7**
Locate and Archive Data	Conduct an inventory of data (bathymetry and topography) from previous studies (either stored nationally or internationally) and archive this data	Marshall Islands, Palau, Samoa, Solomon Islands, Tuvalu, Vanuatu	**6**

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Assess Community Vulnerability	Conduct multi-hazard community vulnerability and capacity assessments to define the level of risk and potential mitigation and preparedness options AND/OR continue multi-hazard community based DRM programs	Cook Islands, Niue, PNG	**3**
Conserve Natural Systems	Consider actions to limit AND OR assess the potentially damaging impacts of near-shore activities to safeguard and protect the environment, including the preservation of outlying reefs, which may mitigate the impact of tsunami	Fiji, Vanuatu	**2**
Village Carpenters Manual	Develop a village carpenters manual including building placement considerations with regard to natural hazards (especially important for public buildings that become evacuation centres)	Solomon Islands	**1**
Calculate Potential Loss	Identify potential losses (or actual losses) due to tsunami impacts as an advocacy and planning tool to encourage investment in tsunami risk reduction	PNG	**1**

5.9. Public and Stakeholder Awareness, Education and Training

There is a number of community education programs for natural hazards implemented across the 14 PICs. Many of these programs included some mention of tsunami (refer Figure 15a and 15b). Very limited media education exists (refer Figure 15c). Across the board tsunami education challenges exist. These challenges can lead to an inadequate community response during tsunami events. Some of these challenges include:

- Tsunami being rare in comparison to other hazards such as cyclones/typhoons that PICs experience seasonally. In many communities there is no living memory of tsunami and a long time between events makes maintenance of tsunami knowledge a challenge;
- Tsunami knowledge being based on visual experience of the 2004 tsunami. The majority of coastal communities have no context of tsunami impact or behaviour in their country. This makes educating about small events difficult;
- Unrealistic expectations of the warning system and/or lack of knowledge about how the warning system works (if a warning system exists) as well as lack of specific local information such as evacuation routes;
- Perception that the warning system generates a high frequency of false alarms;
- Uncertainty about the tsunami risk to their community (reflected in the reluctance for most PICs to implement signage without a better understanding of tsunami risk);
- Frequent experience of felt earthquakes that do not result in tsunami and difficulty ascertaining what size of felt earthquake to react to;
- Local knowledge of coastal features perceived to mean tsunami is not a threat (for example, offshore islands will stop tsunami hitting mainland); and
- Non uniform perception of risk across the country formed by tsunami that have occurred and/or warnings that have been issued.

This being said, there are a number of opportunities with regard to tsunami education in PICs including:

- General knowledge of tsunami and their causes;
- Local area knowledge and knowledge of responsibilities of response agencies from experience with other disasters (particularly in cyclone prone areas);
- Strong community support and communication structures;
- A wealth of pre-existing international material and programs (UNESCO media training programmes, ITIC tsunami education material, NOAA TsunamiReady, SOPAC multi-hazard education material) that could be adapted to local use for minimal cost; and
- Incorporating tsunami into awareness programs undertaken for other hazards.

Many of the PICs are susceptible to tsunami from local sources. Consequently, these countries need to be aware of the natural tsunami warning signs. Education of the public to take action based on these warning signs is paramount to an effective tsunami warning and mitigation system. The natural warning signs include the shake of the earthquake, water receding before the arrival of the wave, a load roaring sound coming from the ocean and obviously water surging inland.

Aside from involvement in international training programs, the Tsunami Capacity Assessment Project found very little evidence of any adequate tsunami training for tsunami warning and response officials (refer Figure 15d). This is a significant gap. International training programs

include ITIC Training Program which provides in-country training on seismology and tsunami warning Development of SOPs.

