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Tonga Mission Report

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Contents

Acronyms

ADB	Asian Development Bank
APTC	Australia-Pacific Technical College
AUD	Australian Dollars
DFAT	Department of Foreign Affairs and Trade (GoA)
DMO	Disaster Management Office
EU	European Union
EWS	Early Warning System
EIA	Environmental Impact Assessment
GoA	Government of Australia
GoJ	Government of Japan
GoNZ	Government of New Zealand
GoT	Government of Tonga
GPSS	Global Program for Safer Schools
GGP	Grant Assistance for Grassroots Projects (GoJ)
IDA	International Development Association
INGO	International Non-Government Organisations
JICA	Japan International Cooperation Agency
LDS	Latter Day Saints
MOET	Ministry of Education and Training (GoT)
MFAT	Ministry of Foreign Affairs and Trade (GoNZ)
MoF	Ministry of Finance (GoT)
MoI	Ministry of Infrastructure (GoT)
NBC	National Building Code of Tonga
NEMO	National Emergency Management Office (GoT)
NZ	New Zealand
PACCSAP	Pacific-Australia Climate Change Science Adaptation Planning
PIC	Pacific Island Countries
PUMA	Planning and Urban Management Agency (GoT)
PREP	Pacific Resilience Program (WB)
PTA	Parent Teacher Association
TA	Technical Assistance
TOP	Tongan Pa’anga
USD	United States Dollars
WATSAN	Water and Sanitation
WB	World Bank

Executive Summary

The World Bank (WB) have recently approved $16 million (US) grant to Government of Tonga through their Pacific Resilience Program (PREP) and $1.15 million has been allocated for the retrofit or reconstruction of school facilities. To compliment this the WB propose to provide technical assistance through the Global Program for Safer Schools. The aim of this study is to assess the vulnerability of existing school infrastructure in Tonga to natural hazards and to determine the contributing factors of risk to school infrastructure. Identifying these factors will help the GoT, with WB support, to develop a school reconstruction/ retrofitting program through the PREP. The observations made in this report are the result of a 7-day field mission carried out by two Arup Consultants in September 2015.

The Kingdom of Tonga is a Polynesian sovereign state comprised of 177 islands, 52 of which are inhabited. Tonga's location adjacent to the Tonga trench and the 'cyclone belt' of the Pacific makes it vulnerable to earthquakes, tsunamis and tropical cyclones. The United Nations University ranked Tonga with the second highest disaster risk index globally, due to its exposure to natural hazards and ability to respond in the aftermath of disasters.

Tonga has 140 Primary schools and 37 Secondary schools spread across the four main island groups. There is currently no demand to increase the number of schools, but the need to replace the existing infrastructure is increasing. In total, close to 18,000 children are enrolled in schools and therefore at risk if school infrastructure is not safe and resilient to natural hazards.

During the site surveys it was observed that site selection and physical planning of the school sites is rarely undertaken, with many schools across Tonga on exposed sites. Structural vulnerabilities were found on school buildings which arise from three main factors: a lack of engineered school designs; poor quality control and supervision during construction and a lack of maintenance of school infrastructure, therefore increasing their susceptibility to damage from natural hazards. Furthermore there are opportunities for improvement in the planning, design, construction and operation and maintenance of school infrastructure. Addressing these factors will assist to decrease the exposure and vulnerability of school infrastructure.

Technical engineering expertise in Tonga is limited and ministries find it difficult to source staff with the skills required to fill engineering roles. Introducing the requirement for construction practitioners to be registered in Tonga or to a suitable overseas institution is the first step to ensuring they have the required skills, qualifications and experience to design and construct buildings.

It is recommended that the entry level investment of US$1.15m from the PREP should be used to develop a retrofitting program for a number of schools. It is further recommended that technical assistance through the GPSS is provided in the preparation of tools, guidelines and training to build the capabilities of government agencies and the local construction profession to support the initial PREP investment and then a larger comprehensive school infrastructure program which could be funded by WB through PREP or other donors.

1 Introduction

Each year, natural disasters result in school buildings being destroyed or severely damaged leading to loss of life, injury and disruption to education. Global efforts to make schools more resilient have largely focussed on improving awareness and preparedness, so that teachers and children are better placed to take appropriate action in the event of a disaster. Less attention has been paid to the physical performance of school buildings, which is the focus of an initiative by the Global Facility for Disaster Risk Reduction (GFDRR) - the Global Program for Safer Schools (GPSS). This is being designed as a technical assistance (TA) program targeting countries where there is on-going or proposed investment in school infrastructure.

The World Bank have recently approved $16 million grant to Government of Tonga (GoT) through their Pacific Resilience Program (PREP). PREP has 3 components, one of which relates to improving the resilience of public infrastructure and $1.15 million (US) has been specifically allocated for the retrofit or reconstruction of school facilities.

To compliment this commitment to education sector support, the WB have also proposed to provide technical assistance through the GPSS to help improve safety and resilience of the Tonga's school building stock.

The aim of this study is to assess the vulnerability of existing school infrastructure in Tonga to natural hazards, some of which are anticipated to increase as a result of climate change, and to determine the contributing factors of risk to school infrastructure. Identifying these factors will help the GoT, with WB support, to develop a school reconstruction/ retrofitting program through the PREP. The specific objectives of the study are;

- To undertake country diagnostics in order to make recommendations to the WB team, to enable them to formulate a GPSS TA project proposal which will include;
  - Understanding the drivers of risk and range of natural hazards and climate change impacts that may compromise the repair and retrofitting and operation of existing schools infrastructure;
  - Understanding the number and structural typology of existing school infrastructure in Tonga;
  - Assessing the institutional and policy environment and regulatory framework within which schools infrastructure is planned, designed, constructed, operated, maintained, repaired and retrofitted in Tonga. This will inform recommendations for the institutional and policy actions necessary to plan the effective implementation of safer schools principles, improve the quality and enforcement of building codes and build institutional capacity for risk reduction.
- To make recommendations for entry level investments to be financed by the PREP.
- To develop a methodology /roadmap for a nationwide retrofitting/ reconstruction (or relocation) program to bring all schools up to a "suitable" appropriate design standard.

2 Context

The Pacific Island Nations are vulnerable to natural hazards, such as tropical cyclones, flooding, storm surge, droughts, volcanic eruptions, earthquakes and tsunamis. The frequency and severity of climate related hazards is anticipated to increase as a result of climate change. Disasters resulting from these hazards can affect the economic, social, and physical environment and can have a lasting effect on the long-term development goals of these nations.

The Kingdom of Tonga is a Polynesian sovereign state comprised of 177 islands, 52 of which are inhabited. The land mass of all the islands combined totals around 750 square kilometres and is spread out over 700,000 square kilometres in the South Pacific Ocean. The western islands of the archipelago are volcanic, having formed through the subduction of the Pacific plate under the Australia-India plate at the Tonga Trench, while the eastern islands are predominantly low lying coral limestone islands and sandy cays.

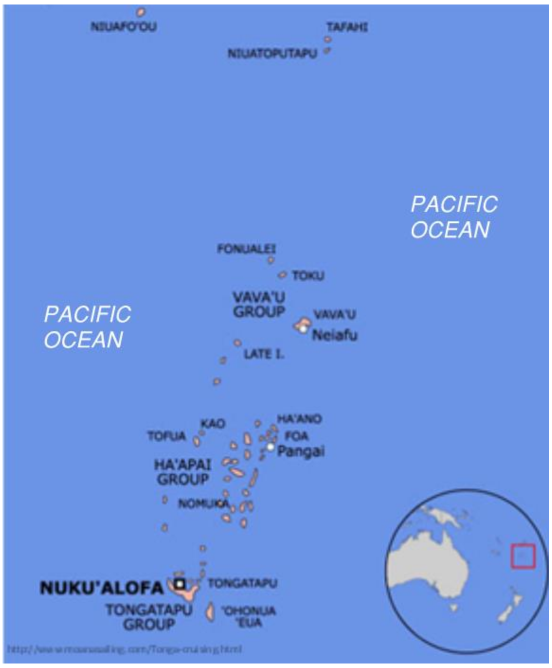


Figure 1: Map and location of Tonga

Tonga's location adjacent to the Tonga trench and the 'cyclone belt' of the Pacific makes it vulnerable to earthquakes, tsunamis and tropical cyclones. The United Nations University ranked Tonga with the second highest disaster risk index globally, due to its exposure to natural hazards and ability to respond in the aftermath of disasters. The World Bank estimates that Tonga will experience yearly losses of 4.4% of GDP due to natural disasters[1].

Tonga has a population estimated at around 105,500[2], 70% of which live on the largest island, Tongatapu. The capital, Nuku'alofa is located on the northern bay of this low lying, coral island making it particularly vulnerable to storm surge and the impacts of tsunamis.

[1] http://www.worldbank.org/en/results/2014/10/01/building-back-better-tonga-cyclone-ian
[2] http://data.worldbank.org/indicator/SP.POP.TOTL

3 Methodology

The observations made in this report are the result of a 7 day field mission carried out by Arup Consultants from 19th to 25th September 2015 and a review of documentation listed in Appendix A.

Key stakeholder consultations included national government departments, school representatives and donor organisations. A full list of stakeholders is shown in the Mission Schedule in Appendix B.

During the mission a total of 14 schools (Appendix C) were visited in order to gain an understanding of the different construction typologies and vulnerabilities. The schools were selected by the Ministry of Education and chosen as priority schools for reconstruction, retrofitting or those to be used for evacuation shelters. The schools represented a range of building conditions, designs and construction typologies. Schools were surveyed using a Rapid Visual Assessment (RVA) form developed by Arup (Refer to Appendix D) and results collected using 'Fulcrum'[3], a web-based data collection App. This tool is designed to provide a fast method of appraising school sites and building structures in order to understand the key site and structural vulnerabilities of school infrastructure.

During the mission, the draft GPSS Roadmap[4] was used as guidance to undertake a diagnostic of the school infrastructure sector in Tonga. The following sections of the report summarise the key findings related to; the existing infrastructure baseline (Section 4), the construction environment (Section 5) and financial environment (Section 6) in which school infrastructure is planned, designed, constructed and operated, with entry level investments to be financed by PREP (Section 7) and a Roadmap to improve the entire building stock (Section 8).

