Water Research Laboratory

Climate Risk Assessment for Avatiu Port and Connected Infrastructure

WRL Technical Report 2013/15
October 2013

by
R J Cox, K Panayotou and R M Cornwell

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

Water Research Laboratory
University of New South Wales
School of Civil and Environmental Engineering

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Project Details

Report Title	Climate Risk Assessment for Avatiu Port and Connected Infrastructure
Report Author(s)	R J Cox, K Panayotou and R M Cornwell
Report No.	2013/15
Report Status	Final
Date of Issue	10/10/2013
WRL Project No.	2010062
Project Manager	Matt Blacka
Client Name	Climate Change Cook Islands
Client Address	Climate Change Cook Islands Office of the Prime Minister Private Bag Rarotonga, Cook Islands
Client Contact	Ana Tiraa
Client Reference	

Document Status

Version	Reviewed By	Approved By	Date Issued
Draft v1.0	M J Blacka	G P Smith	03/07/2013
Final	M J Blacka	G P Smith	10/10/2013

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Acronyms

ACCARNSI	Australian Climate Change Adaptation Research Network for Settlements and Infrastructure
AGO	Australian Greenhouse Office
AusAID	Australian Agency for International Development
BoM	Bureau of Meteorology
CCCI	Climate Change Cook Islands
CIPA	Cook Islands Port Authority
CITC	Cook Islands Trading Company
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DIICCSRTE	Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education
MOIP	Ministry of Infrastructure and Planning
MSL	Mean Sea Level
NES	National Environment Service
PASAP	Pacific Adaptation Strategy Assistance Program
PCCSP	Pacific Climate Change Science Program
TAU	Te Aponga Uira
TC	Tropical Cyclone
WRL	Water Research Laboratory
UNSW	The University of New South Wales

1. Introduction

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering of The University of New South Wales (UNSW) has been undertaking and is currently finalising a five volume report series for the project *Coastal Adaptation Needs for Extreme Events and Climate Change, Avarua, Rarotonga, Cook Islands*. The project was initiated by the Cook Islands Government under the Pacific Adaptation Strategy Assistance Program (PASAP). The project is funded by the Australian Agency for International Development (AusAID) through the Australian Government's Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE) with contract administration undertaken by Climate Change Cook Islands (CCCI). The key objectives of the overall project were to:

- Understand the risks posed by changes to sea level and wave behaviour on coastal infrastructure and communities in the Avarua area, particularly during extreme events;

- Identify needs and develop options for responses to the risks; and

- Build local capacity to understand the science and manage the risk assessment and planning process.

The vulnerability to climate change and importance of ports of Pacific Island countries to their national economies was brought to the attention of DIICCSRTE by ACCARNSI (Australian Climate Change Adaptation Research Network for Settlements and Infrastructure) and PIANC Australia following the Pacific Maritime Transport Alliance conference held in Tonga in October 2012.

Following discussions between WRL, ACCARNSI, DIICCSRTE and CCCI, and in recognition of the important role of the Avatiu Port to the community of the Cook Islands, an additional study was commissioned as an extension to the original WRL project *Coastal Adaptation Needs for Extreme Events and Climate Change, Avarua, Rarotonga, Cook Islands*. This study, titled "*A Qualitative Climate Risk Assessment for Avatiu Port and Connected Infrastructure*" (part of the five volume report series), uses Avatiu Port (Figure 1.1) as a case study for implementing a qualitative climate risk assessment methodology that can later be applied to other Pacific Island ports. The methodology, through a process of surveys and information gathering with port and connected infrastructure managers in Rarotonga, was to identify the existing and primary risks of climate change on port facilities and operations. In addition, the project identifies the secondary risks to supply and services for the Rarotonga and wider Cook Islands communities including fuel, energy, water, communications, transport, consumables and tourism. Critical linkages between the port and connected infrastructure services were identified and their associated risks qualified. The project assessed existing adaptive capacity and present adaptation options for facilities and operations identified as being at high risk.

Figure 1.1: Avatiu Port, 2013 (Photo: CIPA)

2. Avatiu Port, Avarua and Rarotonga

The Cook Islands comprise thirteen (13) inhabited and two (2) uninhabited islands spread over nearly two million square kilometres of ocean between French Polynesia and American Samoa (Figure 2.1).

The town of Avarua is the capital of the Cook Islands and is on the north coast of the Island of Rarotonga, within the Southern Group of volcanic islands. Avarua is the hub of the Cook Islands economy and industry, and is the most densely populated residential area on any of the Cook Islands. Government and police offices, the major telecommunications receivers/transmitters, water and solid waste treatment facilities, landfill sites, international airport, main fuel stores, Avatiu Harbour (which processes all incoming freight to Rarotonga and the other Cook Islands), as well as the main shopping and residential districts are all situated along the Avarua to Nikao stretch of the Rarotongan coastline (Figure 2.2 and Figure 2.3). The major diesel powered electricity plant, operated by Te Aponga Uira (TAU), is inland and at an elevated location. Tourism is the main economic sector of the Cook Islands (BoM and CSIRO, 2011) and the tourism industry depends heavily on the functionality of this stretch of coast.

The coastline of Rarotonga is typical of volcanic Pacific Islands, with a shallow fringing lagoon (approximately -0.3 m Mean Sea Level (MSL) bed elevation) dropping into the deep ocean via a very steep carbonate reef system. At different locations along the coast, the lagoon varies in width from 50 m to several hundred metres. The surrounding reef has a rim slope of approximately 1V:15H extending down to 30 m MSL, then a steeper reef face of approximately 1V:1.3H extending to water depths of several kilometres.

The northern coastline is dominated by two passages through the reef system, these being Avatiu and Avarua harbours. Aside from the harbours, the foreshore has either man-made armoured slopes of 1V:5H or natural slopes of approximately 1V:10H. These slopes form a foreshore "bund" that varies in elevation from 2.5 m to 5 m MSL along the coast. Landward of this foreshore bund the topography is a lower basin with elevation typically between 2 m MSL and 3 m MSL. Most of this lower area has been developed over time, aside from a few areas that are more permanent swamp zones used primarily for agriculture (such as inland from Avatiu harbour). The lower inland area is drained to the lagoon by a network of man-made stormwater channels and pipes with natural and modified streams. Detailed survey of the area as undertaken by WRL within the project is presented in Blacka *et al*. (2013).

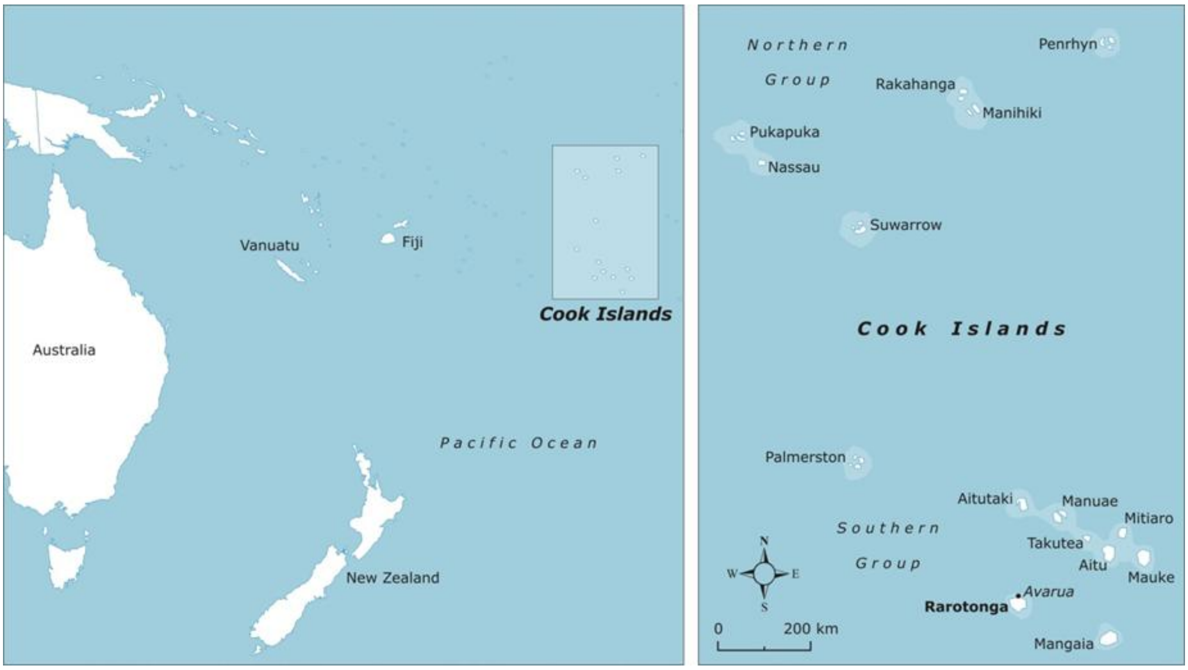

Figure 2.1: Location

Figure 2.2: Avatiu to Nikao Stretch of Coast, 2013 (Photo: CIPA)

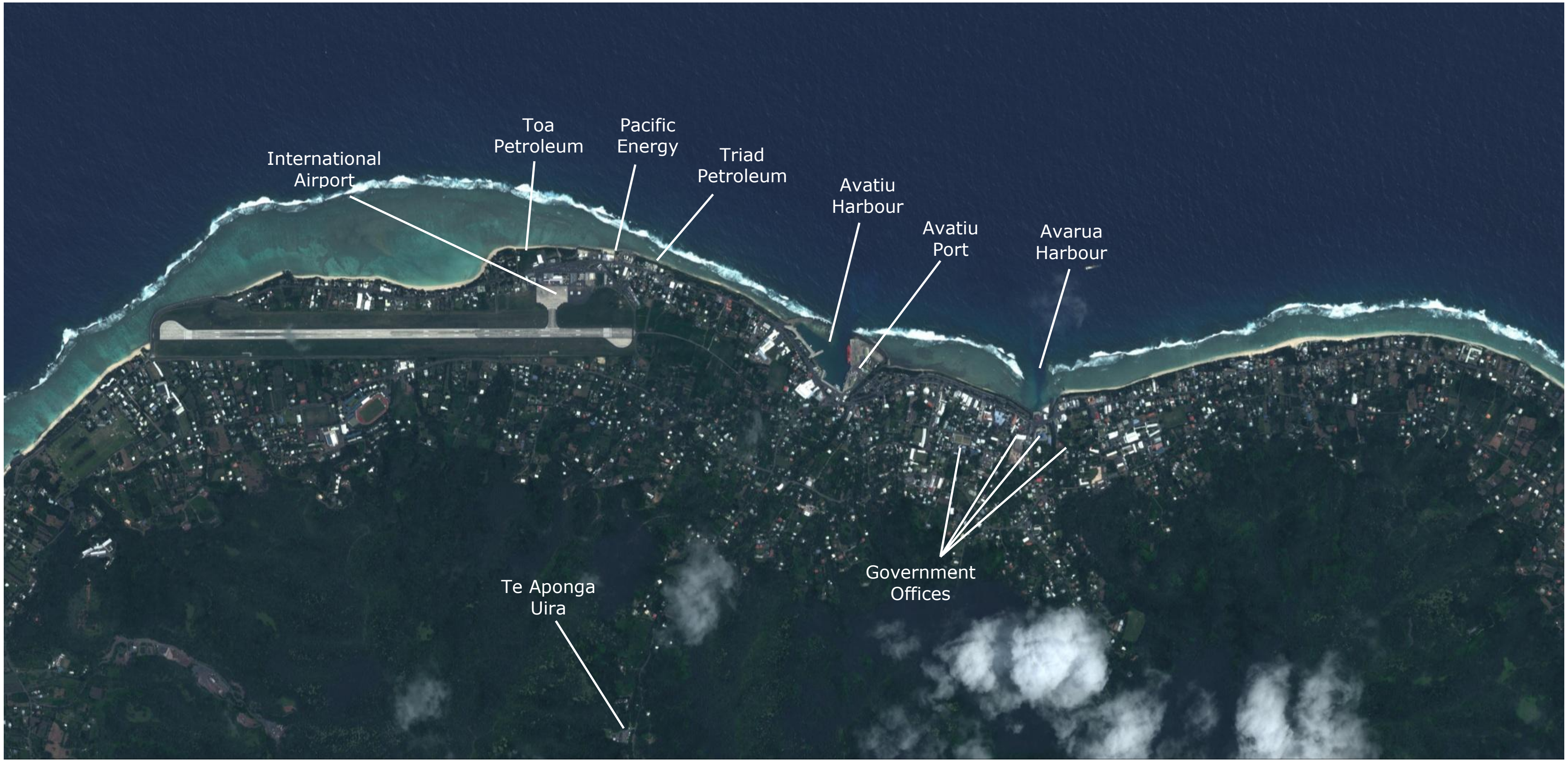

Figure 2.3: Study Area

3. Climate Change

The BoM and CSIRO (2012) examined future climate projections for the Pacific region and compiled specific country climate reports. In relation to port infrastructure and operations the projected regional climate changes of issue can be summarised as:

- Temperature increases (will be moderated by ocean waters);
- Trade wind shifts (variations in latitude and seasonality);
- Rainfall changes (regional and seasonal shifts in average rainfalls affect water supply and agriculture whilst more intense extremes affect flooding);
- Storm intensity increases (more extreme winds and waves);
- Cyclonic changes (fewer occurrences but higher intensity with design and operational implications); and
- Importance of Southern Oscillation Index SOI (rainfall and cyclone frequency and intensity vary with El Niño/La Niña cycle).