5.9.1. Status of Key System Components

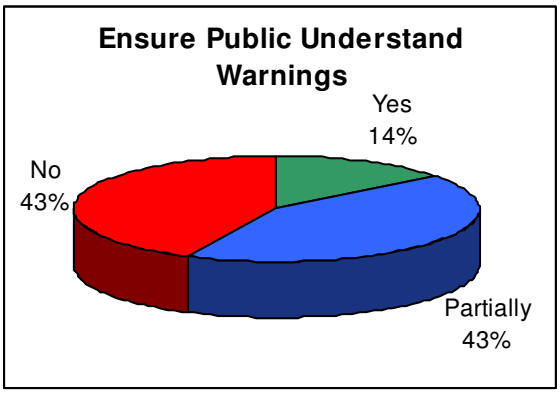


Figure 15a: Measures have been taken to ensure the public understand and take action in the event of a tsunami warning being issued

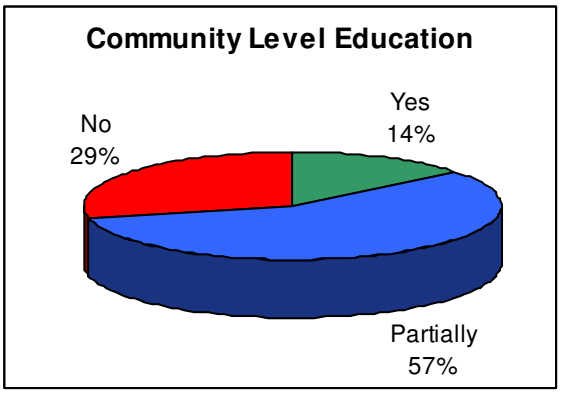


Figure 15b: Community level education and preparedness programs exist for tsunami

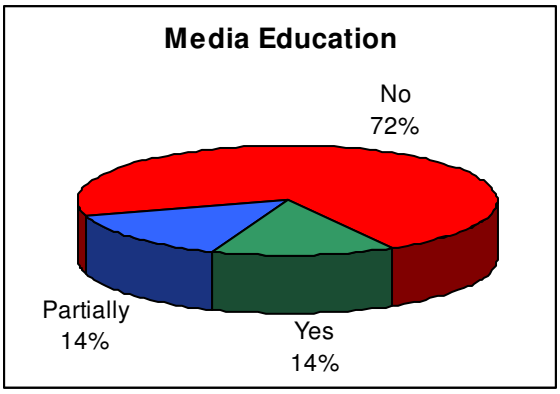


Figure 15c: Training programs for the National media exist for natural hazard and tsunami

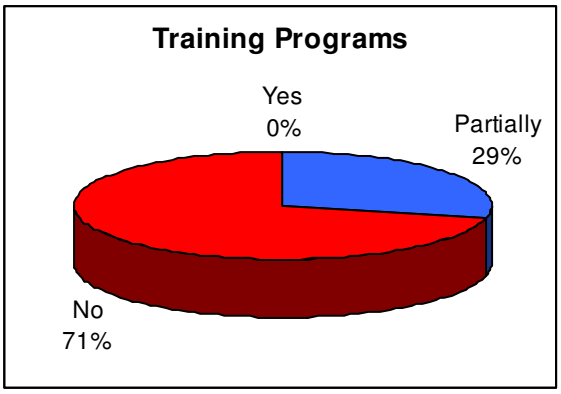


Figure 15d: Training programs exist for officials involved in tsunami warning and response

5.9.2. Key Regional Recommendations to Address Priority Issues

Key recommendations to address priority issues in tsunami public and stakeholder awareness, education and training are outlined in Table 15. Key recommendations across the region include expansion or development of tsunami awareness programs (using existing materials), development of tsunami training programs for tsunami warning and response officials, development of media education programs and incorporation of earthquake and tsunami into school curriculum.