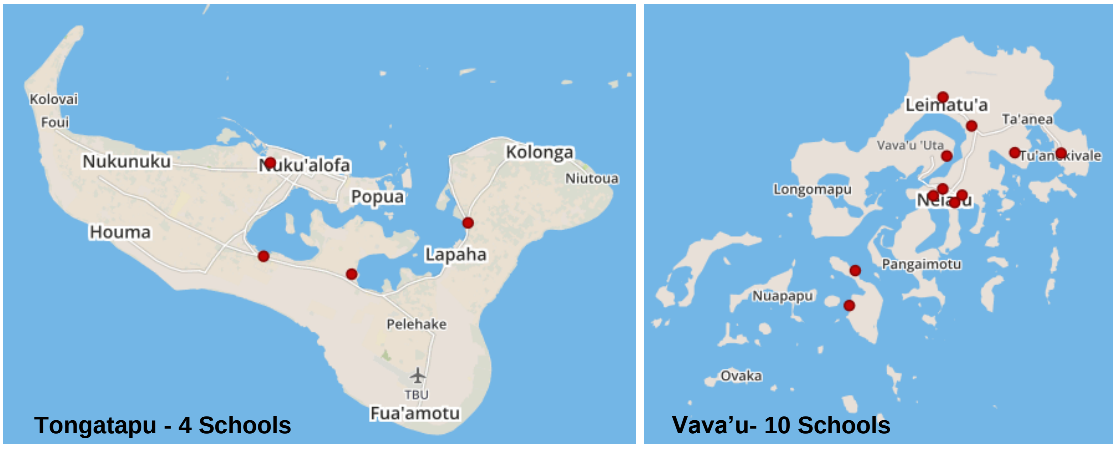


Figure 2: Locations of schools visited in Tonga on Tongatapu and Vava'u

3 http://fulcrumapp.com/
4 Roadmap for Safer Schools, Guidance Note, Draft , Arup, 20th August 2015

4 Existing School Infrastructure Baseline

4.1 Hazards

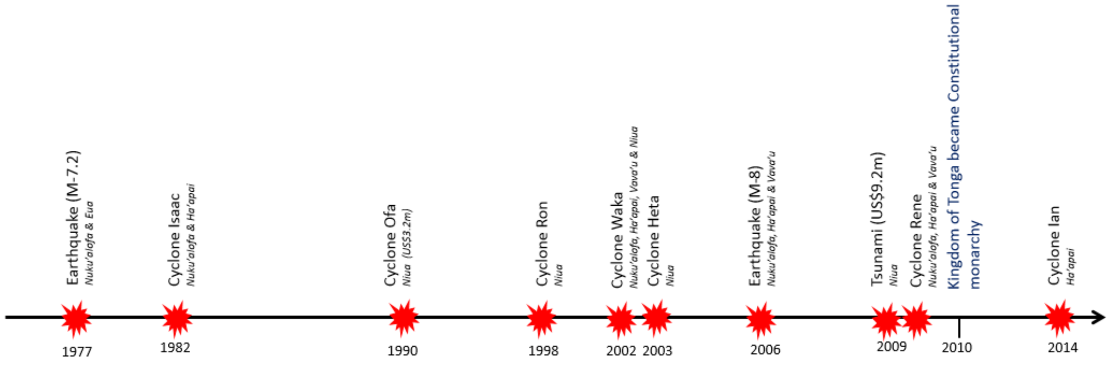


Figure 3: Timeline of major hazard events in Tongan history

Major disasters over the last decade have provided a distressing reminder of Tonga's exposure to natural hazards, with tsunamis, earthquakes and tropical cyclones all causing damage to infrastructure and loss of life across the nation.

Figure 3 details the major natural disasters that have affected Tonga in since the 1970s. Tropical Cyclone Ian in 2014 was a Category 5 storm that caused approximately 111 million TOP (US$50 million[5]) damage to infrastructure predominantly around the central Ha'apai group of islands. This followed in the wake of six other major cyclones that have affected Tonga since Cyclone Isaac in 1982, which devastated the nation and left 45,000 residents homeless.

Due to Tonga's location adjacent the subduction zone at the Tongan Trench, earthquakes are also regularly felt across the islands with major earthquakes in 1977 and 2006 causing damage to a large number of structures. A magnitude 8 earthquake off American Samoa in 2009 generated a Tsunami which swamped the harbour on Tonga's northern island of Niuatoputapu, with waves travelling 600m inland, killing nine people and causing widespread damage.

As a result of these recent disasters, there appears to be a good level of public awareness around the risk posed by hazards, in particular, cyclones and tsunamis and there is evidence that cyclones and earthquakes are considered to some extent in the design and construction of buildings.

Localised flooding due to heavy rainfall, landslides in steep terrain and coastal erosion does not appear to be considered in the planning or design of building infrastructure. These local hazards have an impact on school infrastructure and mitigation measures should be employed through appropriate site selection and civil engineering works.

Several technical assistance programs have been carried out by donors in an attempt to understand better the hazard risk and reduce the impact of natural hazards across the Tongan archipelago. These include;

[5] http://www.worldbank.org/en/results/2014/10/01/building-back-better-tonga-cyclone-ian

- The Pacific-Australia Climate Change Science Adaptation Planning Program (PACCSAP) in 2012 undertook LiDAR surveys of Tongatapu and Lifuka to model the effects of coastal inundation due to sea level rise and tsunamis. These inundation maps have been used to inform tsunami evacuation plans for the capital, Nuku'alofa, which are publicly communicated through evacuation route maps and signage (Figure 4). Currently there is no tsunami early warning system (EWS) infrastructure in place in Tonga, however the Japan International Cooperation Agency (JICA) have expressed an interest in investing in EWS systems, through working with the GoT.

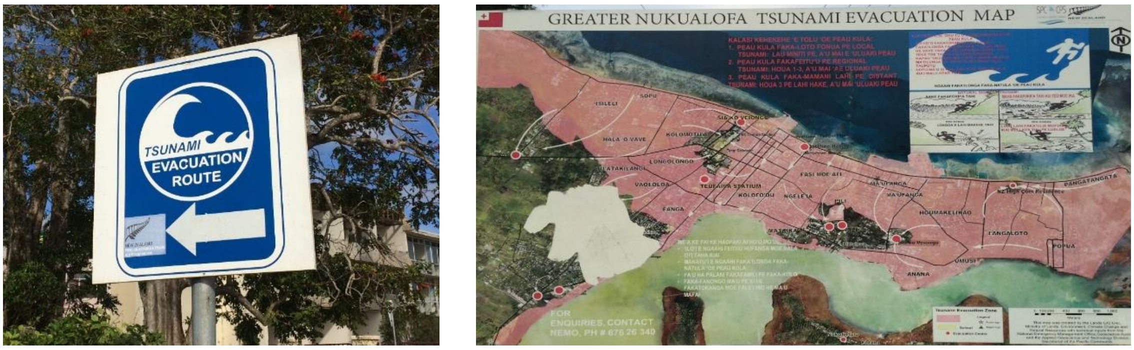


Figure 4 Tsunami Evacuation Routes in Nukualofa

- EU urban planning project in 2009, in partnership with the GoT Planning and Urban Management Agency (PUMA) developed hazard maps which have been collated into a GIS database. The extent to which the maps are currently used to inform the planning approvals process is unclear and they don't appear to have been made widely available to other government departments.
- The Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) in 2011 developed wind speed and earthquake hazard maps. These were reviewed during the mission and correlate to the design loads detailed in the Tongan Building Code.

Opportunity 1:

There is an opportunity to combine the existing hazard and risk data available so it can be used more readily in the planning and design of school infrastructure.

The existing hazard maps for Tongatapu could be augmented by the development of detailed hazard maps for all inhabited islands across Tonga. These maps could be incorporated into PUMA's existing GIS asset management database and combined with planning regulations to inform the development of land use plans to provide guidance on safer locations for the construction of schools in the future.

Risk reduction and disaster preparedness planning could be carried out for schools that are currently located in tsunami zones. This could be established through working with the National Emergency Management Office (NEMO) and include the establishment of early warning systems, evacuation plans and practicing drills in schools. The NGO 'Live and Learn' are already carrying out training on evacuation drills in some communities in Tonga and could be a potential partner.

4.2 Existing School Infrastructure

Tonga has 140 Primary schools and 37 Secondary schools spread across the four main island groups. In total, close to 18,000 children are enrolled in schools and therefore at risk if school infrastructure is not safe and resilient to natural hazards.

Primary school education is compulsory (years 1-8) in Tonga and access to education is good, with a primary school typically located in every village. For secondary schooling, many students travel to larger regional centres and board at school or with other relatives in the area. There is currently no demand to increase the number of schools, but the need to replace the existing infrastructure is increasing. The MOET do not have a clearly defined school infrastructure plan and until recently an asset management register for school infrastructure did not exist which made it difficult to identify and prioritise maintenance and repair works effectively. Through consultation with the Ministry of Infrastructure (MoI) - Land & Transport Division it was mentioned that they have an existing asset management and GIS database but it is unclear what data is included and whether it is up to date. The MOET do not appear to be aware of the database and as a result school maintenance and repair has been carried out in an ad-hoc manner, with works largely addressing immediate needs; often superficial repairs such as painting and louvre replacement.

Over the past year a local consultant (Niulolo Prescott) was engaged by the MOET to carry out a nation-wide survey of the school infrastructure assets. This work was undertaken in order to prioritise the retrofitting and reconstruction of school infrastructure as input information for the WB PREP. Whilst the surveys do not capture all the aspects of a detailed engineering assessment, they do address many of the key structural vulnerabilities such as connections, roof fixings and the condition and quality of structural elements. The findings are documented in report format with supporting images and are complimented by an approximate depreciated value of each building. Each building is categorised from A (good condition) to E (Poor condition) which has been used by MOET to rank the order of priority for rectification works. The survey is a comprehensive package of work and provides a good basis on which to prioritise works for a future school infrastructure investment program. It would be useful to convert the results of the surveys into a format that is broadly accessible across the ministry and can be managed and updated as a live system.

School as Evacuation Centres

School buildings in Tonga are often used by members of the community for shelter during cyclones. The MOET is supportive of the use of schools for this purpose for periods of up to two weeks after a disaster, where no other facilities exist within the community to provide suitable protection. Periods longer than two weeks were seen as disruptive to student’s education and a return to classes was seen as a vital part of returning a sense of normalcy to student’s lives.

MOET are currently working with NEMO to coordinate an approach for the use of schools as evacuation centres and see this as a potential opportunity to access increased levels of funding from the DMO to upgrade school infrastructure, although this needs to be confirmed. Additionally, DFAT are sponsoring Pacific Risk Resilience Programme (PRRP), which includes a process of mapping evacuation centres across Tonga to help inform where evacuation centres may be required and whether the schools in the community may be suitable.

The use of schools for this purpose reinforces the need to build engineered structures, constructed to high quality standards in order that they can withstand natural disasters and enable continuity of occupancy.