More specifically for the Cook Islands, the ADB (2005) identified the following climate conditions to be potential sources of risk:

- Extreme rainfall events;
- Drought;
- High sea levels and extreme wave heights;
- Strong winds;
- Cyclones with occurrence of high sea levels, strong winds and extreme waves; and
- Extreme high air temperatures.

Tropical cyclones (TCs) have been identified as the major climate event impacting the Cook Islands with extreme consequences and therefore a very high risk categorisation. Between the 1969-70 and 2009-10 summer cyclone seasons there were forty-seven (47) TCs that passed within 400 km of Rarotonga, an average of eleven (11) per decade or just over one (1) per year. There is a significant trend for cyclones to occur in El Niño years (average of fifteen (15) per decade) compared to La Niña years (average of six (6) per decade). In the 2005-06 season there was an unprecedented occurrence of cyclones whereby five (5) TCs passed nearby Rarotonga, most of which were classified as Category 5 Severe Tropical Cyclones (BoM and CSIRO, 2011). While this brought about immediate concern as to the impacts of climate change on TC frequency and intensity, there has since been a relative lull with very few TCs passing through this region in recent years.

The Pacific Climate Change Science Program (PCCSP) analysis for the Cook Islands (BoM and CSIRO, 2011) projects that there will be no change or a possible reduction in the formation of tropical cyclones as a results of climate change. There was moderate confidence that the overall number of tropical cyclones would decrease in the Cook Islands area. However, projections also indicated a southward shift in the regions of most intense cyclones, with areas south of 20 degrees latitude (which includes Rarotonga) likely to see an increase in the proportion of more intense tropical cyclones.

A detailed review of the impacts of TCs in the Cook Islands was undertaken in de Scally *et al.* (2006), however, in terms of coastal processes there is relatively little recorded quantitative data or observation. WRL Report TR2013/13 (Blacka *et al.,* 2013) provides a summary of the more severe cyclone events to impact the north coast of Rarotonga since the early 1800s and attempts to quantify some of the observations. Undoubtedly the worst cyclone in living memory for most residents of Rarotonga is TC Sally (1987), which resulted in widespread flooding from storm surge, overtopping and rainfall (Figure 3.1), but also destroyed and damaged many buildings along the coast through direct wave overtopping impacts (Figure 3.2).

Figure 3.1: Post TC Sally (1987) Damage at Avatiu Harbour (Image: Don Dorrell)

Figure 3.2: TC Sally (1987), Wave Bore Impacting Banana Court Shops, Avarua CBD (Image: Coco Photo)

The series of five (5) cyclones in 2005 (Meena, Nancy, Olaf, Heta and Rae) also resulted in areas of significant localised damage. While there are good video records of these events, there was very little quantitative data recorded. Although TC Sally (1987) and the 2005 cyclones resulted in significant destruction, TC Sally was relatively low in intensity (Category 2) while passing over Rarotonga, and none of the cyclones of 2005 tracked directly (though several easily could have). In considering cyclone observations recorded throughout history, Blacka *et al.* (2013) advised that events with severity equivalent or worse than TC Sally have impacted the north coast of Rarotonga approximately ten (10) times since 1820, which would make TC Sally an event with ARI of the order of twenty (20) years. The events more severe than TC Sally that have been recorded include situations where storm surge is reported to have reached the foot of the mountains in the area of the LMS mission house in Avarua. Should such an event occur today, the complete town area that is modern day Avarua would be almost completely inundated by storm surge. The resulting destruction would be much more devastating and widespread than occurred in TC Sally.

4. Risk Assessment Approach

4.1 General

The risk management methodology adopted in this study generally sought to align itself with the principles, framework and process set out by the International Standard for Risk Management, ISO 31000:2009. A review of literature in this area confirmed the suitability of the International Standards approach as a starting point for climate change risk management specific to port operations. The Australian Greenhouse Office (AGO) Guide to Climate Change Impacts and Risk Management 2006 is an extremely useful guide to interpreting and implementing the Risk Management Standards in relation to climate change. The approach taken by McEvoy *et al.* (2013) was purportedly "underpinned by ISO 31000" with a key modification being the "integration of primary data from port personnel to determine current vulnerability". This thinking was influential to the final methodology used in this study.

A "hybrid risk/vulnerability" approach, where a consideration of current day vulnerabilities to extreme weather events is integrated with an assessment of future climate risks, was considered by McEvoy *et al.* (2013) to provide greater value to port operations. Accordingly, McEvoy *et al.* (2013) reasoned that a vulnerability assessment was a useful method for overcoming adaptation barriers that arose through inconsistencies between typical planning horizons and climate projection timelines. Another beneficial consequence was that, if implemented near the beginning of the process, a "first pass" vulnerability assessment could not only act as a filtering tool but would assist in identifying assets that required a more intensive risk assessment. McEvoy *et al*. (2013) considered vulnerability to be a function of:

- Hazard exposure (the extent to which a port may be subjected to climatic events such as high temperatures, varying rainfall, high winds, waves or cyclones);
- Sensitivity (the degree of negative impact on the port's infrastructure and ability to provide services); and
- Adaptive capacity (ability to manage these impacts).

In turn, the combination of these three elements formed a single measure of vulnerability. While these three elements were suggested as the basis for assessing vulnerability, this study did not rigidly enforce the recording of or standardise the weighting attached to each. It was considered preferable to keep measurement and recording to a minimum, particularly at this early qualitative stage of risk assessment.

4.2 Port Specific Elements of a Risk Assessment Approach

A key elements approach is promoted by the AGO to encourage risk identification (AGO, 2006:42). Stenek *et al.* (2011) provided the following port specific key elements through which to identify risk:

- Vehicle movements inside Port;
- Demand, trade levels and patterns;
- Goods storage;
- Environmental performance;
- Navigation and berthing;
- Goods handling;
- Inland connected infrastructure;
- Social performance; and
- Insurance.

McEvoy *et al*. (2013) favoured an assets and personnel-based approach. The final methodology adopted in this study was an amalgamation of the Stenek *et al.* (2011) and McEvoy *et al.* (2013) approaches. The operational elements from Stenek *et al.* (2011) were applied to each of the port's core assets. Similar to the port operational categories, a series of key elements were also developed to classify consequence. These included:

- Interruption/halt to logistical operations;
- Interruption to boat movements;
- Increased maintenance costs;
- Deferment of capital expenditure;
- Increased insurance costs;
- Adverse reputational impact;
- Environmental impact;
- Regulatory impact;
- Lost time due to staff or contractor injuries;
- Adverse safety impact;
- Staff unable to attend work; and
- Altered dredging schedule.

Previous port risk assessment processes typically limited themselves to the immediate port environment (e.g. McEvoy *et al.* (2013) confined themselves to the "port environs"). The Stenek *et al*. (2011) approach, while extending to consider the impact that extreme events had on inland transportation infrastructure, did not look holistically at the wider range of connected infrastructure that both affect port operations and are affected by them. In developing the methodology to be used in this study, it was recognised that this symbiotic relationship between port operations and connected infrastructure needed to be considered. Accordingly, this study focussed on both the port operations and the connected infrastructure and their reliance on each other.

The importance of stakeholder engagement was recognised in meetings/discussions/interviews being held with as many of the staff of the port and key managers and operational staff of the connected infrastructure and service providers across government and the private sector.

4.3 Objectives and Risk Assessment for this Study

In order to ensure this process allowed for the capturing of factual and anecdotal information from the port and connected infrastructure users, several means of gathering information needed to be part of the overall methodology. A key focus of this project was the interview process in which a series of discussion/interviews took place in the Cook Islands with relevant stakeholders. Prior to the site visit and interviews, a desktop study was undertaken to understand the current practices in port and connected infrastructure risk assessments and specific climate change events for the Cook Islands. Based on this, a series of three (3) surveys were prepared to capture the vulnerability, qualify risks and identify adaptive capacity for both the port infrastructure and associated connected infrastructure. These three (3) surveys (see Appendices B and C) were utilised during the discussion/interviews and are outlined below:

- First Pass Vulnerability Assessment Part A;
- First Pass Vulnerability Assessment Part B; and
- Qualitative Risk Assessment.

In the *First Pass Vulnerability Assessment Part A*, the vulnerability of the following key assets or operational areas were assessed against the defined extreme climatic events of High Wind, High

Rainfall, high waves, temperature, sea level rise and cyclonic events (where cyclonic events are a specific extreme weather event generally understood to be a combination of high wind, high rainfall, high waves and elevated sea levels):

- Water-based;
- Interface;
- Land-based; and
- Connected infrastructure.

While earthquakes and tsunamis may have application to some Pacific ports, these were not included because of their limited relevance to Rarotonga.

All relevant stakeholders (i.e. representatives from the Port, connected infrastructure and government representatives) were asked to rate the vulnerability of each asset or connected infrastructure against the listed climate events using a score that was indicative of the relationship between the hazard exposure, sensitivity and adaptive capacity (as outlined in Section 4.1). A rating of one (1) represented no perceived vulnerability, a rating of two (2) represented some vulnerability, a rating of three (3) represented moderate vulnerability (with a suggested benchmark that port operations are likely to be down for hours), a rating of four (4) represented significant vulnerability (with a suggested benchmark that port operations are likely to be down for days), while a rating of five (5) represented significant vulnerability where operations are likely to cease for a number of weeks or altogether (refer to Appendix B).

The second survey, *First Pass Vulnerability Assessment Part B* sought a greater appreciation for the role played by connected infrastructure. A four-point rating scale was used to rate how important each piece of connected infrastructure was to maintaining port operations. A rating of Low represented all port operations continuing largely unaffected, a rating of Medium represented critical port operations continuing but with somewhat reduced efficiency or delay, a rating of High represented significantly reduced port operational ability and a likely port shut-down in the absence of relief, while a rating of Very High represented a complete inability for the port to function without the corresponding infrastructure (refer to Appendix B). Rating was then sought for the converse - the importance of port operations for the continued operation of each identified piece of connected infrastructure (see also Appendix B).

The *First Pass Vulnerability Assessment (Parts A and B)* was contingent upon appropriate background information and historical knowledge. Involving people with such knowledge was recognised to be crucial to the success of this project. Thus this project was conducted in consultation with experienced port managers and operational staff as well as a wide range of experienced senior representatives of the connected infrastructure and/or stakeholders.

Typically, one of the difficulties with conventional risk assessments is the mono-directional focus. The focus tends to lie on singularly ascertaining consequences to port operations at the expense of consequences that may play out in broader contexts. The method utilised in this study draws out an appreciation for the level of symbiosis between port operations and connected infrastructure, somewhat overcoming the common mono-directional limitations and providing a more valuable appreciation of impacts, vulnerability and risk to climate change both within the Port and across the connected infrastructure and services.