Table 15: Key Regional Recommendations: Public and Stakeholder Awareness, Education and Training

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
Awareness Program	Expansion of the current OR development of a tsunami community awareness program. Collaborate between organisations and incorporate the program into a multi-hazard framework supported by work plans and budgets. Build evaluation into this program to review its effectiveness. Include awareness raising of tsunami warnings, action to take on receiving a warning, post event education and natural tsunami warning signs for those countries with local tsunami generation sources	Cook Islands, FSM, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu	**14**
Training Program	Develop a tsunami training program, including training for emergency managers, science / warning agencies and others involved in tsunami warning and mitigation within the country. Training should be conducted within a competency-based framework where appropriate (for example, for issuing tsunami warnings)	Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, PNG, Solomon Islands	**10**
Media Education	Develop a tsunami media education program to assist the media to understand the tsunami hazard and warning procedures, therefore passing the correct information onto the community. This should be incorporated into a multi-hazard framework	Cook Islands, FSM, Fiji, Marshall Islands, Nauru, Palau, Tonga, Tuvalu, Vanuatu	**9**

Descriptor	Recommendation & Project Opportunity	Relevant to SOPAC Member Countries	No. of Countries
School Curriculum	Include earthquake and tsunami into school curriculum OR expand on current earthquake and tsunami curriculum to include tsunami preparedness (warning process and action to take) within a multi-hazard framework. Include training for teachers on curriculum delivery	Cook Islands, Kiribati, Marshall Islands, Nauru, Palau, PNG, Solomon Islands, Tonga, Tuvalu	**9**
Awareness Program – Use of Existing Materials	Network with regional / international agencies, such as ITIC and SOPAC regarding accessing existing tsunami awareness materials	Cook Islands, FSM, Fiji, Marshall Islands, Nauru, Palau, Samoa, Tonga, Vanuatu	**9**
Training Needs Analysis for DRM	Complete a training needs analysis and development of a national training framework for DRM	Marshall Islands, Nauru, Palau, PNG, Tonga	**5**
Awareness Program – Special Needs Groups	Identify dialect / language groups as well as other community / business sectors that may require tailored tsunami awareness programs (for example, tourism)	Fiji, Palau, Samoa	**3**
Signage	Develop and implement tsunami signage to international standards within populated coastal areas and tourism centres	Samoa, Vanuatu	**2**
Anti-vandalism Program	Develop a media program to raise community awareness of the importance of early warning equipment to reduce vandalism (for example, vandalism of solar panels)	PNG, Solomon Islands	**2**

6. Next Steps

6. Next Steps

Essentially, each national report provides an improvement strategy. PICs involved in the project are encouraged to use their National Tsunami Capacity Assessment reports to guide both national projects and projects funded by development partners to achieve targeted improvements of their tsunami warning and mitigation systems. In turn, this will assist in improving systems for other natural hazards.

The recommendations of both the National and Regional reports provide an opportunity to mitigate the risk of tsunami on PICs through development and implementation of focused projects for which there is an identified need. Ideally, implementation of a large program of work could be completed to enhance tsunami warning and mitigation systems in PICs using this Regional report as an overarching strategic framework. This of course, is contingent on the availability of human and financial resources from development partners and the priority of tsunami in comparison to basic human services and other hazards.

The adoption of a multi-hazard approach to early warning systems has been widely embraced internationally as a requirement to meet the resource demands of planning for DMR. In order to meet the requirements of early warning and mitigation for the tsunami hazard, tsunami specific requirements also exist. Annexure 4 provides a checklist for developing new projects based on the recommendations of this project. It is most important to engage PICs in project development, ensuring projects have a practical focus on building capacity to create an environment where independent action can take place on a national level.

Due to the technical nature of tsunami warning and mitigation systems it is necessary to enhance the strategic connection between international scientific and technical agencies to actively assist PICs in the implementation of integrated and sustainable technical solutions.

The Bureau has facilitated the dissemination of both National reports and this Regional report to development partners and other stakeholders to ensure maximum exposure of results in the hope of facilitating further capacity development projects being undertaken based on the results of this project. As the key client for completion of the project and the funding body, AusAID are the key development partner that has been provided with the results of the assessments. Already, the Pacific Public Sector Linkages Program (PPSLP) 2009/10 funding has been approved by AusAID for a project, *Tsunami Preparedness - Capacity Development in the Solomon Islands.* This project will build the capacity of Solomon Island frontline agencies to undertake a coordinated, whole of government, private sector and non-government organisation approach to tsunami management by completion of a holistic national Tsunami Response Plan and technical support for key agencies to develop and test Standard Operating Procedures (SOPs). This project, which commenced in April 2010, is being lead by the Bureau and the Solomon Islands NDMO in conjunction with other technical partners.