Opportunity 2:

There is an opportunity to review and combine the existing asset management and GIS databases developed by PUMA and MoI and integrate them in to a centralised geospatial asset management database. This would create a powerful tool for the planning, prioritisation and management of school and other infrastructure works. There needs to be clarity on which Ministry will be responsible for the database and ensure it is updated. PUMA (soon to be National Spatial & Planning Authority) seem keen to coordinate with the other line ministries to ensure it is regularly updated.

Mr Prescott is a valuable asset to the MOET and there an unique opportunity to build on this local knowledge base within government to review and incorporate the information he has collected in to the asset management database, in order to develop a preliminary investment plan for the repair, retrofit or reconstruction of school infrastructure which could be funded through PREP.

The geo-spatial database presents a further opportunity to identify and prioritise which schools could be used as evacuation centres.

Exposure

There is little evidence in Tonga that site selection and physical planning of the school sites is undertaken, with many schools across Tonga on exposed sites.

The following list details site selection and planning issues that were observed during the surveys and highlights ways in which the risk of exposure can be minimised or mitigated. Examples to illustrate these findings are provided in Appendix E1.

- With an average elevation of around 5m above sea level, many of the (49) primary and secondary schools across Nuku'alofa are at risk from tsunami and storm surge. One particular school (Neiafu) was visited in Vava'u, which was constructed only metres from the water line. Whilst it is not cost effective to construct school infrastructure to withstand the forces of a tsunami, or build structures to raise them above the expected water surge level, the provision of early warning systems and development of evacuation plans can assist communities to prepare for these events. Wherever possible schools should be located on higher ground inland from coastal areas.
- Schools in low lying areas of Tongatapu are exposed to localized flooding during intense rainfall events. Where it is not possible to locate schools away from these areas, the damage to buildings and contents can be minimised through the provision of site drainage and by raising building floor levels above the surrounding area and flood level.
- Some school buildings were located adjacent to large trees which can fall and damage buildings during high winds and earthquakes. Furthermore there was evidence of leaf litter collecting on roofs which without regular clearing, can

lead to premature corrosion of roofs and gutters and in schools reliant on rainwater it can reduce drinking water quality.

In some communities, the opportunities for good site selection and physical planning of schools may be compromised by the limited availability of land. In the past, a lack of planning tools within the government may have also limited their ability to advise on suitable site locations. With the development of hazard maps and the GIS database through the previous EU program, there is potential for PUMA to provide guidance on site selection during the planning stages for schools. PUMA management have indicated that this process is being put in place, but the extent to which it is currently being undertaken in unclear. Early involvement from PUMA, soon to be National Spatial Planning Authority Office (NSPAO), in the planning phase of schools would assist in ensuring schools are constructed in the best locations available. To ensure the best utilisation of funding, where schools are to be reconstructed, PUMA should be consulted on the suitability of school sites before significant funds are apportioned to particular schools.

Opportunity 3:

There is an opportunity to develop planning guidelines for appropriate site selection, site assessment and civil engineering works to reduce the exposure of school infrastructure. This guidance could specifically target the most prevalent site specific hazards such as flooding due to storm surge, high rainfall and tsunamis. These should be developed in line with hazard and risk maps and incorporated into the planning regulations.

Vulnerabilities

During the site surveys it was observed that many schools throughout Tonga displayed structural vulnerabilities which increase their susceptibility to damage from natural hazards. These vulnerabilities arise from three main factors: a lack of engineered school designs; poor quality control and supervision during construction and a lack of maintenance of school infrastructure.

From the surveys, five common structural typologies were identified as shown in Table 1. A full list of the structural vulnerabilities that were observed is documented in Appendix E2, along with further detail on the remedial or preventative actions that can be carried out to limit the effects of these vulnerabilities.

The main vulnerabilities that were observed during the surveys were:

- Many buildings appeared to be non-engineered structures and lacked a clear or sufficient lateral stability system. This makes them particularly vulnerable to collapse under cyclonic and seismic loads.
- Structural forms were often irregular, with some buildings being longer than four times their width, or built in ‘L’ or ‘C’ shapes. An irregular structural form reduces the buildings ability to resist earthquake loads.
- Large roof overhangs and verandas were common to many of the schools visited, which, without suitably robust connections increases the risk of roof uplift in strong winds. When verandas are connected to main roofs, they can be the “initiating point” for loss of the whole roof. Most buildings visited also had gable

ends, which when constructed in masonry and not suitably reinforced can become a hazard during earthquakes.

- Incorrect or poor quality materials were selected for use. Some standard school designs used masonite for external cladding, which is a poor choice for use in outdoor applications. Untreated softwood was also observed, which is susceptible to insect and fungal attack. Inadequately washed sea sand was used for concrete production at many schools, leading to the premature corrosion of reinforcement and the spalling of concrete.
- Insufficient and poorly detailed connections between structural elements were regularly observed: roofing sheets were nailed rather than screwed to the purlins; purlins were skew nailed rather than strapped to rafters; rafters and trusses were poorly connected to walls and timber frame walls were not suitably anchored to foundations. In areas of high winds and earthquakes it is critical that these connections are robust and maintained. In the absence of documentation, it is unclear whether the poor quality of these connections was due to inadequate design, the absence of design information or a failure of builders to follow the design.
- Structures were degrading due to lack of maintenance and the severe coastal environment: timber and plywood cladding was regularly seen in poor condition due to a lack of regular painting; connections between structural elements were rusting, leaving them prone to failure; and roof sheets were corroded, leading to leaks inside classrooms and damage to ceilings and building contents. Without regular maintenance, many elements of a building are prone to premature failure, particularly when exposed to extreme winds or seismic loads.

Buildings will always fail at their weakest link and identification of structural vulnerabilities is a critical component in the development of a building retrofitting program. Without addressing all of the key vulnerabilities in a building, an investment in building repair can be wasted when the weakest points fail, leading to wider structural damage.

Opportunity 4:

A detailed review of the MOET survey could be carried out to determine the key structural vulnerabilities that have been inspected during the survey and where gaps may remain. Any gaps observed should be taken into consideration when planning retrofitting and reconstruction works during a future program, to ensure that all structural vulnerabilities are addressed.

A retrofitting guideline could be developed to assist in strengthening existing buildings. This guideline would include an assessment process for determining the key structural vulnerabilities of a building, typical retrofitting details and specifications which reflect the works required to address the issues typically encountered for common structural typologies.

Building Typology	Photo	Advantages	Disadvantages
Unreinforced masonry Concrete block with no reinforcement		• Durable if material quality and workmanship is managed • Easy to build • Cheap • Use of local materials	• Vulnerable in seismic regions
Reinforced masonry Concrete block with vertical and / horizontal reinforcement		• Durable if material quality and workmanship is managed • Seismic resistance if constructed properly • Use of local materials	• Slow to build • Requires skilled workers for correct assembly of reinforcement
Reinforced Concrete Frame with Masonry infill		• Durable if material quality and workmanship is managed • Seismic resistance if constructed properly (infill walls must be tied together) • Use of local materials	• Slow to build • Masonry façade may not be tied in • Complex seismic reinforcement detailing • Requires skilled workers for correct assembly of reinforcement • Requires an understanding of good seismic detailing

Timber frame Lightweight timber frame with timber or plywood cladding		• Easy to build • Quick to build • Timber frame is lightweight and ductile and thus is good for seismic	• Untreated timber susceptible to insect attack and weather degradation • Materials are imported • Requires regular maintenance • Can be vulnerable in high winds if not appropriately detailed
Mixed Masonry and Timber Low level masonry skirt wall with timber at higher level		• Masonry wall at low level gives durability in splash zone • Lightweight upper level walls reduces seismic load	• Two different trades are required • Detailing between materials can be complex • Untreated timber susceptible to insect attack and weather degradation

Table 1: Construction Typologies of Schools Visited

5 Construction Environment

5.1 Institutional Environment and Regulatory Framework

Responsibilities

The table below summarises the responsibilities of stakeholders for school infrastructure during each stage of the asset lifecycle.

Stage	Task	Body Responsible	Description
Planning	Needs Assessment	MOET	MOET is responsible for identifying a new school asset but often the school principal alerts the MOET to the need. The MOET is then responsible for identifying a donor to fund the works. Government funds are not understood to be have been previously used for new school construction.
	Site Selection	MOET/ MoI	Schools are built on government land or noble land which is leased to the MOET
Design	Delivery	MOET	MOET have educational infrastructure standards which must be adhered to.
		MoI - Building Division	Model school designs have been developed in the past for different projects. There is currently no model school design which is broadly adopted.
		Community/ Donors	Some communities carry out their own design for school buildings
	Building Permit	MoI - Building Division	Plans are lodged with MoI who co-ordinate the building approval process with other ministries such as Ministry of Health, Fire Department, Ministry of Environment & Climate Change and PUMA to issue a building permit.
Construction	Procurement	MoF	MoF are responsible for tendering works that are delivered by GoT. Donor often carry out their own procurement
	Contract Management	Unclear	
	Supervision & Issue of Occupancy Certificate	MoI - Building Division	MoI has responsibility to inspect structures during construction. MoI provides a certificate of completion
Operation and Maintenance	Ownership	MOET	
	Routine Maintenance and Repairs	MOET	MOET has a responsibility for maintenance of the school infrastructure. Repair works are identified by the Principal/PTA who contact the MOET to alert them of issues. Sometimes PTA carry out repairs, using funds raised from within the community.

During the stakeholder consultations it was observed that there are opportunities for improvement in the planning, design, construction and operation and maintenance of school infrastructure. Addressing these factors will assist to decrease the exposure and vulnerability of school infrastructure as explained in more detail below.

Planning

The limited formal planning processes in Tonga increases the vulnerability of school infrastructure to damage from natural hazards. It is understood that currently there are no planning regulations or land use plans developed for Tonga, which can be used as a reference for government to make planning decisions about suitable locations for the construction of schools.

The planning process for buildings in Tonga is presently in a state of transition. Currently drawings are submitted to MoI to obtain a building permit, however, it is unclear to what extent this is undertaken for school building applications. It is the responsibility of the MoI to coordinate building approvals from the different ministries through a referral system. Approval of the site location, which is part of this process, is the responsibility of PUMA who consult with the community to assist with the siting of school infrastructure. This assistance seems to focus on land ownership rather than assessing the physical characteristics and exposure of the site, which is critical for reducing risk to natural hazards. There is evidence that this is not carried out for all school buildings and the MOET survey notes that 31 of 49 schools in Tongatapu did not have proper land acquisition processes documented. Formal documentation of land agreements should be sought before any further donor investments are made in these schools.