A combination of Part A and Part B was used to determine which assets or operations were at a higher risk. Based on this, these assets or operations were further assessed in the *Qualitative Risk Assessment*. The *Qualitative Risk Assessment* captured information regarding:

- Existing risk (based on consequence and likelihood);
- A description on understanding of future climate risk (based on consequence and likelihood);
- Description of past historical events and capacity to adapt, and an assessment on the future capacity to adapt; and
- Likely consequences and operational areas that could be impacted.

In assessing future risk to climate change, instead of using the 5-point scales of present climate consequence and likelihood used in Part A and Part B, consequences were assessed as higher or lower and likelihoods as more or less than present conditions.

In order to complete this survey, the stakeholders assessed and rated the adaptive capacity of each asset through application of treatment options outlined in the Risk Management Standard. These included the ability to:

- Avoid the risk (by deciding to halt, or not start the activity that is at risk);
- Accept the risk (perhaps in order to pursue an opportunity);
- Remove the source of the risk;
- Change the likelihood;
- Change the consequence;
- Share the risk (particularly through insurance opportunities); or
- Retain the risk.

In regards to assessing the operational impacts, a four-point qualitative scale was used that considered disruption of operational objectives. This was undertaken for both current climate risk and perceived future climate risk.

As part of the stakeholder consultation additional information was gathered which assisted in the risk assessment for this study. These included the following:

- Historical information regarding events that impacted on each of the assets or operations over 10 and 30 year timeframes; and
- General comments and descriptions of the consequences flowing from each of the past climatic events on the port, operation areas, connected infrastructure and in the region in general.

4.4 Interviews Conducted

Between 7 and 14 June 2013, site visits and a series of formal and informal interviews were undertaken as part of this project. The interviews and discussions with staff of CIPA focussed on identifying the risks and vulnerability of the Avatiu Port as a result of future climate hazards. The interviews and discussions with staff of relevant government Ministries, private sector service providers and port end users focussed on identifying the risks and vulnerability of critical infrastructure and services, and the relative importance of connections with the Avatiu Port. In turn an assessment or discussion was undertaken in regards to the adaptive capacity of the Port and connected infrastructure. The list of interviewees and the type of interview/discussion undertaken for each in relation to the Port is outlined in Table 4.1. Feedback sessions with CIPA staff and the various government and private sector infrastructure and service providers were held on 29 and 30 July 2013. An interview with Telecom Cook Islands was held on 30 July 2013. The information gathered during these meetings and the associated site visits form the basis of the assessment herein.

Table 4.1: Summary of Interviews

Date	Time	Person	Position	Organisation	First Pass Vulnerability Assessment	Qualitative Risk Assessment	Discussion
7 June 2013	2 pm	Numerous	Various	CIPA	No	No	Yes
10 June 2013	11 am	Saungaki Rasmussen	Harbour Master	CIPA	Yes	Yes	Yes
	2 pm	Andre Tuiravakai	Port Operations Manager	CIPA	Yes	Yes	Yes
11 June 2013	12 pm	Ben Parakoti	Independent	Consultant	No	No	Yes
12 June 2013	8.30 am	Lucy and Louise	Finance and Admin	CIPA	Yes	Yes	Yes
	10 am	Charles Carlson	Director	EMCI	No	No	Yes
	11.30am	Gaye Whitta	General Manager	CITC	Yes	Yes	No
	3 pm	Joseph Akarura Teupa Mana Paul Maoate	Acting Director, Policy Planning and Asset Management Project Engineer Project Engineer	MOIP	Yes	No	Yes
13 June 2013	9 am	Graeme Wiig	Manager	TRIAD	No	No	Yes
	10 am	Mii Nichols	Aviation Manager Cook Islands	Pacific Energy	No	No	Yes
	11 am	Joseph Brider Mii Matamaki Vavia Tangatataia	Deputy Director Senior Environment Officer Manager- Advisory and Compliance Dvn	NES	Yes	No	Yes
	1 pm	Bim Tou	General Manager	CIPA	Yes	Yes	Yes
	2 pm	Tony Wearing	Manager Air Traffic Services and Emergency Planning	Airport Authority	No	No	Yes
14 June 2013	9 am	Halatoa Fua	CEO	Cook Islands Tourism	No	No	Yes
	10 am	Api Timoti Alex Napa	CEO Project Manager	TAU	Yes	No	Yes
30 July 2013	10 am	Jules Maher	CEO	Telecom Cook Islands	No	No	Yes

5. Risk Assessment of the Port

5.1 Port Assets, Operations and Connected Infrastructure

As part of the stakeholder engagement process, the Cook Islands Port Authority (CIPA) provided the assets register for the Port (Appendix A). This asset register has been broken down into four (4) key areas to better categorise related assets. They were grouped according to their physical location in the Port and their relationship to the shipment logistical functions performed and are outlined below. In addition to this, anecdotal information gathered as part of the interview process is also provided below to give context to the assets, operations and connected infrastructure prior to the detailed interview assessment presented in Sections 5.2 and 6.2.

5.1.1 Waterside

The waterside group included breakwaters, the vessel access channel and turning circle (encompassing operations related to navigability and safety) and operationally significant craft such as tugboats. The performance of this group had the most direct impact upon the sea-supply chain.

It was ascertained that there were two cargo ships that operated on approximately three-week cycles. The first operated on an 18-day cycle; the second operated on a 21-day cycle. They were not necessarily coordinated as each had separate supply client contracts.

If weather conditions on arrival at Port were such that entry, berthing or turning were deemed unsafe by the Harbour Master, vessels would either (depending on the expected delay) wait offshore until conditions were safe for entry; reroute and return after visiting another port; or miss the scheduled berth entirely. Given the length of time between shipments and the strong demand from the tourist industry for a regular and reliable supply of imported goods, the implications of the latter two options are particularly significant.

General indications of safe operating parameters from the Harbour Master included winds of no greater than 20 knots in any direction. High waves did not have a defined limit but were subjectively assessed. The Port is particularly sensitive to wave direction. North-easterly waves are the most unsafe yet also the most common.

Further limitations to safe berthing and turning stem from the availability and capacity of the tug boat to assist berthing vessels. The present tug has a limited bollard pull of 5 tonnes. This is quite small when compared to the larger 30 t bollard pull tug that was on site during the Port's reconstruction. The smaller tug is however, fit for purpose as it can be removed from the harbour and transported to safe higher ground inland in the period leading up to an impending cyclone. Redelivering the tug to the Port relies on road and slipway access that may have been affected.

5.1.2 Interface

The interface group consists of wharves, slipways and facilities for both recreational vessels and commercial fishing.

Sea level rise has presented issues to this group of assets in many ports worldwide through increasingly causing the operability ranges of wharves and material handling equipment to be exceeded. However, at Avatiu the wharves and berthing facilities have been considerably upgraded in recent times as part of an overall port redevelopment that was completed in 2012. They are in very good condition and possess excellent adaptive capacity. They are expected to survive a cyclonic event and return to duty within hours.

The slipway on the other hand is vulnerable to damage from displaced rocks from the western breakwater.

In the event of a cyclone, commercial and fishing boats as well all removable components of the associated facilities, are moved to higher ground. If any vessels are too large to be transported overland they are sent to sea or moved to more sheltered moorings on the other side of the island.

5.1.3 Land Based

Land based assets encompass administrative and office buildings, storage and transit sheds, open storage and container stacking areas, mobile cranes, forklifts, and trucks. Other significant plant and equipment also fall within this category. Goods handling and storage, and vehicle movements around the port are the operational areas that this group is most concerned with.

Many port operations have critical thresholds relative to wind speeds. Cranes (land based gantry or mobile and/or ship mounted) may be unable to be moved when wind speeds pass over a certain threshold, and in extreme wind speeds they have to be taken out of operation altogether to avoid damage.

Low-lying storage areas that are not adequately protected by seawater defences will be vulnerable to coastal flooding, while areas with inadequate drainage can be flooded by heavy rainfall. Increased occurrence of goods spoilage because of flooding can also damage the Port’s reputation.

The two main storage sheds at Avatiu were significantly damaged in cyclone Meena (2005) due to overland flow from the lagoon to the north-east. These were upgraded with lower-level concrete floodwalls that were designed to survive cyclonic events of the intensity of TC Sally (1987).

There is a danger however, that the reclamation of the area to the east of the harbour (which has reduced the adjacent stream’s capacity to discharge water in flood events) will affect the magnitude of the risk presented. The effect that the dredging has had on tidal movements and wave set up at the entrance of the sea has yet to be modelled but was identified as being a relevant consideration in assessing the exposure of these assets.

Overall, the adaptive capacity of the removable land-based assets is excellent. Three (3) LPG gas containers that supply gas for cooking and water heating are mounted on solid foundations. Procedures are in place for securing these containers when a cyclone approaches, however the structural design criteria could not be ascertained.

5.1.4 Connected Infrastructure

This group looked at connecting infrastructure including roads (including bridges), stormwater (flooding), fuel supply (diesel, petrol, aviation and gas), power, communications, water, food and goods as well as waste (water and solid) services.

Early consultations with CCCI led to the inclusion of Tourism Cook Islands, Cook Islands Airport Authority, Emergency Management Cook Islands, and the National Environmental Service (NES) in the Risk Assessment process.

5.2 Outcomes of Interviews with Port-Related Staff

In order to ascertain the potential impacts of climate change on the Port, the interviews focussed on the four (4) main components of port related activities and reliance on associated infrastructure i.e. the water-side infrastructure, interface infrastructure, land-based infrastructure and connected infrastructure, as discussed in Section 5.1. Interviews were undertaken with the following key CIPA staff:

- General Manager;
- Harbour Master;
- Port Operations Manager; and
- Port Finance and Administrative staff.

Where completed, the results of the First Pass Vulnerability Assessments A and B and the Qualitative Risk Assessment are provided in Appendices B and C. In addition, outlined below are the range of responses and interpretation of survey questions across the various staff depending on their role and responsibilities e.g. the Harbour Master has focussed more on water-side operations due to their relevance to his the role and responsibilities.

5.2.1 Response from Port General Manager

From an operations perspective in the Port, risk from climatic events is less than it has been over the years due to the recent redevelopment of the port, which included mitigation measures as part of the redesign. The principal remaining concerns were high winds, high waves and cyclones which would affect the breakwater, access channel and tug boat. However, it is worth bearing in mind the adaptive actions the Port already has in place. Presently, when a cyclone warning is received, all vulnerable items are removed. This covers a mobile crane, tug boat as well as other plant and equipment.

Vulnerability of the Port to a Category 3 cyclone would be moderate whereas a Category 5 cyclone would result in destruction of the whole town and recovery time for the Port and the connected infrastructure would likely take weeks at a minimum. Of particular note is the high reliance of the Port on connecting road and fuel infrastructure, where the Port’s operational ability would be significantly reduced and a Port shut-down likely if these were damaged. In turn the Port operations are of high importance to fuel, power, food and goods for continued economic and community well-being.

5.2.2 Response from Harbour Master

In general the reliance of the Port on the connected infrastructure is considered low. However, the reliance of the connected infrastructure on the Port is considered medium to high for fuel and power, medium for food, goods and roads, but low for communications, water and waste services.

Specifically, for each asset or operation, the vulnerability to climatic events is that:

- Breakwaters are only somewhat vulnerable to sea level rise and cyclone events;

- The vessel access channel and the tug boat are moderately to significantly vulnerable to high wind, high rainfall and high waves, and both would cease operation during a cyclone event;
- The interface assets, wharves and slipways are significantly vulnerable to cyclone events; and
- Land-based infrastructure is considered not at all vulnerable as the majority of these assets are removed from site in the event of a cyclone. The only land-based assets that would be significantly vulnerable are the administration and office buildings; the storage buildings having been significantly upgraded in recent years.

Connected infrastructure is categorised as somewhat vulnerable for food and waste services, moderately vulnerable for communication and water and significantly vulnerable for fuel and power, all in relation to port operations in a cyclone event.

The existing risk to high wind and rainfall is considered high, while it is considered very high for high waves and cyclones with respect to the access channel and tug boat operations. The overall adaptive capacity to these events is considered similar to past risk and adaptive capacity, although the recent redevelopment of the port, including the dredging of the access channel has improved the effectiveness of channel and tug operations.

In regards to the wharves, the risk from high waves and sea level rise is considered medium, while the risk from cyclones is considered high. Overall the adaptive capacity has increased with the recent redevelopment.