There is no doubt that this assessment project has laid the foundation for the potential to provide widespread, meaningful and practical solutions to the tsunami hazard. In closing, it is recommended that the progress of PICs in improving their tsunami warning and mitigation systems be monitored by revisiting this assessment project in the future. The time frame for such a review will depend on activity level in this field over the coming years.

6.1. Acknowledgements

In conclusion, the Project Manager would like to extend thanks to AusAID for providing funding for completion of this project and all those staff at the Bureau who worked tirelessly to see the assessments through to their conclusion.

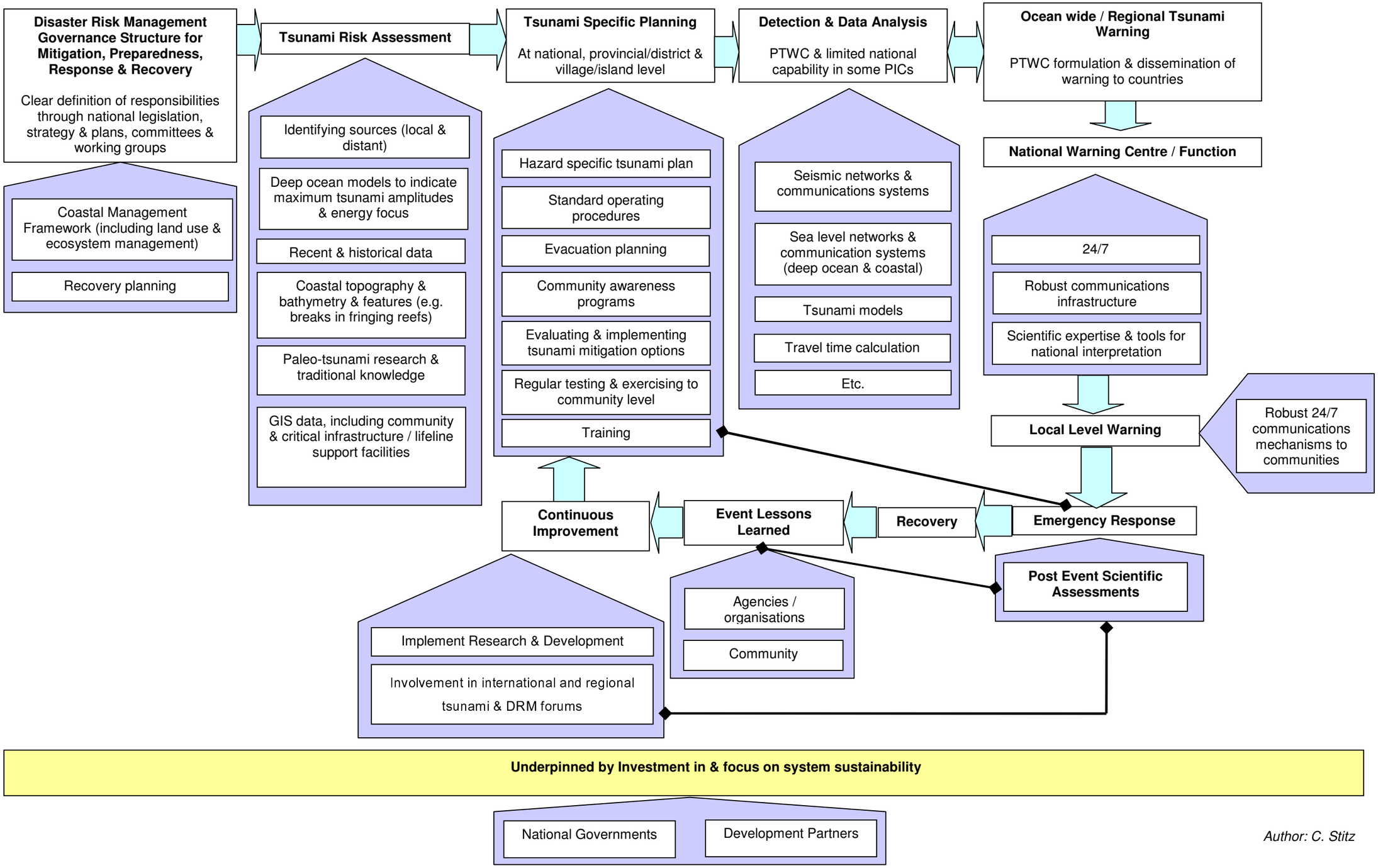
The Bureau would also like to thank project partners AGD and SOPAC and all other experts that participated in various assessment teams from University of Guam, New South Wales State Emergency Services, New Zealand Meteorological Service, Tasmania State Emergency Service, Intergovernmental Oceanographic Commission, NOAA, USAID and telecommunications contractors.