The National Spatial Planning Act (2012) is scheduled to pass parliament in the coming months, which will result in the establishment of the National Spatial Planning Authority Office (NSPAO). This will be an independent body responsible for providing Development Consent through a permit system. According to PUMA, the granting of a permit will consider the 'suitability of the site for the proposed development, including consideration of natural hazards'.

The National Emergency Management Office (NEMO) do not appear to have a defined role in the planning processes for school infrastructure. As NEMO are a key organisation in Tonga reviewing and updating hazard information, their limited involvement in the planning process may mean that the best information available is not always being used.

Opportunity 5:

The change in government structure and new planning act provides an opportunity to develop planning regulations and land use plans which should include up to date hazard and risk information and be used to advise on planning for school infrastructure.

Design

Currently the MOET and MoI do not have a designated standard classroom design which is used for the (re)construction of schools. Typically communities carry out the design of school buildings and the limited level of engineering input into their design in Tonga places buildings at increased risk of damage from natural hazards. Building users are also at risk, particularly if these structures are used as shelter during cyclones.

The MoI developed a model school design in 1980s which was an engineered timber design. The design seems to be well engineered and from the site visits it appears that most of the details are robust and well-constructed. The users have concerns over some of the details relating to functionality i.e. high level windows. In more recent years, through a number of school reconstruction programs following major cyclones and earthquakes, various standard school designs have been developed, often by donor organisations. Throughout the site surveys, around four different standard designs were observed, some of which were clearly engineered designs, while others showed a lack of structural engineering design.

Faith based organisations also construct primary and secondary schools and maintain their own assets. During interviews with multiple stakeholders it was noted that schools constructed by the Latter Day Saints (LDS) consistently stood up to cyclone and earthquakes and there was a desire for all schools to be built to "LDS Standards". These schools were seen to be very well maintained and widespread community support for the church has given the LDS ample funds to carry out a program of quality school construction and maintenance.

The MOET school infrastructure survey report provides some guidance on proposed standard architectural floor plans for classrooms and WATSAN facilities, which it intends to form the basis for minimum performance standards for school buildings. These would provide a good starting point on which to develop standard engineered school designs.

Opportunity 6:

Development of a well communicated model school building design and specification would provide a consistent approach to school construction that takes into account the relevant hazards and ensures compliance with the NBC. A review of documentation for past standard school building designs (if available) could be undertaken to determine the suitability of these designs for future programs. The review should capture the lessons learnt from previous designs to be incorporated into new designs, if these are deemed to be required.

Material developed in this package should take into account the level of education and training of the construction workforce. The use of clear, visually conveyed and 3D documentation can assist in the presentation of construction details to workers who have not had formal training. Step by step, 'Lego style' construction manuals can also assist lower skilled workers to understand the staging of construction works. Any design that is developed must take into account the variability in site conditions and provide options and guidance on design modifications.

Technical assistance could be provided to the MOET and MoI in the production of this standard drawing set, as well as additional support for the development of a Technical Specification and BoQ. This complete set could be collated to form a cohesive 'model school construction manual'. The scope of standard designs could incorporate classroom buildings, water supply, sanitation facilities and administration buildings.

Any new model school designs that are developed should be tailored to reflect the prevalent hazards that structures are exposed to. Hazards such as cyclonic winds and earthquakes are addressed through compliance with the building code. Careful consideration should also be given to material specifications in order to address material quality and durability, which is particularly important to prevent corrosion of steel elements and degradation of timber. The effects of corrosion may be reduced through the use of corrosion resistant fixings such as stainless steel strapping and hot dip galvanised elements. Large diameter fixings such as bolts for trusses, and U-bolts for tie downs should be used in preference to gang nails and galvanised iron strapping to provide increased durability.

Building Codes (and land-use planning) are recognised as important mechanisms for reducing disaster risk in areas subject to high winds and seismic activity. National Building Code of Tonga (NBC) was brought into effect by the Building Control and Standards Act 2002 and was updated in 2007 to refer to the Building Code of Australia 2004. In the absence of national standards for design, construction and materials, the Standards produced by Standards Australia and Standards New Zealand have been referenced with earthquake provisions adopted from the California Building Code 1998. The Tongan code appears to have limited contextualisation to the typical construction methods in Tonga and it relies heavily on international codes and standards. In Tonga the MoI Building Division are responsible for enforcement of the NBC, however, the building inspectors are not engineers and have not undertaken any formal engineering training. It is likely that the code is too complex hindering the ability and willingness of the construction industry, developers and government to adopt them.

MoI stated that ADB are funding a Technical Assistance project to review and update the NBC as part of their Climate Resilience Sector Programme. Under the new Planning Act, PUMA representatives indicated that the NSPAO will be responsible for updating all codes and standards, although this was not confirmed with MoI. In undertaking an update of the NBC its limitations should be recognised and any updates should be undertaken in consultation with the wider construction industry and government ministries. Using a recognised international code as a main reference to update the NBC is a good way to incorporate international best practice. It needs to include necessary adjustments to hazard levels (wind speed and earthquake) determined for Tonga, current understanding and best practice; reflect local forms of construction and perceptions of risk; and be part of a wider culture of safety and environmental concern that includes education and training at all levels of society, as well as legislation and enforcement.

Another limitation of the NBC, unlike in other international standards, is that no guidance is given on the Importance Levels of different building types based on their post disaster use. This is important if schools are to be used as evacuation centres. Moreover, the Building Regulations only require buildings with two or more storeys and all public buildings with a span greater than 8m, or height greater than 3m to have an engineering certification. Under this condition, most school buildings in Tonga would not require any form of engineering certification or design. To ensure the safety of school buildings, the building regulations should be amended to include provisions that all schools buildings require engineering certification, irrespective of their size.

Construction

For all government managed school construction projects, the MoF is responsible for tendering for the contractor but there appears to be ambiguity about who manages the contract once it is awarded. The contract is always awarded to the lowest price bidder who meets the technical requirements, as opposed to the bidder who represents the best value for money. This increases the reliance on good documentation and specification of buildings to ensure the construction quality.

Quality control of workmanship and materials during construction of school buildings was observed to be a key challenge. The inspection for compliance with the NBC during construction is the responsibility of Building Inspectors from the MoI Building Division. Five building inspectors are responsible for the inspection of approximately over 200 buildings in Tonga per year with access to only one vehicle and are therefore constrained in their ability undertake inspections of all buildings nationally during construction. It is unclear if there are defined points throughout construction when MoI inspectors are scheduled to inspect works, however a certificate of completion is issued by the MoI once a building is constructed. The checks undertaken to verify NBC compliance are unknown.

To address the shortfall in capacity within the Building Division, an additional seven inspectors are being recruited across the islands. These staff are understood to predominantly have carpentry or drafting backgrounds and are unlikely to have had formal engineering training. This may limit their understanding of safe construction and the application of the NBC.

Moreover, there are a number of ways the Building Division could operate more effectively, given the limited resources available. Create a register of contractors and allow contractors who have a good track record to self-certify that their work complies with the Building Regulations, keeping photographic evidence. Contractors that don’t meet expected level of construction quality could be black listed from a government register therefore incentivising contractors to comply with building regulations. A Review Consultant role could be created in the regulations, defined as an independent consultant who reviews and checks the design and construction of complex developments (2 stories and above) to ensure they comply with the building regulations. This would enable building inspectors to dedicate their time to simpler construction projects, including one storey schools.

Opportunity 7:

Technical Assistance could be provided to increase the capabilities of the MoI, by delivering training on basic engineering principles to Building Division staff. This training should include components on good construction practice, how to identify key structural vulnerabilities and the fundamentals of the NBC.

Furthermore, there is an opportunity to provide technical assistance to develop an inspection process for Building Inspectors that is written in to the Building Regulations. This should include inspection schedules and checklists for MoI Building Inspectors, to assist them in carrying out site inspections during construction.

Operation and Maintenance

The MoET is responsible for the operation, maintenance and repair of school infrastructure. With limited budgets and the islands dotted over 800km (700,000 km2) of ocean from north to south, there are both economic and logistical challenges for the MOET around the maintenance of public school infrastructure. Without suitable capacity and resources to attend to the maintenance demands of this infrastructure, often the regular maintenance falls by default to the Parent Teacher Associations (PTAs) at each of the schools. Due to the challenges in providing ongoing maintenance, any new model school building designs that are developed should minimise the maintenance requirements as a high priority. After good design and quality construction, regular maintenance is the key contributor to the long term provision of safe school infrastructure.

Opportunity 8:

There is an opportunity to develop a school maintenance manual for PTAs, which highlights the key areas of a building which require maintenance, how to recognise when it needs to be maintained and the interval at which it should typically be inspected. The manual developed should use illustrations wherever possible and be appropriate for the intended audience. An accompanying inspection checklist and inspection schedule may assist PTAs to plan and carry out maintenance works. Outputs from school inspections by the PTA could be used to provide the MOET up with up to date information on the condition on the building stock, which can be incorporated in to the proposed database in order to monitor, manage and prioritise maintenance and repair works.

5.2 Construction Capability & Capacity

Technical engineering expertise in Tonga is limited and ministries find it difficult to source staff with the skills required to fill engineering roles. The MoI was aware of five professionally qualified engineers working on Tongatapu, and the CEO of MoI was the only staff member within the organisation with engineering qualifications. Introducing the requirement for construction practitioners to be registered in Tonga or to a suitable overseas institution is the first step to ensuring they have the required skills, qualifications and experience to design and construct buildings.

To study engineering, Tongan nationals are required to travel abroad, with most students seeking higher education in either Australia or NZ. The high costs of study and living in these countries is a barrier to students pursuing educational opportunities. Tonga has struggled to retain local engineers that have studied overseas due to higher salaries and increased opportunities that are available elsewhere. To help address skills shortages in Tonga, DFAT have developed the Australia Awards Scholarship program, which supports students to study at Australian Universities. It is understood that staff from ministries that receive support through these programs are bonded to return to work within ministries for two years at the completion of study. There is an opportunity for Tonga to promote the construction profession and highlight the importance of good quality construction to improve Tonga's resilience to natural hazards to encourage students to study engineering and return to the country.

JICA also provide funded places in Japanese education institutions for up to 20 people per year, for non-degree based training courses. Selection for participation in these programs is based on a needs assessment undertaken by MoF. This creates an opportunity to prioritise engineering/ construction training within the MoI and MOET staff.

There is currently no requirement in Tonga to ensure contractors are competent in construction. In the UK and the USA certification schemes exist that confirms the skills and experience of contractors; in the USA the Division of Capital Asset Management and Maintenance (DCAMM)[6] conduct the certification process and in the UK there is the Construction Skills Certification Scheme (CSCS)[7]. In the UK the Construction (Design and Management) Regulations (CDM)[8] introduced in 2007 gives guidelines to clients or developers about how to assess the competence of organisations or individuals (designers or contractors). Similar legislations might be considered in Tonga.