5.2.3 Response from Port Operations Manager

Overall the Port Operations Manager stated that the Port had a medium reliance on several pieces of connected infrastructure, namely power, communications and water; and these same connected infrastructure were reliant on the Port. Key water-based infrastructure is vulnerable to high wind, high waves and cyclones, while Port interface assets and land-based assets are moderately to significantly vulnerable. Roads and fuel are moderately vulnerable and power, communications and waste services are significantly vulnerable to cyclone events.

Existing risk to high wind, high waves and temperature is considered high however the capacity to adapt to these future climate risks is considered adequate where work would only be impacted for a few hours if that.

The risk of impacts from sea level rise and cyclones is considered very high, with more of these impacts likely in the future. Adaptive capacity is considered at least adequate, where disruptions would range from minor to major, depending on the event. For instance most assets that can be removed from site are removed when a cyclone warning has been given. Assuming little or no impact to these assets, the Port is able to be operational including the tug, within half a day to one day.

5.2.4 Response from Port Finance and Administrative Staff

The vulnerability of the Port to the connected infrastructure is considered very low. However, the vulnerability of the connected infrastructure to the Port is considered medium for fuel and power and low for roads, communications, water, food, goods and waste services. In the past, while there have been times when there have been fuel shortages owing to tankers not arriving, this was somewhat mitigated through the rationing of fuel.

The vulnerability of the Port to a cyclone event is considered high with the access channel and commercial fishing and recreational vessel facilities all being significantly vulnerable and the wharves and storage/transit sheds being moderately vulnerable.

The adaptive capacity to a cyclone event is considered adequate. The main consequences of a cyclone event would be interruptions to logistics operations, interruption to boat movements, increased maintenance costs, potential adverse reputational impact, potential environmental impact, regulatory impact, lost time due to staff or contractor injuries, safety, staff not able to attend work and other business consequences.

The main operational areas that would be impacted include vehicle movements inside the port, demand, trade levels and patterns, goods storage, environmental performance, navigation and berthing, goods handling, inland connected infrastructure, social performance and insurance.

5.3 Summary

The perceptions of vulnerability and risk to the various assets, operations and connections to infrastructure vary across the Port management and staff. The interpretation, presented by WRL below, is a balanced view taking into account the various perceptions and relevant experience of the interviewed staff with more weight being given to views of experienced managers/staff in areas of responsibility:

- Overall, the current means of managing vulnerability and risk to natural hazards are working effectively for the Port where the Port has advanced warning. Notification of cyclones provides a three to four (3 - 4) day lead time which is typically enough time to respond and ensure that operational impacts are minimal to nil;

- Accordingly, the adaptive capacity of the Port to future climate related events also seems to be managed well. In particular, changes to the Port in the recent redevelopment have ensured increased navigability, deeper basin allowance and more efficient quay wall alignment which will be beneficial in the lead up to and recovery from future events; and

- Notwithstanding this, in the event of a direct hit cyclone or impacts from a near-passing higher category cyclone such as a nominal 100 year ARI event as identified in Blacka *et al.* (2013), the capacity of the Port to respond and efficiently recover may require further assessment and planning, and will likely result in longer downtime periods in Port recovery and operations.

6. Risk Assessment of the Connected Infrastructure

6.1 Connected Infrastructure

The economy of the Cook Islands is more than 75 % dependent upon tourism. With this comes an expectation for high levels of service delivery in respect to power, communications, transport, water, waste, food and goods, public health and the environment. The importance of ports to the viability and well-being of Pacific Island communities has been identified in various reports.

Infrastructure/services provided by the responsible Government or private sector if affected by climate change and extreme weather may impact on port services and/or are likely to be at risk from the loss of the Port services in Rarotonga. In consultation with CCCI and CIPA, roads, bridges, drainage, water supply, water and solid waste, fuel, airport, power, food and goods, communications, tourism, emergency management and environmental services were all identified as key connected infrastructure/services that may affect or be affected by port operations and services particularly during extreme weather and with climate change.

6.2 Outcomes of Interviews with Connected Infrastructure Related Industries

As part of determining the potential impacts of climate change on the Port, it is also important to understand the impact of weather and climate on the connected infrastructure and the inter-relationships with the Port, the wider economy and well-being of the Cook Island community. Outlined in sections 6.2.1 to 6.2.10 are the outcomes from the following interviews:

- Emergency Management Cook Islands (EMCI);
- Cook Islands Trading Company (CITC) (food and goods);
- Ministry of Infrastructure and Planning (MOIP) (roads, bridges, drainage, water, waste);
- TRIAD Pacific Petroleum (fuel);
- Pacific Energy (fuel);
- National Environment Service (NES);
- Cook Islands Airport Authority;
- Tourism Cook Islands;
- Te Aponga Uira (TAU) (power-electricity) ; and
- Telecom Cook Islands (communications).

Where completed, the results of the First Pass Vulnerability Assessments A and B and the Qualitative Risk Assessment are provided in Appendices B and C. Accordingly, the range of responses and interpretation of survey questions across the various stakeholders depending on their role and responsibilities are presented below.

6.2.1 Emergency Management Cook Islands (EMCI)

EMCI stated that the major events of concern were cyclones, and in particular, a direct hit. In the event of such a direct hit severe cyclone, it was believed that most of the connected infrastructure would be damaged.

For instance, during the 2005 series of cyclones the power shut down. Accordingly, knowing how to react and having replacement materials and the like in stock is part of current emergency planning and workshops. The disaster management group meets regularly where at least once a year there is a full desktop and operational check ,i.e. mock scenario trial which includes key Port and airport staff.

It is believed that there is a significant reliance on the Port in terms of food supplies and tourism. In the past there have been shortages of bread, sugar, rice (for the Northern Group Islands) and alcohol. Overall, EMCI stated that the Port is crucial to the connected infrastructure and community of the Cook Islands.

6.2.2 Cook Islands Trading Company (CITC)

CITC is the main supplier of food and goods in the Cook Islands. Discussion with CITC about the vulnerability of CITC's business to routine port operation, the Port's reliance on the connected infrastructure and CITC's vulnerability to climate change events, resulted in the following key observations:

- The Port has a low reliance on the key connected infrastructure outlined in the survey, whereas several of the key connected infrastructure are highly reliant on the Port for continued operation (i.e. fuel, power, food and goods);
- The Port water-based and interface infrastructure is significantly vulnerable to cyclones (Category 5) whereas land-based infrastructure is less vulnerable as several items can be removed from site in the event of a cyclone. Further, numerous other components of the site (e.g. storage facilities) have been upgraded in the recent redevelopment and have reduced their vulnerability to cyclones; and
- Connected infrastructure is moderately to significantly vulnerable, and would be down for several hours to days depending on the amount of clearing after an event. CITC stated that they would endeavour to be open within hours/as soon as possible, as part of their rapid response.

Overall CITC believed that the existing risk to cyclones (Category 5) was high but that their adaptive capacity was adequate, i.e. moderate disruption with normal work resuming within three to five (3 - 5) days. The main consequences would include interruption to logistics operations, interruption to ship movements, increased maintenance costs, increased insurance costs, potential environmental impact and staff not able to attend work. The main operational areas impacted would include goods storage, environmental performance, navigation and berthing and goods handling.

As part of the adaptive measures that CITC have in place there are:

- Underground tanks at CITC petrol station that can be filled with fuel if need be;
- Emergency diesel generators to maintain refrigerated food storage and operate businesses – up to three (3) month diesel supply stored at elevation near the power station; and
- CITC has three (3) months' supply of food and goods stored as a preventative measure.

Notwithstanding this, in the event of an extreme 1:100 year ARI cyclone event similar to that identified in Blacka *et al.* (2013) the adaptive measures may not be sufficient to withstand the event and additional measures may be needed. The primary CITC storages are located behind the supermarket and may be severely impacted with potential exposure to high surge and waves. The same area is utilised for storage of containers which might better be relocated to higher ground in the lead up to a severe cyclone.

6.2.3 Ministry of Infrastructure and Planning (MOIP)

MOIP believed the Port was only somewhat vulnerable to impacts of cyclones as they felt that several of the impacts had been mitigated through the recent redevelopment of the Port and that most moveable infrastructure would be removed from the Port site and placed further inland to higher elevation for protection. The main concerns for the Port were with respect to the reliance on the roads and communication infrastructure. These were rated as a medium concern as it was believed that critical operations could still continue, albeit with reduced efficiency and/or delay.

Overall MOIP stated that cyclones were the main weather event that was most concerning in terms of service disruption. Connected infrastructure with a medium level of reliance on the Port included the power, fuel, food and goods. In regards to connected infrastructure MOIP also stated the following:

- Roads would be out of service for days; bridges would likely be out for even longer. The ring road system provides various alternative routes and there exists reasonable adaptive capacity;
- All infrastructure for fuel is located along the coastline. Accordingly, these are vulnerable, as fuel storage tank destruction is a possibility and these would take several months to rebuild. MOIP noted that fuel and gas supply could be distributed to the island directly from the ship if necessary as an interim measure;
- Water quality would be impacted in a cyclone. However, this is mostly owing to sediment and can be filtered;
- In regards to food supplies, most people will have stocked up with necessary supplies at the beginning of a cyclone season and again at the time of the warning;
- All local agriculture would be destroyed in a Category 5 cyclone; and
- Waste (water and solid) would be impacted as a result of flooding, high rainfall and high winds. This would take some time to rectify.

6.2.4 TRIAD Pacific Petroleum (TRIAD)

Discussion with TRIAD centred around the current processes and mechanisms to respond to events, level of reliance on the Port and adaptive capacity.

TRIAD is reliant on the shipping supply and has concerns about supplies running out. Accordingly, the Port plays a role in that chain of events. Nevertheless, in the event that the Port was shut down, TRIAD has adaptive measures to ensure supply could still be delivered. It would consist of the tanker anchoring immediately offshore of the TRIAD facility (weather dependent) and connecting a floating temporary pipeline from ship to shore - the tanker would bring its own reinforced hose and floats. In addition, if a tanker could not arrive, the storage amount on the island is approximately 57 - 58 days. Storage is important as many industries are reliant on TRIAD including the power station and the use of fuel in the transport distribution of food and goods.

In addition to being vulnerable to Port closures, TRIAD’s pipeline and fuel storage tanks are also somewhat vulnerable to storm surge and cyclones. In 1987 several tanks were severely damaged having been dislodged from their location, the pipeline from the Port was lifted and the beach seaward of the site was heavily eroded. Since that time, mitigation measures including the construction of a coastal protection wall, ensuring all fixed tanks are full and that all road tankers are moved to higher ground prior to a cyclone, are now implemented. It was noted that the fuel storage tanks sit on the ground and rely only on their mass for stability. Additional adaptive measures for storm surge and wave impact in a 1:100 year ARI cyclone as recently described by Blacka *et al.* (2013) may be needed.

6.2.5 Pacific Energy

Pacific Energy relies on the Port for the delivery of petrol, aviation and diesel fuels. Aviation and diesel fuels are transferred from tankers berthed at Avatiu Port via pipeline for storage at Pacific Energy or TRIAD tank storage areas. Petrol is unloaded at the Port from cargo vessels in 30,000 litre tank-tainers which are transferred by road transport. Generally, tankers are scheduled to arrive at the Port every 6 weeks. In the event that a delivery did not occur due to a shipping delay and/or closure of the Port, Pacific Energy has approximately four to six (4 – 6) weeks' worth of fuel/diesel in storage to meet contract obligations. If closure of the Port lasted longer than this, Pacific Energy would need to identify adaptive measures such as rationing supplies to users on the island. This would greatly impact the airport and the tourism industry with significant ramifications for the overall economy.

Several years ago bad weather delayed the delivery of supply which led to storage levels dropping to approximately half normal levels. In 2005 during multiple cyclones it was stated that despite the Port being evacuated on several occasions, there was no interruption to any fuel supply services provided by Pacific Energy. Overall, the vulnerability of Pacific Energy to the port is moderate.