We extend our sincere thanks to each country for the contribution of all those who participated in the assessment workshops, particularly those who made their time available to help coordinate the visits as well as those that assisted in the review of documents. Your in-country expertise was unquestionably the most important input into the assessment process. We hope the project results can be useful now and in years to come as you strive to protect your communities.

7. Annexure & Attachments

7. Annexure & Attachments

7.1. Annexure 1 – Strategic Overview: End to End Tsunami Warning & Mitigation Systems in the Pacific Islands



7.2. Annexure 2 – References

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7.3. Annexure 3 - Glossary of Terms

Definitions are taken from UNISDR, ITIC, GA and Bureau sources. Further detail can be found at **http://ioc3.unesco.org/itic/contents.php?id=328**

Bathymetry - The measurement of the depth of the ocean floor from the water surface and is the oceanic equivalent of topography.

Capacity - A combination of all the strengths and resources available within a community, society or organization that can reduce the level of risk, or the effects of a disaster.

Capacity building - Efforts aimed to develop human skills or societal infrastructures within a community or organization needed to reduce the level of risk.

Disaster - A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.

Disaster Risk Management (DRM) - The systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards.

Disaster Risk Reduction (DRR / disaster reduction, DR) - The reduction of disaster risks and adverse impacts of natural hazards, through systematic efforts to analyse and manage the causes of disasters, including through avoidance of hazards, reduced social and economic vulnerability to hazards, and improved preparedness for adverse events.

Early warning - The provision of timely and effective information, through identified institutions, that allow individuals exposed to a hazard, to take action to avoid or reduce their risk and prepare for effective response.

Emergency management - The organization and management of resources and responsibilities for dealing with all aspects of emergencies, in particularly preparedness, response and rehabilitation.

Epicentre - The point on the Earth's surface directly above where the earthquake originated within the Earth.

Hazard - A potentially damaging physical event, phenomenon and/or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

Hypocenter - The initial rupture point of the earthquake.

Inundation - The horizontal extent of flooding from the sea.

Mean sea level - The average height of the sea surface, based upon hourly observation of tide height on the open coast or in adjacent waters which have free access to the sea.

Mitigation - Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards.

Moment Magnitude (Mw) - A measure of the energy release by an earthquake. There are a number of different scales for measuring the magnitude. The Moment Magnitude is based on the size and characteristics of the fault rupture, and can be determined from long-period seismic waves.

Natural hazards - Natural processes or phenomena occurring in the biosphere that may constitute a damaging event.

Paleo-tsunami studies – The study of long-term geologic records to provide insight into past tsunami inundations including the estimation of time and recurrence intervals. Paleotsunami research is based primarily on the identification, mapping, and dating of tsunami deposits found in coastal areas, and their correlation with similar sediments found elsewhere locally, regionally, or across ocean basins.