Schools in Tonga are built by a range of actors, ranging from qualified building professionals through to community members without formal construction training. A number of buildings were seen throughout the site surveys that were clearly constructed by professional builders and were built to a high standard. Many school buildings were also observed to have been poorly constructed, with basic structural deficiencies such as subsiding foundations, inadequate roof

[6] http://www.mass.gov/anf/property-mgmt-and-construction/design-and-construction-of-public-bldgs/contractor-certification/
[7] http://www.cscs.uk.com
[8] Managing Health and Safety in construction, CDM Regulations 2007.

connections and masonry walls without reinforcement or core filling. This highlights the importance of developing clear model school designs for builders to follow and providing good supervision of works during construction.

Opportunity 9:

There is an opportunity to create a professional engineering body like the IPES in Samoa which is a licensing body for construction professionals and is dedicated to improving the quality of construction in Samoa.

To account for the limited engineering training of MoI staff, a guidance document could be developed to assist staff in the checking of building designs for compliance with the building code. An inventory of typical details such as connections, reinforcing details and member span tables would assist staff to undertake basic checks and make recommendations to applicants on designs that are submitted. Providing clear visual documentation of these details would provide the MoI with resources that they could freely distribute to applicants for inclusion in their building designs to improve the general level of construction quality. Training of staff would be required in the use and application of these resources.

6 Financial Environment

6.1 Historic, Current Investment

Historic, current investment in school infrastructure in Tonga has largely been supported by international bilateral and multilateral donors. Details of the major historic and current investments in school infrastructure are listed in Appendix F. Whilst there are a number of smaller ongoing programs, for example the Japanese Embassy's Grass roots programme and various donor funded renovation programmes, many of the larger infrastructure programs have been funded in response to previous natural disasters, including; DFAT and ADB's Cyclone Issac's and Ian's reconstruction programmes.

The renovation programmes such as the Tongan School Grants Program which has been administered through the Tonga Education Support Program (TESP), funded by NZAid and the World Bank), and AusAid's repair programme (2010-2013) have provided much needed support for the on-going maintenance of school infrastructure. Works are prioritised in collaboration with the MoET although there does not appear to be any consideration to the structural integrity of the building. Many schools seem to have been provided with support but still remain vulnerable to natural hazards. Maintenance and renovation programmes should be done in parallel with retrofitting programmes. Guidance material identifying critical details that make a school more resilient to natural hazards would help donors and school communities identify critical issues.

Individual schools that have been implemented by donors are often not appropriate for the local context, such as JICA's Vava'u High School, which has been designed and largely constructed by Japanese work force using Japanese construction materials and methods. This model makes maintenance difficult due to the unfamiliar construction techniques and lack of availability of specialist materials, for example, steel protection paint. School infrastructure implementation should build on the capacity and capability of the local workforce and be appropriately designed to ensure long term durability and resilience.

A key differentiator in the success of donor funded programs for school construction lies with the level of supervision that is provided during construction. Schools constructed to an engineered design, with supervision of works by skilled professionals for example, the Government of Taihiti's schools, are regularly seen to be of higher quality than that those delivered without quality control procedures in place. Whereas programs that provide money and responsibility direct to the community without appropriate technical support, such as the Japanese embassy's Grass Roots Program, often result in poor quality buildings.

6.2 Lessons Learnt from Previous Programs

Reviewing the outcomes of the different donor funded programs, it can be seen that a number of programs have been challenged to ensure the long term provision of safe school infrastructure. Future programs should be delivered in a way that addresses the following issues:

- Renovation programs should address the key structural vulnerabilities first, before attending to superficial repair works. Investment in cosmetic repair works is wasted if buildings cannot withstand the impacts of natural hazards.
- Schools should be constructed using materials which are in commonly used, where the maintenance requirements are understood and replacement parts can be locally sourced. Maintenance of heavy gauge steel sections is challenging in Tonga and thus not recommended.
- All schools should be constructed using engineered designs which respond to the local and regional hazards and comply with an appropriate engineering design standard.
- All school infrastructure programs should provide clarity on who is responsible for taking design responsibility for retrofitting and/ or reconstruction and who is responsible for assuring the quality of materials and workmanship on site and ensure the construction is in line with the design intent. Suitably qualified resources should be identified for each of the roles

Opportunity 10:

To improve the quality of school construction, building regulations should be reviewed and amended to include provisions for mandatory third party engineering inspections of school buildings during construction. This would force donors to ensure that suitable processes are in place for the supervision of construction on site.

7 PREP Entry Level Investment

The prospective WB program aims to provide an entry level investment of US$1.15m into the repair, retrofitting or reconstruction of school infrastructure. Two key opportunities are available for the utilisation of these funds;

1) Reconstruction of one or two schools (depending on school size)
2) Develop a retrofitting program for a number of schools

Reconstruction

Selection of the schools to be part of the program should be based on the prioritisation schedule developed by the MOET, through their school infrastructure survey. NEMO and MOET are also collaborating to identify which schools could be used as evacuation centres. Any investment in school infrastructure through the PREP should be carried out in reference to these two surveys, to ensure that money spent on infrastructure is part of a long term plan within the MOET and maximises community benefit.

School reconstruction in one or two schools would be simpler in scope and management due to the concentrated nature of the works. Using a model school design with a single contractor and good site supervision, the project could likely be rolled out quickly. This approach may yield faster results and build relationships within the ministry, providing scope for the development of a larger schools retrofitting or reconstruction program. It would have the disadvantage of addressing the needs of only one or two communities, but may serve as an example of how model schools could be rolled out across the country for future construction.

Retrofitting

A retrofitting program would provide much needed funding for the upgrading of the existing building stock and would maximise program reach by strengthening a large number of assets against damage due to natural hazards. During the MOET survey a number of school buildings were highlighted which pose an immediate risk to student safety. These buildings may provide the best starting point for a retrofitting program if they can be cost effectively upgraded.

Due to the lower probability of seismic damage compared to cyclone damage and the complexity of seismic retrofitting, a retrofitting program should initially focus on strengthening existing structures against cyclones, through works such as tying down the roof and strengthening the connections across the roof structure. Retrofitting works such as this this should only be undertaken on structures which are shown to have sound walls and foundations (likely made from reinforced concrete block),

A detailed engineering inspection would be required for each building to determine the specific works required, ensuring that all the key structural vulnerabilities are addressed. The disadvantage of a retrofitting program is that different interventions may be required for different building types.

Recognising the value of the existing building stock and the frequency of cyclone events, it is recommended that the entry level investment for the PREP may have the largest impact on the school sector by focussing on retrofitting existing structures. By addressing the key vulnerabilities of structures before a disaster, the extent of damage to existing building stock can be minimised, which may represent the best value for money intervention. Figure 5 below maps out the entry points for a WB reconstruction or retrofitting program depending on building condition and vulnerability factors.

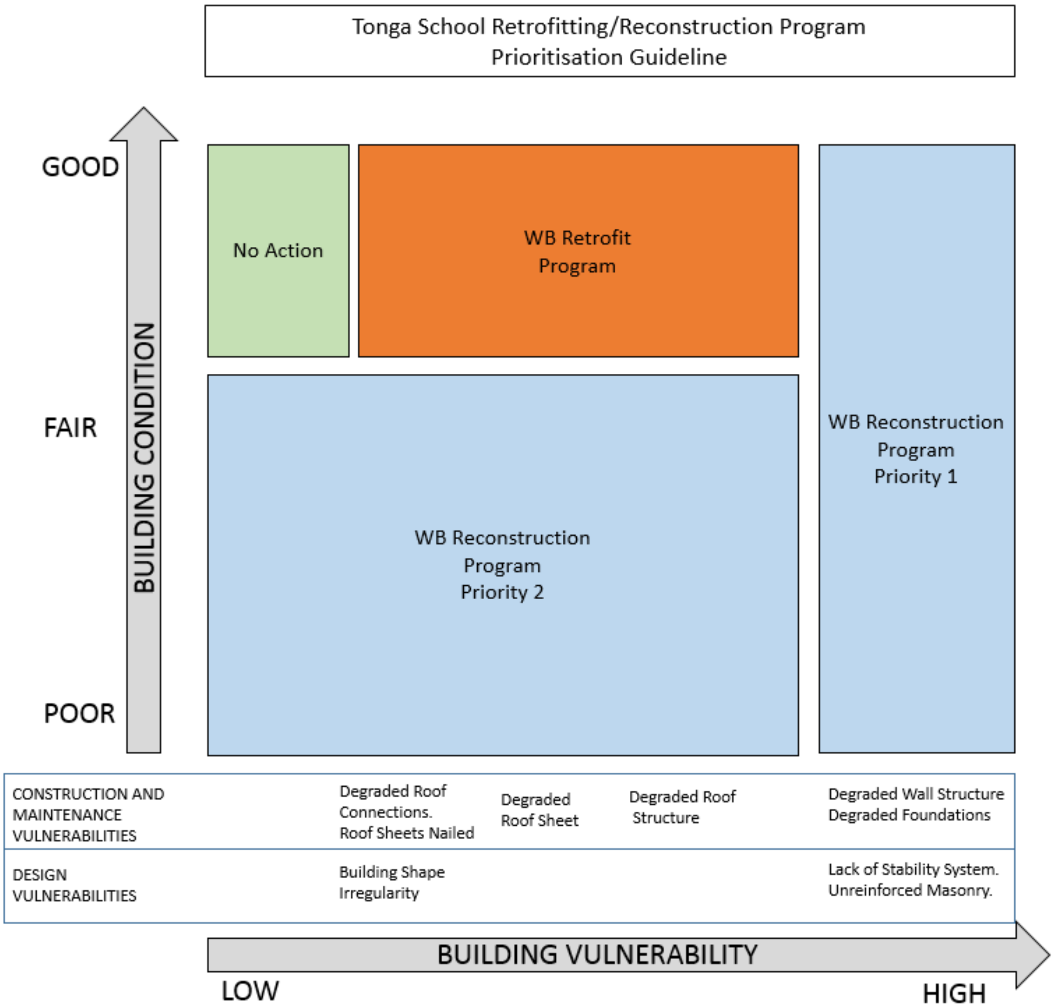


Figure 5 Entry points for a school infrastructure retrofitting /refurbishment program

It is critical that any works undertaken by contractors as part of the entry level PREP program or the wider school reconstruction and retrofitting programme should be supervised by a suitably qualified third party to provide quality assurance.