6.2.6 National Environment Service (NES)

Discussion with NES outlined the following key areas of concern in relation to connected infrastructure's reliance on the Port and the vulnerability of the port to climatic events:

- The redevelopment of the Port has mitigated several potential climate change impacts, e.g. sea level rise and some storm surge. Cyclones and high wind still impact the Port and its operations;
- Following a cyclone event NES believed that the port is most reliant on the roads (including bridges and the drainage system) and these would be given priority in post-event clearance;
- Power, communications, water, food, goods and waste services would all be impacted in a cyclone event (e.g. Category 5 event) as well. However, their reliance on the Port is not critical as mitigation measures have been put in place over the years, e.g. prior to a cyclone season people stock up on non-perishable food as this is part of an emergency awareness program; and
- In the event of cyclones and fuel shortages there have been times when fuel has been rationed and this measure of adaptive capacity could be adopted in the future.

Overall, the reliance of the Port on the connected infrastructure was rated by NES to be between low and medium, whereas the reliance of the connected infrastructure on the Port was categorised as high for fuel, power, food and goods, and low for the other connected infrastructure.

6.2.7 Cook Islands Airport Authority

The aviation industry relies on the Port for fuel supply as most jets refuel at Rarotonga airport. JetA1 aviation fuel is stored in tanks at Pacific Energy from where it is delivered to the airport by underground pipeline. Average usage is 20,000 litres of JetA1 fuel per day. Some jets may be able to do a return flight with enough fuel if measures are taken to manage the maximum weight allowances in the event that this would be required. There is a 12-week storage supply of jet fuel to support normal aviation re-fuelling operations in the event that the Port closed or the overall fuel supply ran low.

On-site diesel generators can sustain power if need be to run the whole airport including the control tower, runway lights and arrivals/departure facilities.

Other issues relating to climate change include the height restriction of nearby infrastructure such as cranes on ships in the Port. This is currently managed effectively through regular communication. However, increased sea level rise could have an impact on how often cranes in use at the Port may need to be lowered to meet height restrictions during landing and take-off.

6.2.8 Cook Islands Tourism

According to the tourism industry, cyclones are the major threat to tourism with both direct and indirect impacts linked to the Port. The tourism industry generates 75 % of the Cook Islands GDP and is therefore highly dependent on the Port. Observations were also made as to how dependant the Port is on the tourism industry. For instance, if there was a downtown in tourism, there could be a downturn in the Port's import business as the Port is the main supplier of tourism supplies such as food, alcohol and building supplies.

Notwithstanding this, there have been no incidences of the tourism industry running out of supplies as a result of a climate-related event or Port closure, as supplies are delivered every 18-21 days, and hotels and the like have storage supplies in the event of the a delayed ship or the Port being closed for a period of time. In addition, it was noted that resilience has improved dramatically in recent years with the Port becoming more efficient and being upgraded.

In regards to longer term impacts, it was outlined that there is merit in the port industry and tourism industry meeting regularly to identify climate adaptation needs and future planning horizons. In doing so, the need to factor climate changes into future capacity building in tourism (and the associated reliance on the Port and vice versa) could be captured.

6.2.9 Te Aponga Uira (TAU)

Discussions with TAU centred around how vulnerable the power generator business is to climate change and its reliance on the port for fuel.

At present Pacific Energy has the supply contract for diesel to TAU. TRIAD is contracted by TAU to store the diesel fuel and uses TRIAD fuel tankers to deliver diesel to TAU. TAU has a fuel supply manager located at the TRIAD depot where 1.1 million litres of diesel for the power station is stored in above ground tanks. TAU has diesel storage for 150,000 litres at the power station which uses an average of 20,000 litres per day. Power demand is presently about 4 MW having declined in recent years from an earlier high of 5.2 MW. Power is generated by eight (8) diesel plants of varying capacity and manufacture with an installed capacity of 10.9 MW. Generally only three (3) plants are needed to meet daily demand, providing significant resilience (even when allowing for maintenance and breakdown). The daily demand curve has changed from an evening to an afternoon peak with increased reliance upon air conditioning.

TAU stated there are supply chain risks if there was a disruption to diesel fuel supply arising from extreme weather impacts to the fuel storage areas by the coast or damage/closure of the port. TAU stated that previously there had been two (2) occasions where supply of diesel had become quite low. Accordingly, there is now a contractual agreement that there must be a minimum of one (1) month diesel supply stored in the tanks at TRIAD.

In the event of a cyclone that could damage the Port or fuel/diesel suppliers or other connected infrastructure, TAU noted the following:

- All connected infrastructure and the community are reliant on the Port in some way;
- Contingency measures for the possibility that the TRIAD depot is damaged include filling all road tankers and other storage containers – providing 10 days emergency supply;
- TAU can manage fuel shortage by controlled load shedding. This is a minimisation technique where power is switched on and off to pre-defined areas on timed schedules;
- Power, communications, water, food, goods and waste services would all be impacted by future climate events (i.e. Category 5 cyclone) and although there are adaptive measures, the recovery period would be great and coordination of services and supplies would be required;
- In regards to vulnerabilities, TAU believed the Port had a very high reliance on roads and bridges in the event of a cyclone but only low to medium reliance on all other connected infrastructure; and
- The connected infrastructure had a high to very high reliance on the Port for fuel, power, food and goods.

The Cook Islands government has a progressive Renewable Energy target based on significant incorporation of photo-voltaic solar. With a progressive reduction in power from diesel over the next decade the demand for diesel and the number of tanker movements into the Port will diminish with resultant reductions in Port income. Reduced diesel demand may inadvertently also impact on aviation fuel security as the number of tanker movements reduces.

6.2.10 Telecom Cook Islands

Telecom provides fixed line, mobile phone and internet services across the Cook Islands. The installed fixed line system on Rarotonga is robust with underground copper-wire and fibre optic looped network which has self-healing ability if a section is lost. Two (2) satellite dishes, fixed line switches and mobile 2.5G equipment are located at the Telecom Avarua site. New and replicate systems have and will continue to be located in a new building at the less cyclone exposed site at Aro'a in the west corner of the island – these include two 03B satellite dishes, a back-up geostationary satellite antenna, fixed line switches and upgraded mobile equipment.

In October, prior to the cyclone season, Telecom undertake a safety and performance check of all equipment including satellite dishes and cable tie downs for the mobile phone and radio towers. In the event of an approaching cyclone the satellite dishes at Avarua are locked down with the resultant loss of international voice and internet services. The mobile phone towers survive most cyclones but some may be toppled in an extreme event. Temporary repairs to towers by "bootlegging" can be effected with service recovery within two (2) weeks whilst full tower replacement if required takes three (3) to six (6) months. The importance of the single radio tower in providing mobile radio communications for Emergency services during cyclones emerged during discussions. The radio tower is in a highly exposed location. It was significantly upgraded in early 2012 and additional solar panels and batteries are planned before the end of 2013. This facility can be relied on to support emergency services when most needed.

A widespread impact and loss of service to the mobile phone network arises from loss of power if it extends beyond the six (6) hour battery backup capacity at the towers. Some towers have backup generators to provide some mobile phone coverage in the event of extended power cuts (which can arise as result of damage to the power infrastructure during high winds and cyclones).

Telecom rates its infrastructure and services as being not vulnerable to high wind, rainfall, waves, temperature and sea level rise. In respect to cyclones, with the preparations in place vulnerability to events of the scale of TC Sally is considered moderate (loss of services for hours) whilst vulnerability increases to significant (loss of services for days) for cyclones of the severity of 1:100 year ARI scale predicted by Blacka *et al.* (2013).

Telecom perceptions of the vulnerability of the Port and its operations to extreme climate were consistent with those of the Port – not vulnerable to rainfall and temperature, moderately vulnerable to high winds, high waves and sea level rise and significantly vulnerable to cyclones.

Loss of Telecom provided mobile and internet services during a cyclone has potentially medium impact on port operation for a limited period of time, services being expected to be resumed in hours or days depending on the severity of the cyclone.

The port services have low impact on Telecom operations. However it is noted that Telecom relies on the Avatiu Port for the shipment of equipment into Raratonga and subsequent distribution to the outer islands. The volume of shipping is not large but it is high technology equipment and critical to maintaining and growing communications services across the Cook Islands.

6.3 Summary

The perceptions of vulnerability of the Port and the connected infrastructure vary across the different connected infrastructure providers and stakeholders. The reliance of the Port on the connected infrastructure and vice versa seems to range from low to very high depending on the nature of the connected infrastructure.

WRL's interpretation is a balanced view taking into account the various perceptions and relevant experience of the interviewed stakeholders – more weight being given to views of experienced managers/staff in areas of responsibility:

- The Port has a high to very high reliance on the road (and bridges) in the event of a cyclone but only low to medium reliance on all other connected infrastructure;
- In contrast the connected infrastructure had a high to very high reliance on the Port for fuel, power, food and goods with flow on to aviation, tourism and overall economy and community well-being. Overall, the current means of managing vulnerability and risk to natural hazards is working rather effectively for the Port where the Port is able to respond in a suitable amount of time (notification of cyclones provides a three to four (3 – 4) day lead time) and recover to ensure that impact to operations and connected infrastructure is minimised;
- Accordingly, the adaptive capacity of the Port to future climate related events also seems to be managed well. In particular changes to the Port in the recent redevelopment have

ensured increased navigability, deeper basin allowance and more efficient quay wall alignment, which will be beneficial in the lead up to and recovery from future events. Similar climate proofing of other connected infrastructure is warranted; and

- Notwithstanding this, in the event of a direct hit cyclone or impacts from a near-passing higher category cyclone, e.g. a nominal 1:100 year ARI event as identified in Blacka *et al.* (2013), the capacity of the various infrastructure, businesses and Port to survive such an event and to recover requires further assessment and planning. Significant damage can be expected across all infrastructure with extended losses of service and a long and expensive recovery.

7. Conclusions

An overall approach of applying risk based methodology to identifying current and future climate change vulnerability and risk to ports and connected infrastructure has been developed. This approach has been applied to Avatiu Port and the connected infrastructure in Rarotonga as part of the *Coastal Adaptation Needs for Extreme Events and Climate Change, Avarua, Rarotonga, Cook Islands* Project.

Key findings from the study are :

- Cyclones which are projected to increase in intensity with climate change create the highest risk to port and connected infrastructure;
- The Port's practice of removing all assets (water and land based) from the Port region in face of an approaching cyclone is an effective adaptation response which limits the risk and for 1:20 year ARI TC Sally event operations can be expected to resume within a few days;
- The recent upgrades to the Port (with allowance for sea level rise) have assisted in limiting future damage and risk;
- The Port relies upon the road and bridge infrastructure network but can operate without water, power and communications; and
- In contrast the fuel, power, airport, food and goods and thus tourism and the economy rely heavily upon the port.

New information by WRL (Blacka *et al.,* 2013) on 1:100 year ARI cyclone extreme water levels, wave bores and runup levels that can be expected with climate change are yet to be absorbed by the Port and connected infrastructure managers. High damage and likely destruction of shoreline assets previously believed at moderate risk can be expected.

This case study has advanced knowledge and built capacity in understanding and responding to climate risk amongst key managers and operational staff of the Port and connected infrastructure providers, be they in government or private sector. The importance of engaging with stakeholders has been invaluable in this study and should be considered as a necessary approach in any future climate change adaptation assessments for other Pacific Port projects.

This study has demonstrated the value of the qualitative risk assessment process in raising awareness (from a CEO level through management to operational staff) and the building of adaptive capacity. This report provides a general methodology that can be utilised in Qualitative Climate Risk Assessments for other ports in the Pacific.