Public awareness - The processes of informing the general population, increasing levels of consciousness about risks and how people can act to reduce their exposure to hazards. This is particularly important for public officials in fulfilling their responsibilities to save lives and property in the event of a disaster.

Relief / **response** - The provision of assistance or intervention during or immediately after a disaster to meet the life preservation and basic subsistence needs of those people affected. It can be of an immediate, short-term, or protracted duration.

Risk - The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions.

Risk assessment/analysis - A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend.

Run-up - The maximum height of the water onshore observed above a reference sea level. Run-up is usually measured at the horizontal inundation limit.

Seismic - Of or having to do with earthquakes.

Shoaling - The process by which tsunami wave heights increase as they approach the shore.

Subduction zone - An area on the earth where two tectonic plates meet and move towards one another, with one sliding underneath the other and moving down into the earth at rates typically measured in centimetres per year.

Topography - The physical configuration of the surface of the land, including its elevation, slope, and orientation.

Tsunamigenigic - Capable of generating a tsunami. For example: a tsunamigenic earthquake, a tsunamigenic landslide.

Vulnerability - A set of conditions and processes resulting from physical, social, economic, and environmental factors, which increase the susceptibility of a community to the impact of hazards.

Wave amplitude - This is quoted as half the wave height. It should be recognised that tsunami waves are typically not symmetrical.

Wave height - The vertical distance between the trough and the crest of a wave.

Wavelength - The mean horizontal distance between successive crests or troughs of a wave pattern.

Wave period - The time taken for a one wavelength to pass a given point.

7.4. Annexure 4– Checklist for Development of New Projects/Programs based on the Recommendations of this Project

No.	Project Planning Aspect	Yes/No, Evidence
1	Is the project filling an identified gap that is not being adequately addressed by existing projects and programs or has a need for the project been demonstrated by a gap analysis process?	
2	Is the project a priority for the Country/Regional (would the project be supported by the Country/Region)? Is the project supported by Country/Regional policy and partners?	
3	Does the project address a proven Country/Region risk and go some way to reducing that risk?	
4	Does the project provide tangible impact for dollars spent or will it result in considerable reductions in expenses associated with the risk (cost benefit ratio)	
5	Is a plan for sustainability within the Country/Region required (e.g. Funding)? This is particularly vital for technical equipment)	
6	Does the project avoid replication with existing projects within the target area or synergise with these projects where possible?	
7	Has the project been fully costed and timelines identified?	
8	What are the mechanisms for project coordination with and reporting back to: • Stakeholders in-country • The funding provider • Regional disaster management and meteorological forums • Internal to the project agency	
9	Does the project deliver benefits across multiple hazards?	
10	Is regional/in-country capacity being built by: Implementation of the project through in-country or regional organisations? *Capacity building: activities which strengthen the knowledge, abilities, skills and behaviour of individuals and improve institutional structures and processes such that the organisation can efficiently meet its mission and goals in a sustainable way*	
11	Does the implementing project agency have strong internal senior management commitment to ensure ongoing support and completion of the project?	
12	Does the project demonstrate best international practice?	
13	Does the project take account of cultural sensitivities, gender equity and best practice aid delivery?	
14	Does the project lead to success on the ground? What are the project's tangible outcomes and outputs?	
15	What evaluation mechanisms are built into the project?	
16	Does the project represent best use of funding available (e.g. through partnership contributions or contributions from the target Country/Region)	

No.	Project Planning Aspect	Yes/No, Evidence
17	Has consideration been given to the best implementation partners for the project? For example: • In-country or Regional Organisation counterparts • Possible implementing parties (donors, Australian State or Federal agencies, contractors, international experts)	
18	Meets aid funding guidelines negotiated with funding bodies	

Author: C. Stitz

7.5. Attachment 1 – CD of National Reports and Regional Report.

In addition to on the websites outlined in Table 3, electronic PDF copies (in large and small file sizes) of National Reports and the Regional Report can be found on the CD attached.