8 Recommendations for GPSS TA

It is recommended that the World Bank invest in technical assistance through the GPSS in the preparation of tools, guidelines and training to build the capabilities of government agencies and the local construction profession to support the initial PREP investment and then a larger **comprehensive school infrastructure program** which could be funded by WB through PREP or other donors.

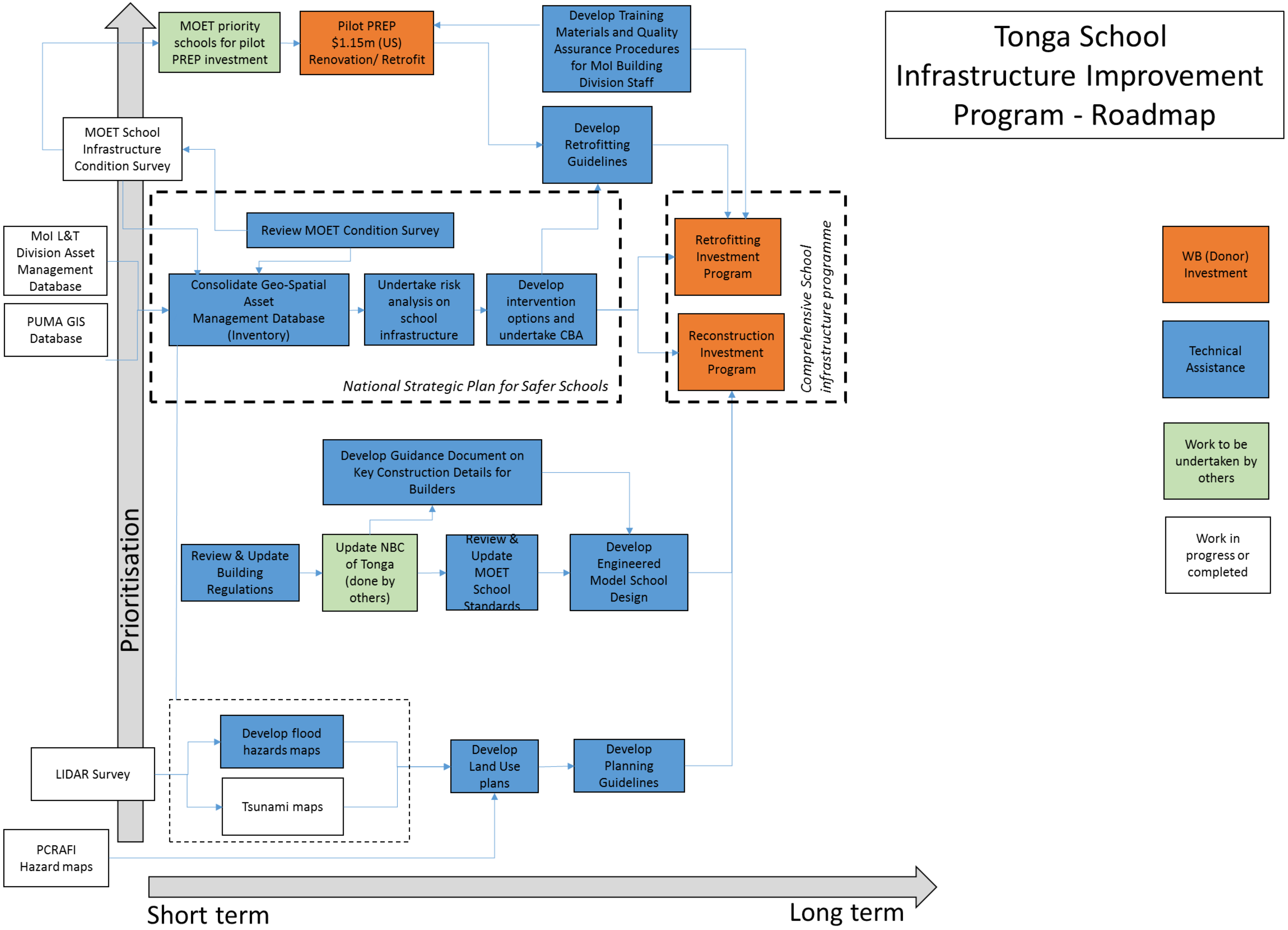
Figure 6 provides a Roadmap for the recommended TA programme and school infrastructure investments to improve the safety of school buildings in Tonga.

In order to implement a large scale **comprehensive school infrastructure program** which will have a long term impact, it is recommended that a **National Strategic Plan for Safer Schools (NSPSS)** is developed. Planning and designing a **NSPSS** is critical to diagnose the problem and prioritize the high risk schools, hence this should be undertaken in the short term. Development and implementation of the plan will require an understanding of both the hazards to all schools and the condition of all school building assets.

Currently information on hazards and school infrastructure assets is located between three ministries including; MOET (school condition and valuation survey undertaken by Mr Prescott, 2015), PUMA (EU hazard mapping, 2009) and MoI - Land and Transport Division (GIS data management system funded by WB). There is an opportunity to provide technical assistance to combine this information into a centralised **geo-spatial asset management database**. When combined, this tool could be used to carry out a **risk analysis** to determine the vulnerability and exposure of the current school building stock and assist in the prioritising, management and monitoring of infrastructure works.

The MOET school condition survey provides a comprehensive level of detail on the condition and value of existing school assets. It is recommended that a **review** of this document is carried out to **validate the prioritisation** of school infrastructure investments. It is recommended that retrofitting interventions are developed and that a **cost/benefit analysis** is undertaken for retrofitting existing buildings versus new construction.

Figure 6 Roadmap for a Safer Schools Technical Assistance Program



It is recommended that further Technical Assistance is provided to support a long term, large scale school infrastructure program;

- **Review and Update the Building Regulations** to ensure the safety of school buildings. This should include; the provision that all schools buildings require engineering certification, irrespective of their size; defining the roles and responsibilities of the different parties involved in implementing school infrastructure; the development of site inspection protocols.
- **Develop Planning guidelines** to include guidance for MoI staff and the community on site selection, site assessment and site planning measures that can be implemented to reduce the exposure of school buildings to natural hazards. In the long term, development of **land use plans,** which, included all hazards including flooding, would provide clear guidance on suitable locations for school construction.
- **Develop an Engineered Model School Design for Tonga -** The National Building Code of Tonga is scheduled to be updated through an ADB TA project, which is currently being led by the MoI. To assure the quality of new school buildings there is an opportunity to **develop an engineered, adaptable model school design** for primary schools in Tonga that could be built as part of a (re)construction programme. The designs should be communicated, in a clear, visual and accessible format that is appropriate for the local workforce, who are unlikely to have a technical background. As part of this process, previous standard school building designs should be evaluated to capture the 'lessons learnt' for adoption into new designs. It is recommended that the **current MOET building standards are reviewed** and compared against best practice structures in a comparable context. The standard design should include a Technical Specification and BoQ which could be collated to form a cohesive 'construction manual' for school buildings. Development of a standard design will provide a consistent approach to school construction that takes into account the relevant hazards and ensures design compliance with the NBC.
- **Guidance and Training to Building Inspectors;**
    - To aid building inspectors in checking the compliance of building designs to the NBC a **basic guidance document** with a catalogue **of best practice design and construction details** such as connections, reinforcing details and member span tables would assist staff to undertake basic engineering checks and make recommendations to applicants on designs that are submitted. Providing clear visual documentation of these details would provide the MoI with resources to freely distribute to the builders in the community for inclusion in their designs to improve the general level of construction quality.
    - Providing an adequate level of inspection and supervision of works during construction is a factor impacting on the quality of

school building construction. The MoI Building Division appear to be under resourced and underfunded making it difficult for the few building inspectors undertake site inspections. Currently, Building Inspectors are not professional engineers and therefore could benefit from **specific training on quality assurance procedures during construction.**

- A Pilot PREP investment presents an opportunity to undertake a small number of retrofitting works and use this program to develop a **school building retrofitting guideline.** It is recommended that the guidelines would include typical details and specifications which reflect the works required to address the key structural vulnerabilities for common structural typologies. Development of this document would help to standardise and streamline works and support the efficient roll out of a large scale school retrofitting program.

9 Conclusion

The WB mission to assess existing school infrastructure in Tonga identified that there is a need to improve the quality of public school facilities across the nation. An ageing building stock and a lack of maintenance has allowed many school facilities to deteriorate into a state of disrepair, which in some cases is impacting on the ability of teachers to deliver the school curriculum. The government has been challenged to provide an adequate level of support for the ongoing construction, repair and maintenance of school facilities.

A range of opportunities for investment were identified during the mission, which could assist to improve the safety of school infrastructure. These opportunities would support the Tongan education sector through and entry level investment of US$1.15m for the retrofitting or reconstruction of school buildings through a pilot program. Works in this program could be further strengthened by a range of technical assistance opportunities, to assist staff at government ministries and the workers in the construction to improve the quality of school building construction.

Improving the quality of new school buildings and the retrofitting existing school buildings to address the key structural vulnerabilities will assist to reduce the damage to school infrastructure from natural hazards. The provision of safe school infrastructure in Tonga has the potential to provide both shelter to communities during cyclones and allow students to return to school as soon as possible in the aftermath of natural disasters, minimising the disruption to their education.