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Appendix A: Cook Island Port Authority – Selected Extracts from Asset Register

PORT AUTHORITY - RAROTONGA

FOR THE MONTH ENDED 31/05/2013

	Date of Purchase	Supplie	Color,	Locatic
BUILDINGS				
Fuel Storage				
Harbour Master Building (Green Biosecurity office)				
Gear Store				
Substation				
Canteen Building				
Workshop Building				
New Ports Admin Office				
Shed No. 3				
MOT Building				
New Gate House - container ho	27/07/2012	Macdc	SPWS4769989	
New Fenncing Works from Shec	23/08/2012	Raro Welding		
WHARF STRUCTURE				
Wharf Structure - inc new bollai	7/02/2011	Triad Petroleu	Area n	
Eastern Breakwater				
Western Port Development Stages 1 - 3				
Welcome Cruise Ship Signage	5/11/2010	Simple Signs		

GENERAL PLANT & EQUIPMENT

GPE EQUIPMENTS HEAVY DUTY

GPEE1	1 x Atlas Copco Compressor (portable) on wheels			Green	Worksl
GPEF1	2 x ANSUL Fire Extinguisher in Shed 2				Shed#2
GPEF2	1 x Womald fire extinguisher			CANTEEN KIT	Worksl
GPEF3	Chubb Fire Extinguisher, dry powder				Worksl
GPEF5	1 x 180L solar water heater witl	26/01/2010	Raina Trading/		OFFICE
GPEF6	1 x Petrol Air Compressor	2/08/2011	Tyre Force Ltd		Worksl
GPEF7	1 x Eletric Water Blaster	18/10/2011	diesel Express		Worksl

GPE OTHERS

GPEO1	1 x Pr Container Cleaning Frame	13/10/2008	Rarotonga We	Out wh
GPEO2	1 x Pr Container Cleaning Stand:	18/08/2009	Raro Welding	Out wh
GPEO3	2 X Grass Cutter (Stihl FS120)	26/11/2003	Beco Ltd	Worksl
GPEO4	6 x concrete anchor blocks with 1 x 25m light stand with halogens (ir			
GPEO5	10 x Speed Limit Sign Posts	17/07/2009	Raro Welding	Out wh
GPEO6	7 x Telescopic Cone Barriers for	15/10/2009	CI Fire & Safet	Shed -

GPEO7	8 x Transit Cone with reflective	15/10/2009	CI Fire & Safet	Shed -	
GPEO8	2 x Square Tanks for Rubbish Di:	7/12/2009	Taio Sł	green	Out wł
GPEO9	4 x MENNEKES Power Meter Boxes			Yellow	Office
GPEO10	2 x Portable Toilets	28/10/2004	Wini Pacific		Out wł
GPEO11	1 x Portaloo	28/02/2011	Wini P	Grey	Out wł
GPEO12	1 x Portaloo	28/02/2011	Wini P	Grey	Out wł
GPEO13	1 x Aluminium Ladder - 9 steps	15/03/2011	Vonnia	Grey	Worksl
GPEO14	2 x Gang Way		3 x aluminium		Out wł
GPEO15	1 x Environ portaloo for Raro	1/01/2013	Enviroı	Grey	Out wh
GPEO16	5 x Life Buoy Sets (lifebuoy, 30 I	25/03/2013	Expres	Orange	

STEVEDORING EQUIPMENT

	As per 2004 Revaluation List		
FLTM7	40" Spreader	1/12/2004	Fowler Machinery Lt
FLTM8	20" Spreader	1/08/2006	Fowler Machinery Ltd

FORKLIFTS

FLTM1	Nissan - 3 Ton - NO. 7				
FLTM2	Nissan - 3 Ton - NO. 8				
FLTM3	Nissan - 3Ton - No.6				
FLTM4	18T Luxford Forklift				
FLTM5	35T Kalmar hoist				
FLTM6	32T Omega Hoist				
FLTM9	2003 Hyster 4 container Stackeı	24/09/2009	SG Equipments		
FLTM10	1 X Lonking LG35 Diesel Forklift:	22/11/2012	Alrite :	Engine	50% pa
FLTM11	1 X Lonking LG35 Diesel Forklift:	22/11/2012	Alrite :	Engine	50% pa

VEHICLES

MOVB1	Bike - Yamaha Crypton (100CC)	22/02/2005		Red	OPS
MOVB2	Bike - Yamaha Spark	31/01/2008		Blue	OPS
MOVB3	Bike - Yamaha Vega ZR 4 Stroke	26/01/2011	Pickeri	Blue	Office
MOVT1	Truck - Daihatsu - new tray at I	22/10/2004		Green	OPS
MOVT2	Truck - Isuzu D/Cab	28/02/2006		Grey	Office
MOVB4	1 x new 2012 Yamaha Vega ZR I	11/09/2012	Pickeri	Engine	Chassis

MOVO1	Tugboat	7/07/2009	Raro Welding	
MOVO2	Boat Cradle with wheels			OPS
MOVO3	HAF Liftraft - 6 person	1/12/2012		HM
MOVO4	1 x 4.5 mtr Aluminium Pontoon	7/05/2013	Raro Welding	

WHARF FIXTURES & SERVICES

Electrical Fittings

WFSF1	Shed Switchboard (in Taio Lean to Building)
WFSF2	Distribution board (shed 3)
WFSF3	Distribution board (shed 2)
WFSF4	Water Reticulation
WFSF5	Harbour headlight
WFSF6	Electrical Services - upgraded Office cables May11

Navigation Aids

WFSE1	1 x Solar Marine Lights (Green)	5/02/2009	Sealight Pty Li	Worksl
WFSE2	1 x Navigation Buoy (Green)	5/02/2009	Sealight Pty Li	Worksl
WFSE3	2 x solar powered lights	5/02/2009	Sealight Pty Li	
WFSE4	New navigationa lGreen Bouys	22/09/2012	Reid Technology	

Appendix B: First Pass Vulnerability Assessment Parts A and B

Avatiu Port Authority - Chief Executive Officer

PART A: HOW VULNERABLE ARE PORT ASSETS TO EACH OF THE FOLLOWING CLIMATIC EVENTS?

	Asset or Operation	High Wind	High Rainfall	High Waves	Temperature	Sea Level Rise	Cyclonic Event	Cyclonic Event (Category 5)
		VULNERABILITY OF ASSET OR OPERATION						
Water-Based	Breakwaters	1	1	1-2	1	2	3-5	3-5
	Access/Channel	3	1	3	1	1	2-5	2-5
	Tugboats	3	1	3	1	1	1	1
	[other]							
Interface	Wharves	1	1	2	1	1	2	3
	Slipways	1	1	2	1	1	2	4
	Commercial Fishing Facilities	2	1	2	1	1	3	4
	Recreational Vessel Facilities	2	1	2	1	1	3	4
	[other]							
Land-based	Admin/Office Buildings	1	1	1	1	1	2	5
	Mobile Cranes	N/A	N/A	N/A	N/A	N/A	1	2
	Forklifts	1	1	1	1	1	1	2
	Trucks	1	1	1	1	1	1	2
	Other Plant and Equipment	1	1	1	1	1	1	2
	Storage/Transit Sheds	1	1	2	1	1	2	5
	Open Storage Areas	1	1	1	1	1	1	2
	Stacking Areas (Containers)	1	1	1	1	1	1	2
	[other]							
Connected Infrastructure	Roads	2	2	2	1	1	3	4-5
	Fuel	1	1	2	1	1	3-4	5
	Power	1	1	1	1	1	3	4-5
	Comms	1	1	1	1	1	2	4-5
	Water	1	2	1	1	1	3	4-5
	Food	1	1	1	1	1	3	4
	Goods	1	1	1	1	1	3	4
	Waste Services	1	2	1	1	1	3	4

Rating	Vulnerability Description
1	Not at all vulnerable
2	Somewhat vulnerable
3	Moderately vulnerable (Port operation down for hours)
4	Significantly vulnerable (Port operation down for days)
5	Operation ceased (Port operation down for weeks or more)
N/A	Not Applicable

PART B: VULNERABILITY OF PORT RELATED AND CONNECTED INFRASTRUCTURE

Connected Infrastructure	1. Impact on Port	2. Impact from Port
Roads	High	Low
Fuel	High	High
Power	Low	High
Communications	Low	Low
Water	Low	Low
Food	Low	High
Goods	Low	High
Waste Services	Low	Low

1. How important are each of the connected infrastructure to maintaining port operations?
2. How important are port operations for continued operation of each of the connected infrastructure?

Rating	Impact on Port
Low	All port operations continue largely unaffected
Medium	Critical operations able to continue but with reduced effiency and/or delay
High	Operational ability significantly reduced and port shut-down likely without relief
Very high	Port cannot function without

Rating	Impact from Port
Low	Infrastructure largely unaffected by port downtime
Medium	Infrastructure operations able to continue but with reduced effiency and/or delay
High	Infrastructure operatuions significantly reduced - shutdown likely without relief
Very High	Infrastructure unable to function

Avatiu Port Authority - Port Operations Manager

PART A: HOW VULNERABLE ARE PORT ASSETS TO EACH OF THE FOLLOWING CLIMATIC EVENTS?

	Asset or Operation	High Wind	High Rainfall	High Waves	Temperature	Sea Level Rise	Cyclonic Event
		VULNERABILITY OF ASSET OR OPERATION					
Water-Based	Breakwaters	1	1	1	1	2	3
	Access/Channel	1	1	2	1	1	1
	Tugboats	3	1	4	1	1	4
	[other]						
Interface	Wharves	1	1	2	1	2	3
	Slipways	1	1	2	1	2	4
	Commercial Fishing Facilities	1	1	2	1	2	3
	Recreational Vessel Facilities	1	1	2	1	2	3
	[other]						
Land-based	Admin/Office Buildings	1	1	2	2	3	3
	Mobile Cranes	4	1	2	2	1	4
	Forklifts	1	1	2	2	1	4
	Trucks	1	1	2	2	1	3
	Other Plant and Equipment	1	1	2	2	1	4
	Storage/Transit Sheds	2	2	2	2	2	4
	Open Storage Areas	1	2	2	2	2	3
	Stacking Areas (Containers)	2	2	2	2	2	3
	[other]						
Connected Infrastructure	Roads	1	2	2	1	2	3
	Fuel	1	1	2	1	1	3
	Power	3	1	1	2	1	4
	Comms	3	2	1	1	1	4
	Water	1	1	1	2	2	2
	Food	1	1	1	2	2	2
	Goods	1	1	1	2	1	2
	Waste Services	1	1	1	2	1	4

Rating	Vulnerability Description
1	Not at all vulnerable
2	Somewhat vulnerable
3	Moderately vulnerable (Port operation down for hours)
4	Significantly vulnerable (Port operation down for days)
5	Operation ceased (Port operation down for weeks or more)
N/A	Not Applicable

PART B: VULNERABILITY OF PORT RELATED AND CONNECTED INFRASTRUCTURE

Connected Infrastructure	1. Impact on Port	2. Impact from Port
Roads	Low	Low
Fuel	Low	Low
Power	Medium	Medium
Communications	Medium	Medium
Water	Medium	Medium
Food	Low	Low
Goods	Low	Low
Waste Services	Low	Low

1. How important are each of the connected infrastructure to maintaining port operations?
2. How important are port operations for continued operation of each of the connected infrastructure?

Rating	Impact on Port
Low	All port operations continue largely unaffected
Medium	Critical operations able to continue but with reduced effiency and/or delay
High	Operational ability significantly reduced and port shut-down likely without relief
Very high	Port cannot function without

Rating	Impact from Port
Low	Infrastructure largely unaffected by port downtime
Medium	Infrastructure operations able to continue but with reduced effiency and/or delay
High	Infrastructure operatuions significantly reduced - shutdown likely without relief
Very High	Infrastructure unable to function

Avatiu Port Authority - Harbour Master

PART A: HOW VULNERABLE ARE PORT ASSETS TO EACH OF THE FOLLOWING CLIMATIC EVENTS?

	Asset or Operation	High Wind	High Rainfall	High Waves	Temperature	Sea Level Rise	Cyclonic Event
		VULNERABILITY OF ASSET OR OPERATION					
Water-Based	Breakwaters	1	1	1	1	2	2
	Access/Channel	3	3	4	1	2	5
	Tugboats	4	3	3	2	2	5
	[other]						
Interface	Wharves	2	1	3	2	4	4
	Slipways	1	1	2	1	1	4
	Commercial Fishing Facilities	1	1	1	1	1	1
	Recreational Vessel Facilities	1	1	1	1	1	1
	[other]						
Land-based	Admin/Office Buildings	2	1	2	1	2	4
	Mobile Cranes						
	Forklifts						
	Trucks						
	Other Plant and Equipment						
	Storage/Transit Sheds						
	Open Storage Areas						
	Stacking Areas (Containers)						
	[other]						
Connected Infrastructure	Roads	1	1	1	1	1	1
	Fuel	1	1	1	1	1	4
	Power	1	1	1	1	1	4
	Comms	1	1	1	1	1	3
	Water	1	1	1	1	1	3
	Food	1	1	1	1	1	2
	Goods	1	1	1	1	1	1
	Waste Services	1	1	1	1	1	2

Rating	Vulnerability Description
1	Not at all vulnerable
2	Somewhat vulnerable
3	Moderately vulnerable (Port operation down for hours)
4	Significantly vulnerable (Port operation down for days)
5	Operation ceased (Port operation down for weeks or more)
N/A	Not Applicable

PART B: VULNERABILITY OF PORT RELATED AND CONNECTED INFRASTRUCTURE

Connected Infrastructure	1. Impact on Port	2. Impact from Port
Roads	Low	Medium
Fuel	Low	Med-High
Power	Low	Med-High
Communications	Low	Low
Water	Low	Low
Food	Low	Medium
Goods	Low	Medium
Waste Services	Low	Low

1. How important are each of the connected infrastructure to maintaining port operations?
2. How important are port operations for continued operation of each of the connected infrastructure?

Rating	Impact on Port
Low	All port operations continue largely unaffected
Medium	Critical operations able to continue but with reduced effiency and/or delay
High	Operational ability significantly reduced and port shut-down likely without relief
Very high	Port cannot function without

Rating	Impact from Port
Low	Infrastructure largely unaffected by port downtime
Medium	Infrastructure operations able to continue but with reduced effiency and/or delay
High	Infrastructure operatuions significantly reduced - shutdown likely without relief
Very High	Infrastructure unable to function

Avatiu Port Authority - Finance and Administrative Staff

PART A: HOW VULNERABLE ARE PORT ASSETS TO EACH OF THE FOLLOWING CLIMATIC EVENTS?

	Asset or Operation	High Wind	High Rainfall	High Waves	Temperature	Sea Level Rise	Cyclonic Event
		VULNERABILITY OF ASSET OR OPERATION					
Water-Based	Breakwaters	1	1	1	1	1	1
	Access/Channel	3-4	1	3	1	1	4
	Tugboats	N/A	N/A	N/A	N/A	N/A	4
	[other]						
Interface	Wharves	N/A	N/A	2	N/A	N/A	3
	Slipways	1	1	1	1	1	1
	Commercial Fishing Facilities	3	1	3	1	1	4
	Recreational Vessel Facilities	3	1	3	1	1	4
	[other]						
Land-based	Admin/Office Buildings	1	1	1	1	1	2
	Mobile Cranes						
	Forklifts	1	1	1	1	1	1
	Trucks	1	1	1	1	1	1
	Other Plant and Equipment	1	1	1	1	1	N/A
	Storage/Transit Sheds	1	1	1	1	1	3
	Open Storage Areas	1	1	1	1	1	1-2
	Stacking Areas (Containers)	1	1	1	1	1	1-2
	[other]						
Connected Infrastructure	Roads	1	1	1	1	1	1
	Fuel						2
	Power						1
	Comms						1
	Water						1
	Food						N/A
	Goods						N/A
	Waste Services						1

Rating	Vulnerability Description
1	Not at all vulnerable
2	Somewhat vulnerable
3	Moderately vulnerable (Port operation down for hours)
4	Significantly vulnerable (Port operation down for days)
5	Operation ceased (Port operation down for weeks or more)
N/A	Not Applicable

PART B: VULNERABILITY OF PORT RELATED AND CONNECTED INFRASTRUCTURE

Connected Infrastructure	1. Impact on Port	2. Impact from Port
Roads		Low
Fuel		Medium
Power		Medium
Communications		Low
Water		Low
Food		Low
Goods		Low
Waste Services		Low
Gas		Medium

1. How important are each of the connected infrastructure to maintaining port operations?
2. How important are port operations for continued operation of each of the connected infrastructure?

Rating	Impact on Port
Low	All port operations continue largely unaffected
Medium	Critical operations able to continue but with reduced effiency and/or delay
High	Operational ability significantly reduced and port shut-down likely without relief
Very high	Port cannot function without

Rating	Impact from Port
Low	Infrastructure largely unaffected by port downtime
Medium	Infrastructure operations able to continue but with reduced effiency and/or delay
High	Infrastructure operatuions significantly reduced - shutdown likely without relief
Very High	Infrastructure unable to function

Ministry of Infrastructure and Planning (MOIP) - Multiple Participants

PART A: HOW VULNERABLE ARE PORT ASSETS TO EACH OF THE FOLLOWING CLIMATIC EVENTS

	Asset or Operation	High Wind	High Rainfall	High Waves	Temperature	Sea Level Rise	Cyclonic Event
		VULNERABILITY OF ASSET OR OPERATION					
Water-Based	Breakwaters	1	1	2	1	1	5
	Access/Channel	3	1	3	1	1	4
	Tugboats	2	1	2	1	1	2
	[other]						
Interface	Wharves	3	1	3	1	1	4
	Slipways	3	1	3	1	2	4
	Commercial Fishing Facilities	3	1	3	1	1	2
	Recreational Vessel Facilities	3	1	3	1	1	2
	[other]						
Land-based	Admin/Office Buildings	2	1	1	1	1	4
	Mobile Cranes	3	1	1	1	1	2
	Forklifts	2	1	1	1	1	2
	Trucks	2	1	1	1	1	2
	Other Plant and Equipment						
	Storage/Transit Sheds	1	1	1	1	1	4
	Open Storage Areas	1	1	1	1	1	4
	Stacking Areas (Containers)						
	[other]						
Connected Infrastructure	Roads	1	2	2	1	1	4
	Fuel	1	1	2	1	1	5
	Power	2	1	1	1	1	4
	Comms	1	1	1	1	1	4
	Water	1	2	1	1	1	2
	Food	1	1	1	1	1	3
	Goods	1	2	1	1	1	2
	Waste Services	1	3	2	1	1	4
	Solid Waste	3	3	1	1	1	3

Rating	Vulnerability Description
1	Not at all vulnerable
2	Somewhat vulnerable
3	Moderately vulnerable (Port operation down for hours)
4	Significantly vulnerable (Port operation down for days)
5	Operation ceased (Port operation down for weeks or more)
N/A	Not Applicable

PART B: VULNERABILITY OF PORT RELATED AND CONNECTED INFRASTRUCTURE

Connected Infrastructure	1. Impact on Port	2. Impact from Port
Roads	Medium	Low
Fuel	Low	Medium
Power	Low	Medium
Communications	Medium	Low
Water	Low	Low
Food	Low	Medium
Goods	Low	Medium
Waste Services	Low	Low

1. How important are each of the connected infrastructure to maintaining port operations?
2. How important are port operations for continued operation of each of the connected infrastructure?

Rating	Impact on Port
Low	All port operations continue largely unaffected
Medium	Critical operations able to continue but with reduced effiency and/or delay
High	Operational ability significantly reduced and port shut-down likely without relief
Very high	Port cannot function without

Rating	Impact from Port
Low	Infrastructure largely unaffected by port downtime
Medium	Infrastructure operations able to continue but with reduced effiency and/or delay
High	Infrastructure operatuions significantly reduced - shutdown likely without relief
Very High	Infrastructure unable to function

Cook Islands Trading Corporation - General Manager

PART A: HOW VULNERABLE ARE PORT ASSETS TO EACH OF THE FOLLOWING CLIMATIC EVENTS?

	Asset or Operation	High Wind	High Rainfall	High Waves	Temperature	Sea Level Rise	Cyclonic Event
		VULNERABILITY OF ASSET OR OPERATION					
Water-Based	Breakwaters	2	1	2	1	1	4
	Access/Channel	3	1	2	1	1	4
	Tugboats	2	1	2	1	1	4
	[other]						
Interface	Wharves	2	1	2	1	2	4
	Slipways	2	1	2	1	2	4
	Commercial Fishing Facilities	2	1	2	1	2	4
	Recreational Vessel Facilities	1	1	1	1	1	4
	[other]						
Land-based	Admin/Office Buildings	1	1	1	1	1	4
	Mobile Cranes	1	1	1	1	1	1
	Forklifts	1	1	1	1	1	1
	Trucks	1	1	1	1	1	1
	Other Plant and Equipment						
	Storage/Transit Sheds	1	1	1	1	1	4
	Open Storage Areas	1	1	1	1	1	3
	Stacking Areas (Containers)	1	1	1	1	1	3
	[other]						
Connected Infrastructure	Roads	1	1	1	1	2	3
	Fuel	1	1	1	1	2	3
	Power	2	1	1	1	1	4
	Comms	2	1	1	1	1	2
	Water	1	2	1	1	1	3
	Food	1	1	1	1	1	3
	Goods	1	1	1	1	1	3
	Waste Services	1	1	1	1	1	1

Rating	Vulnerability Description
1	Not at all vulnerable
2	Somewhat vulnerable
3	Moderately vulnerable (Port operation down for hours)
4	Significantly vulnerable (Port operation down for days)
5	Operation ceased (Port operation down for weeks or more)
N/A	Not Applicable

PART B: VULNERABILITY OF PORT RELATED AND CONNECTED INFRASTRUCTURE

Connected Infrastructure	1. Impact on Port	2. Impact from Port
Roads	Low	Low
Fuel	Low	High
Power	Low	HIgh
Communications	Low	Low
Water	Low	Low
Food	Low	High
Goods	Low	High
Waste Services	Low	Low

1. How important are each of the connected infrastructure to maintaining port operations?
2. How important are port operations for continued operation of each of the connected infrastructure?

Rating	Impact on Port
Low	All port operations continue largely unaffected
Medium	Critical operations able to continue but with reduced effiency and/or delay
High	Operational ability significantly reduced and port shut-down likely without relief
Very high	Port cannot function without

Rating	Impact from Port
Low	Infrastructure largely unaffected by port downtime
Medium	Infrastructure operations able to continue but with reduced effiency and/or delay
High	Infrastructure operatuions significantly reduced - shutdown likely without relief
Very High	Infrastructure unable to function

National Environment Service (NES) - Multiple Participants

PART A: HOW VULNERABLE ARE PORT ASSETS TO EACH OF THE FOLLOWING CLIMATIC EVENTS?

	Asset or Operation	High Wind	High Rainfall	High Waves	Temperature	Sea Level Rise	Cyclonic Event
		VULNERABILITY OF ASSET OR OPERATION					
Water-Based	Breakwaters						
	Access/Channel						
	Tugboats						
	Combined	3-4	1	3	1	1	5
Interface	Wharves						
	Slipways						
	Commercial Fishing Facilities						
	Recreational Vessel Facilities						
	Combined	3-4	1	3	1	1	5
Land-based	Admin/Office Buildings						
	Mobile Cranes						
	Forklifts						
	Trucks						
	Other Plant and Equipment						
	Storage/Transit Sheds						
	Open Storage Areas						
	Stacking Areas (Containers)						
	Combined	3-4	1	3	1	1	5
Connected Infrastructure	Roads	2	3	3	1	1	4
	Fuel	1	1	1	1	1	3-4
	Power	3	1	1	1	1	4
	Comms	1	1	1	1	1	2
	Water	1	3	1	1	1	3-4
	Food	1	1	1	1	1	4
	Goods	1	1	1	1	1	5
	Waste Services	1	4	4	1	2	4

Rating	Vulnerability Description
1	Not at all vulnerable
2	Somewhat vulnerable
3	Moderately vulnerable (Port operation down for hours)
4	Significantly vulnerable (Port operation down for days)
5	Operation ceased (Port operation down for weeks or more)
N/A	Not Applicable

PART B: VULNERABILITY OF PORT RELATED AND CONNECTED INFRASTRUCTURE

Connected Infrastructure	1. Impact on Port	2. Impact from Port
Roads	Medium	Low
Fuel	Low	High
Power	Low	High
Communications	Low	Low
Water	Low	Low
Food	Low	High
Goods	Low	High
Waste Services	Low	Low

1. How important are each of the connected infrastructure to maintaining port operations?
2. How important are port operations for continued operation of each of the connected infrastructure?