Appendix A

Document Register

A1 Document Register

Type	Title	Author	Year
Fact Sheets/ Brochures/ Articles	Building Permit Application Form	GoT	2015
	Building Permit Application Requirements Check List	GoT	2015
	Dealing with Construction Permits in Tonga	World Bank	2015
Reports	Survey of Tongatapu Primary School's Buildings And Valuation Of The Current Conditions.	MOET, (N. Prescott)	2015
	Valuation of schools in Tongatapu, Vavau, Ha'apai, 'Eua	MOET, (N. Prescott)	2015
	Tonga: Cyclone Ian Recovery Project. Initial Environmental Examination – Disaster Relief Funding - School Reconstruction Projects	ADB	2014
	PCRAFI Country Note, Tonga	GFDRR, SPC, JICA, WB, ADB, GNS Science, Air Worldwide	2011
	Ministry of Infrastructure Corporate Plan, 2015-2018	MOI, GoT	2015
	Tonga 2011 Census of Population and Housing	GoT, Pacific Region Infrastructure Facility	2011
	Tonga National Infrastructure Investment Plan 2013-2023	GoT	2013
	Tonga Meteorological Service – Ministry of Civil Aviation. List of Tropical Cyclones that has Affected at Least a Part Of Tonga from 1960 To Present	Tonga Meteorological Service	2015 (Internet)
	The Tonga Earthquake Of 23 June, 1977 Some Initial Observations	M. D. Campbell, G. R. McKay, R. L. Williams	1977
	Report On Cyclone Isaac, The Kingdom Of Tonga	UNDRO	1982
	Key Results of the World Risk Index Report, 2015	United Nations University	2015
	Tsunami Recovery Priority Plan, Kingdom of Tonga	GoT	2009
Codes and Regulations	National Building Code,2007	GoT	2007

Appendix B

Mission Details

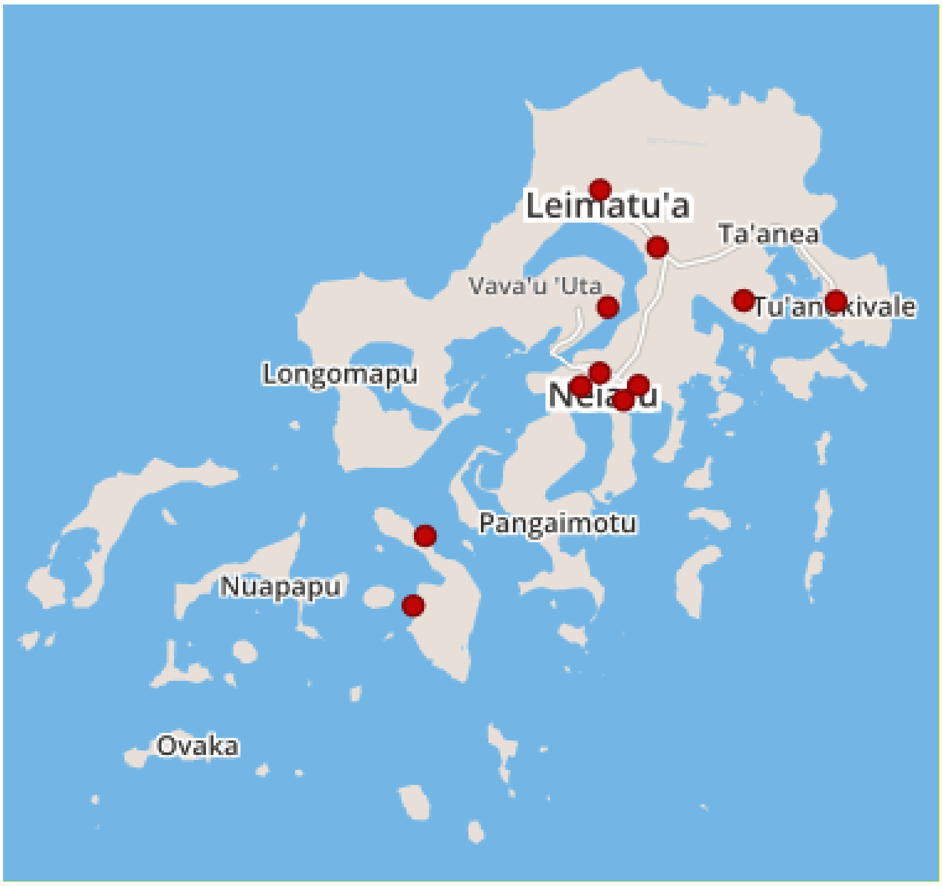
B1 Stakeholder Meetings

Organizations Present
School Visits, MOET, NEMO, World Bank, Arup
School Visits, MOET, NEMO, World Bank, Arup
MEIDECC, NEMO, Meteorological Dept, Ministry of Lands and Natural Resources, World Bank, Arup
MOET, World Bank, Arup
MOI, World Bank, Arup
DFAT, World Bank, Arup
JICA, World Bank, Arup
MOF, World Bank, Arup
PUMA, Arup
School Visits, MOET, Arup

Appendix C

Schools Surveyed

C1 Schools Surveyed



Locations of Schools Visited on Vava'u

Locations of Schools Visited on Nuku'alofa

List of Schools Visited in Tonga

School Name		
Island	Vava'u	
Year built	1970s / 2000s	
Construction Type	Timber Frame, Reinforced Masonry	

School Name		
Island	Vava'u	
Year built	1979/ 1982/ 1985	
Construction Type	Timber Frame, Reinforced Masonry	

School Name		
Island	Vava'u	
Year built	Various Unknown/ 1979/ 2012	
Construction Type	Timber Frame, Reinforced Masonry	

School Name	
Island	Vava'u
Year built	1970/ 1979/ Unknown
Construction Type	Timber Frame, Reinforced Masonry, RC Frame with Masonry Infill

School Name	
Island	Vava'u
Year built	1999/ Unknown (1970s?)
Construction Type	Reinforced Masonry, RC Frame with Masonry Infill

School Name	
Island	Vava'u
Year built	1988
Construction Type	Timber Frame

School Name		
Island	Vava'u	
Year built	1950/ 1990/ 2000/ 2008	
Construction Type	Timber Frame, Reinforced Masonry,	
School Name		
Island	Vava'u	
Year built	1980s, and Refurbished <5 years ago	
Construction Type	Timber Frame	

School Name		 
Island	Vava'u	
Year built	1985	
Construction Type	Steel Frame with Masonry Infill, Reinforced Masonry Columns	

School Name		
Island	Vava'u	
Year built	2000s?	
Construction Type	RC Infill Masonry	

School Name		
Island	Nuku'alofa	
Year built	1970s/ Various Unknown	
Construction Type	Timber Frame, Reinforced Masonry, RC Frame with Masonry Infill, Steel Frame with Masonry Infill	

School Name	
Island	Nuku'alofa
Year built	1960s/ Various Unknown
Construction Type	Reinforced Masonry

School Name	
Island	Nuku'alofa
Year built	1950s/ 1980s
Construction Type	Reinforced Masonry, Timber Frame

School Name	Hala o Vave
Island	Nuku'alofa
Year built	Various Unknown/ 2012
Construction Type	Unreinforced Masonry, Reinforced Masonry

Appendix D

Rapid Visual Assessment

D1 Rapid Visual Assessment

The Arup team used 'Fulcrum'[9], a web based data collection App to design a Rapid Visual Assessment form which was used during the school visits. At each site, data was collected through two main channels:

- An informal user interview with key staff from the school.

  This interview gave information about the history of the school buildings (when/ how/ by whom were they built, who funded them etc.) and how the community and school infrastructure responded to hazards. It provided information on the *social* context in which the infrastructure is located.

- A site exposure assessment and structural assessment of school buildings.

  The site exposure assessment looked at the key factors that contributed to a school site being exposed to natural hazards.

  The building hazard vulnerability assessment was a visual, non-destructive structural survey of the schools buildings. Attention was paid to the key structural vulnerabilities that school infrastructure was exposed to. These surveys provided information on the *physical* context in which the infrastructure is located.

For each school visited, a pdf report was generated, which contains the key information gathered from the user interviews and the exposure and structural assessments. These findings were used to inform the general observations and opportunities for the report.

D1.1 Rapid Visual Assessment Questions

Heading	Subheading	Question
1. Survey Details		
	Background Info	School Name
		Location
		Samoa - Upolu
		Samoa - Savai'i
		Tonga - Vava'u
		Tonga - Tongatapu
		Date
		Time
		Survey Number
		Arup Surveyor 1
		Arup Surveyor 2

[9] http://fulcrumapp.com/

		Photos Of Main Entrance
2. User Interview		
	Contact Details	Contact Name
		Contact Position
		Contacts Duration in Post
	School Details	Number of pupils on site
		Number of staff on site
3. Site Exposure		
	Topography	What is the slope of the site
		Is the site elevated above the surroundings
		Is the site at or near the base of a slope escarpment
		Are there deep cuts into the hill slope
	Water and Drainage	What is the distance to the nearest ocean river body of water
		<50m
		100m
		500m
		>1km
		Unknown
		What is the height above floodplain body of water
		<1m
		2m
		5m
		10m
		>10m
		Unknown
		Are there any man made drainage systems culverts on or near the site
		Photos of drainage systems
		Do the drains appear to be working
	Faults	Are there any linear features or vertical offsets on the site which could indicate an active fault
	Wind	Is the site sheltered shielded from wind eg with natural wind barriers trees
		No shielding
		Partial shielding
		Full shielding
	Vegetation	Are the buildings near large trees that can blow over
	Erosion	Are their signs of heavy erosion on the site
		Is there any evidence of slope stabilisation
		Are there any retention wall construction on or near the site
	Earthquake	Are there sufficient gaps between buildings to prevent pounding
		Is there sufficient space to unsafe structures and potentially damaging debris

	Evacuation	Are there good quality evacuation routes roads to from the school
	Communication	What communication links exist from the school to emergency services
		Radio
		Mobile phone
		Fixed phone
		Internet
4. Building Hazard Vulnerability		
4.1 Questions About the Building		Building identifier
		Photo of building entrance
		Who built the building
		Community - Unsupervised
		Community - Supervised
		Local Contractor
		International Contractor
		Who funded the building
		Community
		Government
		Donor - JICA
		Donor- DFAT
		Donor - MFAT
		Donor - ADB
		Donor - China
		When was it built
		Function of building
		Classrooms
		Offices
		House
		Watsan
		Dormitory
		Church
		Kitchen
		Maintenance/ Storage
		Number of room units in the building
		Is the building permanent or semi-permanent
		Permanent
		Semi-permanent
4.2 Building Configuration	Building Shape	What shape is the building
		Rectangle (L<4B)
		Rectangle (L>4B)

		Square
		L shaped
		T shaped
		Photo of sketch plan
	Soil, Foundations and Floor	Select soil type
		A - Hard rock
		B - Average rock
		C - Dense soil
		D - Stiff soil
		E - Soft soil
		F - Poor soil
		Comments on soil type
		Photos of floor foundations
		Select foundation type
		Pads
		Strips
		Raft
		Piles
		Mixed
		None
		Unknown
		Comments on foundation type
		Floor type
		Concrete Slab
		Crushed Coral
		Timber
		Earth
		Comments on floor
		Is there a damp proof membrane
		Is there evidence of rising damp
		Floor and footing condition
		0% (undamaged)
		10% (minor works required)
		50%
		100% (total destruction)
		Unknown
	Walls/ Columns/ Façade	Photos of walls columns facade
		Building stability system type
		Shear Wall
		Portal Frame

		Cantilever Columns
		Braced Frame
		Galvanised Iron Strapping
		Timber Strut
		Ply Sheet Bracing
		PVC Sheeting Bracing
		Absent
		Unknown
		Wall and column system
		Concrete Columns
		Timber Columns
		Concrete Block
		Timber frame
		Steel Frame
		Bamboo frame
		Stone
		Comments on stability and wall system
		Facade type
		Painted Block
		Cement Plaster
		Corrugated Iron
		Fibre Cement Sheet
		Asbestos
		Timber Cladding
		Bamboo Cladding
		Asbestos
		Facade fixing method
		Screws
		Nails
		Unknown
		Comments on facade
		Is there evidence of rot borer or termite attack in wall timbers
		Yes- Rot
		Yes- Borer/Termite Attack
		No
		N/A
		Cover to wall openings
		Timber- Shutters
		Timber- Louvre
		Metal- Shutters
		Glass- Fixed

		Glass- Louvre
		Mesh/Screen
		No Covering
		Comments on wall openings
		Wall cladding condition
		0% (undamaged)
		10% (minor works required)
		50%
		100% (total destruction)
		Unknown
	Roof	Photos of roof
		Roof structure
		Timber truss
		Timber beam
		Steel truss
		Steel beam
		Bamboo
		Concrete
		Roof slope pitch
		Flat (0-5 Deg)
		Gentle (10-25 Deg)
		Steep (30-45 Deg)
		Roof structure tie downs
		Looped Reinfocement from below
		Galvanised Iron Strapping
		U bolts
		Bolts and brackets
		Skew Nails
		Skew Screws
		Lashed (rope/fibre)
		Timber Dowels
		Absent
		Roof material
		Corrugated Iron
		Tiles
		Concrete
		Natangura
		Roof fixing methodology
		Screws
		Nails
		Unknown

		N/A
		Roof bracing
		Galvanised Iron Strapping
		Timber Strut
		Timber/ PVC brace sheeting
		Absent
		Unknown
		Is there evidence of rot borer or termite attack in roof timbers
		Yes- Rot
		Yes- Borer/ Termite Attack
		No
		N/A
		Are there large eaves or verandahs
		Yes- large eaves
		Yes- large verandahs
		No
		Photos of roof details
		Comments on roof issues
		Roof condition
		0% (undamaged)
		10% (minor works required)
		50%
		100% (total destruction)
		Unknown
	Building Categorisation	Reconstruction category
		Any other comments on building hazard vulnerability section
5. Water and Sanitation		
		Where does the school get water from
		District Supply
		Rainwater Tank
		Bore
		Well
		Creek/ River
		What toilets does the school have
		Toilet - Long Drop
		Toilet - VIP
		Toilet - Flushing
		None
		N/A
		No of toilets male

		No of toilets female
		Additional photos
6. Survey Close		
		Additional comments information
		Additional photos
		Detailed evaluation required
		Yes
		No
		Record completion
		Draft
		Complete

Appendix E

Key Vulnerabilities

E1 Exposure of School Infrastructure

Vulnerability	Description	Preventative Action	Photo
Site Location	Schools built on exposed sites in close proximity to the coast in tsunami zones	Locate schools above tsunami inundation level. Implement early warning systems and develop evacuation maps. Run evacuation drills in schools to prepare students and staff for emergency situations	 
	Schools exposed to localised flooding due to absence of site planning or drainage	Raise school infrastructure above surrounding area. Implement engineering drainage solutions	
	Schools exposed to landslides in areas with steep slopes (limited areas only)	Locate school buildings away from steep slopes.	

Physical Planning	Roof impacted by falling debris and corroding prematurely. Rainwater collection compromised by leaf litter	Locate structures away from large trees or unsafe structures which can fall on structures during a cyclone or earthquake. Provide regular maintenance to clear gutters and roofs of debris	

E2 Key Vulnerabilities

Vulnerability	Description	Preventative Action	Photo
Age of Assets	Many schools are ~30 years old and are degrading due to lack of maintenance and the severe coastal environment	Maintain structures regularly to prevent degradation of materials.	 
Structural Stability	Lack of stability systems Non engineered structures	All school buildings should be engineered. Development of a standard set of engineered drawings will enable MOET to develop a consistent approach to school construction.	

Structural form	Irregular structural form Buildings have L>4B	Buildings should not be wider than 4 times their width. Buildings longer than this should be broken up into two separate structures.	
Poor material quality	Sea sand is often used in concrete and for making concrete block, where the salt content leads to corrosion of steel reinforcement and concrete spalling.	Sea sand be stockpiled for six months and exposed to rainfall and/or washed with fresh water before use, to remove the salt.	 
	Timber degradation due to lack of maintenance or the use of untreated timber, leading to rot, termite and borer attack. Local timber used which is not strength or durability rated.	Preservative treated timber or hardwoods resistant to insect attack should be used. Knowledge of timber species is required if local timbers are to be used to ensure they are durable. A conservative approach to strength grading is required.	 

Material Selection	Masonite used for external cladding is not durable Heavy steel beams require maintenance, and is a system which is not understood locally	Materials selected must be appropriate for the conditions, readily available and be in widespread use.	 
Roof Connections	Poor connection details making schools vulnerable to high winds:Skew nails in lieu of strapping at roof to wall connections Connections corrode over time in the coastal environment.	Provide robust, engineered connections that are durable. Consider using large diameter galvanised bolts or stainless steel strapping. Provide ongoing maintenance for connections	 
	Nails are used in place of screws, which are vulnerable to uplift Poorly galvanised nails initiate corrosion in roof sheet	Use roof screw with cyclone washers for all roof sheet connections. Sheets should be screwed in accordance with manufacturers specification	 

Wall Connections	Poor connection details making schools vulnerable to high winds. Bottom plate is partially anchored, but stud not anchored to bottom plate	All connections should be engineered. Suitably qualified supervision is required on all building sites to ensure that buildings are constructed in accordance with the design intent.	
Unreinforced Masonry	URM is not suited to seismic zones due to its brittle failure mode	Ensure that all masonry is reinforced	
Poor Wall Detailing	Poor detailing reduces structures strength. High level masonry in gable ends is an EQ hazard.	Reinforcing bars should tie between walls and columns. Bond beams are required to provide horizontal connection between columns. Masonry in gable ends should be suitable reinforced or avoided	 

Poor workmanship	A lack of site supervision allows poor quality workmanship to go unchecked. Reinforced masonry column not core filled Foundations built on poor soil have subsided.	Suitably qualified supervision is required on all building sites to ensure that buildings are constructed in accordance with the design intent.	 
Appropriate Design	High level windows are not accessible to close by staff and students. Damage to building contents during high wind events.	All designs should take into account the relevant local hazards and likely resources and capacity of building users. Buildings should be as simple as possible.	 

Appendix F

Donor Programs

Historic, current and planned investment in school infrastructure in Tonga has largely been supported by international bilateral and multilateral donors. Whilst there are a number of smaller ongoing programs for school construction and refurbishment, many of the larger infrastructure programs have been funded in response to natural disasters. The major historic and current investments in school infrastructure and the successes and are listed below.

1982- ADB

Following Cyclone Issac ADB funded a major school reconstruction program using a standard, engineered MoI model school design. Buildings were constructed using timber frame and roof trusses and showed good structural detailing. A large number of these school buildings are still operational, but are currently deteriorating due to a lack of maintenance.

1985- JICA

In 1985 JICA financed construction of the Vava'u High School. Designed by a Japanese consultant, managed by an international contractor and constructed by a local sub-contractor, the school is built with a mixture of Japanese and local materials. The buildings are predominantly constructed with a steel frame clad in reinforced masonry. Due to poor quality construction and insufficient maintenance, many buildings are in a condition that currently places the occupants at risk. Steel members were observed to be severely corroded and concrete slabs showed extensive spalling from the use of unwashed sea sand during construction. Recent seismic damage to the structure has further exposed areas of poor workmanship and material quality, with two storey reinforced masonry columns observed to have no core filling of concrete blocks. In their existing condition, these buildings are a hazard to building occupants.

Parts of the school were renovated in 2008 through the European Union's (EU) Vava'u Social Sector Support program, where some masonry columns were replaced with reinforced concrete columns. Extensive areas of the structures require urgent renovation or reconstruction.

2002- Government of Tahiti

A number of primary schools were constructed by the Government of Tahiti in Vava'u following Cyclone Waka. The buildings consist of an engineered, reinforced concrete moment frame with infill reinforced masonry walls and timber truss roofs. The design was developed by the Tahitians, approved through the MoI and showed good structural detailing. Construction was carried out by Tahitian convicts with local community assistance and all buildings showed a high quality of workmanship.

2005-2011- NZAid and World Bank

NZAid and the World Bank funded the Tonga Education Support Program (TESP) which administered the Tongan School Grants Program (TSGP). This program provided small grants to Parent Teachers Associations to carry out repair works to their schools. The value, extent or types of works that were carried out through this program are not known.

2010-2013 – DFAT

Government of Australia supported the MOET with a AUD$1 million grant to distribute to schools for small infrastructure renovation works. Works were prioritised based on school infrastructure mapping undertaken by MOET in 2010. Refurbishment works were largely superficial and typically provided paint and replacement louvres for windows. Details of the survey are not known, but based on the type works undertaken, the survey appears to not have assessed structural vulnerabilities.

2014-2015- ADB & NZAid

ADB (NZD$2.5m) and NZAid (NZD$5.0m) are currently carrying out the Cyclone Ian reconstruction program, which includes the reconstruction of approximately twelve schools in Ha'apai. Buildings are understood to have been re-built on the same sites and it is unclear if a site selection and physical planning process was carried out to limit the exposure of schools to natural hazards. Buildings were designed by an engineer and architect, but it is unclear whether a building permit was sought prior to construction. A NZ architect has been hired to provide site supervision.

Ongoing- Chinese Government

The Chinese Government periodically provides support to the GoT through the construction of individual schools. Schools typically follow a Chinese design and all materials and labour are provided by the Chinese government. It is not known if schools are designed to the local standards, or which standards are used for design. Tonga High School was constructed through this method, however was not visited during the survey.

Ongoing- Japanese Embassy

The Japanese Embassy funds school construction through their Grant Assistance for Grassroots Projects program, which provides funding up to 10 million Yen (US$85,000) per project. Communities apply directly to the Embassy for funding, who carry out a selection process and identify suitable projects. Projects are approved on the strength of applications are not coordinated with the prioritised needs from the MOET. Approximately two to three schools are funded through this program each year.

Funding from the Embassy is provided directly to the community, who carry out all aspects of the project, from design through to construction. The Embassy advise the community to follow the government regulatory processes, however there does not appear to be checks in place to ensure that this is carried out.

Many buildings are constructed without the input from the MOET or MoI and as a result it is unlikely that many buildings would comply with the NBC. Buildings are constructed by community without professional site supervision which in a number of cases resulted in substandard, unsafe construction

Proposed- MOET with EU

MOET have lodged an application for USD$7.4m with the EU for funding replace buildings in 10 schools across Tongatapu.