Rating	Impact on Port
Low	All port operations continue largely unaffected
Medium	Critical operations able to continue but with reduced effiency and/or delay
High	Operational ability significantly reduced and port shut-down likely without relief
Very high	Port cannot function without

Rating	Impact from Port
Low	Infrastructure largely unaffected by port downtime
Medium	Infrastructure operations able to continue but with reduced effiency and/or delay
High	Infrastructure operatuions significantly reduced - shutdown likely without relief
Very High	Infrastructure unable to function

Te Aponga Uira (TAU) - Chief Executive Officer

PART A: HOW VULNERABLE ARE PORT ASSETS TO EACH OF THE FOLLOWING CLIMATIC EVENTS?

	Asset or Operation	High Wind	High Rainfall	High Waves	Temperature	Sea Level Rise	Cyclonic Event
		VULNERABILITY OF ASSET OR OPERATION					
Water-Based	Breakwaters						
	Access/Channel						
	Tugboats						
	Port in general assessment	3	1	3	1	1	4
Interface	Wharves						
	Slipways						
	Commercial Fishing Facilities						
	Recreational Vessel Facilities						
	[other]						
Land-based	Admin/Office Buildings						
	Mobile Cranes						
	Forklifts						
	Trucks						
	Other Plant and Equipment						
	Storage/Transit Sheds						
	Open Storage Areas						
	Stacking Areas (Containers)						
	[other]						
Connected Infrastructure	Roads	3	2	3	1	1	4
	Fuel	1	1	2	1	1	4-5
	Power	3	1	3	1	2	4-5
	Comms	3	2	2	1	1	4-5
	Water	1	4	2	1	1	3/4-5
	Food	4-5	2-5 (see note)	1	1	1	4-5
	Goods						
	Waste Services	1	4	4	1	2 Now, 5 Future	4-5

Rating	Vulnerability Description
1	Not at all vulnerable
2	Somewhat vulnerable
3	Moderately vulnerable (Port operation down for hours)
4	Significantly vulnerable (Port operation down for days)
5	Operation ceased (Port operation down for weeks or more)
N/A	Not Applicable

PART B: VULNERABILITY OF PORT RELATED AND CONNECTED INFRASTRUCTURE

Connected Infrastructure	1. Impact on Port	2. Impact from Port
Roads	Very High	Low
Fuel	Low-Medium	Very High
Power	Medium	Very High
Communications	Medium	Low
Water	Low	Low
Food	Low	High - Very High
Goods	Low	High
Waste Services	Low	Low
Waste Services (eg oil)	Low	Medium

1. How important are each of the connected infrastructure to maintaining port operations?
2. How important are port operations for continued operation of each of the connected infrastructure?

Rating	Impact on Port
Low	All port operations continue largely unaffected
Medium	Critical operations able to continue but with reduced effiency and/or delay
High	Operational ability significantly reduced and port shut-down likely without relief
Very high	Port cannot function without

Rating	Impact from Port
Low	Infrastructure largely unaffected by port downtime
Medium	Infrastructure operations able to continue but with reduced effiency and/or delay
High	Infrastructure operatuions significantly reduced - shutdown likely without relief
Very High	Infrastructure unable to function

Appendix C: Qualitative Risk Assessment

Tug Boat
Harbour Master

CLIMATE EVENT	EXISTING RISK[*1] Consequence (Impact)	Likelihood	Risk	YOUR UNDERSTANDING OF FUTURE CLIMATE RISK Consequence (Impact)	Likelihood	ADAPTIVE CAPACITY[*2] Past	Future	PAST HISTORY 10yrs	30yrs	CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3] Consequences	Operational Area(s)	Comments
				Higher Lower No Change	*More Less No Change*	*(See legend below)*				*Consequences (see list below)*	*Operational Area(s) (See list below)*	*Comments*
High Wind (e.g crane safety, navigability)	Moderate	Likely	High	More	-	W	W	High	Medium			
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)	Minor	Possible	Medium	No change	-	W	W	Medium	Low			Difference between large ships and tug visibility (eg only need 2 m from boat/ship)
High Waves (e.g navigability, sea supply chain, breakwaters etc.)	Major	Likely	Very high	More	-	W	W	Very High	High			Redevelopment of port makes a positive difference with respect to surge overtopping and waves
Temperature												
Sea Level Rise												
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Extreme	Possible	Very high	More	-	A	A	Very high	High			

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

Likelihood	Consequence: Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	Medium	High	Very High	Very High	Very High
Likely	Medium	Medium	High	Very High	Very High
Possible	Low	Medium	Medium	High	Very High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences

1a Interruption/halt to logistics operations
1b Interruption to boat movements
1c Increased maintenance costs
1d Deferment of capital expenditure
1e Increased insurance costs
1f Adverse reputational impact
1g Environmental impact
1h Regulatory impact
1i Lost time due to staff or contractor injuries
1j Safety
1k Staff not able to attend work
1l Altered dredging schedule
1m Other business consequences

Operational areas

2a Vehicle Movements Inside Port
2b Demand, Trade Levels and Patterns
2c Goods Storage
2d Environmental Performance
2e Navigation and Berthing
2f Goods Handling
2g Environmental Performance
2h Inland Connected Infrastructure
2i Social Performance
2j Insurance

*Could be multiple (e.g 1a, 1b, 1h)
Please use these and/or other descriptions to comment on the impact of the climate event

Access Channel
Harbour Master

CLIMATE EVENT	EXISTING RISK[*1]			YOUR UNDERSTANDING OF FUTURE CLIMATE RISK		ADAPTIVE CAPACITY[*2]		PAST HISTORY		CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3]		
	Consequence (Impact)	Likelihood	Risk	Consequence (Impact)	Likelihood	Past	Future	10yrs	30yrs	*Consequences (see list below)*	*Operational Area(s) (See list below)*	*Comments*
				Higher Lower No Change	*More Less No Change*	*(See legend below)*						
High Wind (e.g crane safety, navigability)	Moderate	Likely	High	Higher	More	W	W	High	High			Similar adapative capacity over 30 year history until recent port upgrades
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)	Moderate	Likely	High	No Change	No Change	VW-W	VW-W	High	Medium			Non cyclone season, less rain. During cyclone season there is rain. When vessel comes in during heavy rain, cannot see therefore cannot bring vessel in (visibility and therefore safety)
High Waves (e.g navigability, sea supply chain, breakwaters etc.)	Major	Likely	Very high	Higher	More	A	A	Very high	High			Can see that these days high waves are different from 10-20 years ago, waves are higher
Temperature												
Sea Level Rise												
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Extreme	Possible	Very high	Higher	More	A	A	Very High	High			Bad weather outside of hurricane season - seeing it occur outside these times. NB (major) do have existing practice that in advance of a cyclone evacuate whole port of all ships and cargo etc.

Key for Columns above

EXISTING RISK

Likelihood		Consequence: Insignificant	Minor	Moderate	Major	Extreme
	Almost Certain	Medium	High	Very High	Very High	Very High
	Likely	Medium	Medium	High	Very High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Medium	Medium

ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption – work continues as normal)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

CONSEQUENCE(S)

1a Interruption/halt to logistics operations
1b Interruption to boat movements
1c Increased maintenance costs
1d Deferment of capital expenditure
1e Increased insurance costs
1f Adverse reputational impact
1g Environmental impact
1h Regulatory impact
1i Lost time due to staff or contractor injuries
1j Safety
1k Staff not able to attend work
1l Altered dredging schedule
1m Other business consequences

OPERATIONAL AREA(S)

2a Vehicle Movements Inside Port
2b Demand, Trade Levels and Patterns
2c Goods Storage
2d Environmental Performance
2e Navigation and Berthing
2f Goods Handling
2g Environmental Performance
2h Inland Connected Infrastructure
2i Social Performance
2j Insurance

*Could be multiple (e.g 1a, 1b, 1h)
Please use these and/or other descriptions to comment on the impact of the climate event

Wharves
Harbour Master

CLIMATE EVENT	EXISTING RISK[*1] Consequence (Impact)	Likelihood	Risk	YOUR UNDERSTANDING OF FUTURE CLIMATE RISK Consequence (Impact)	Likelihood	ADAPTIVE CAPACITY[*2] Past	Future	PAST HISTORY 10yrs	30yrs	CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3] Consequences	Operational Area(s)	Comments
				Higher Lower No Change	*More Less No Change*	*(See legend below)*				*(see list below)*	*(See list below)*	
High Wind (e.g crane safety, navigability)												
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)												
High Waves (e.g navigability, sea supply chain, breakwaters etc.)	Minor	Possible	Medium	No change	More	W	VW	High	High	-	-	Adaptive capcity: past has been W and in future its VW as a result of new wharf
Temperature												
Sea Level Rise	Moderate	Possible	Medium	Higher	More	W	VW	Medium	Medium	-	-	Existing risk is strongly influenced by wharves being designed and installed for allowances on climate change/SLR
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Major	Possible	High	Higher	More	A	A	High	High	-	-	-

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

		Consequence				
		Insignificant	**Minor**	**Moderate**	**Major**	**Extreme**
Likelihood	**Almost Certain**	Medium	High	Very High	Very High	Very High
	Likely	Medium	Medium	High	Very High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences

1a Interruption/halt to logistics operations
1b Interruption to boat movements
1c Increased maintenance costs
1d Deferment of capital expenditure
1e Increased insurance costs
1f Adverse reputational impact
1g Environmental impact
1h Regulatory impact
1i Lost time due to staff or contractor injuries
1j Safety
1k Staff not able to attend work
1l Altered dredging schedule
1m Other business consequences

Operational areas

2a Vehicle Movements Inside Port
2b Demand, Trade Levels and Patterns
2c Goods Storage
2d Environmental Performance
2e Navigation and Berthing
2f Goods Handling
2g Environmental Performance
2h Inland Connected Infrastructure
2i Social Performance
2j Insurance

*Could be multiple (e.g 1a, 1b, 1h)
Please use these and/or other descriptions to comment on the impact of the climate event

General

Cook Islands Trading Corporation General Manager

CLIMATE EVENT	EXISTING RISK[*1]			YOUR UNDERSTANDING OF FUTURE CLIMATE RISK		ADAPTIVE CAPACITY[*2]		PAST HISTORY		CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3]		
	Consequence (Impact)	Likelihood	Risk	Consequence (Impact)	Likelihood	Past	Future	10yrs	30yrs			
				Higher *Lower* *No Change*	*More* *Less* *No Change*	*(See legend below)*				*Consequences (see list below)*	*Operational Area(s) (See list below)*	*Comments*
High Wind (e.g crane safety, navigability)												
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)												
High Waves (e.g navigability, sea supply chain, breakwaters etc.)												
Temperature												
Sea Level Rise												
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Major	Possible	High	No Change	No change	A	A	High	High	1a - c, 1e, 1g 1k-m	2c, 2d, 2e, 2f	Possible that based on whether it is a direct hit cyclone and includes brekwater rocks rolled into harbour. Note rocks installed approx 5 years ago.

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

		Consequence				
		Insignificant	**Minor**	**Moderate**	**Major**	**Extreme**
Likelihood	**Almost Certain**	Medium	High	Very High	Very High	Very High
	Likely	Medium	Medium	High	Very High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences

- 1a Interruption/halt to logistics operations
- 1b Interruption to boat movements
- 1c Increased maintenance costs
- 1d Deferment of capital expenditure
- 1e Increased insurance costs
- 1f Adverse reputational impact
- 1g Environmental impact
- 1h Regulatory impact
- 1i Lost time due to staff or contractor injuries
- 1j Safety
- 1k Staff not able to attend work
- 1l Altered dredging schedule
- 1m Other business consequences

Operational areas

- 2a Vehicle Movements Inside Port
- 2b Demand, Trade Levels and Patterns
- 2c Goods Storage
- 2d Environmental Performance
- 2e Navigation and Berthing
- 2f Goods Handling
- 2g Environmental Performance
- 2h Inland Connected Infrastructure
- 2i Social Performance
- 2j Insurance

*Could be multiple (e.g 1a, 1b, 1h)

Please use these and/or other descriptions to comment on the impact of the climate event

Overview
Finance and Administrative Staff

CLIMATE EVENT	EXISTING RISK[*1] Consequence (Impact)	Likelihood	Risk	YOUR UNDERSTANDING OF FUTURE CLIMATE RISK Consequence (Impact)	Likelihood	ADAPTIVE CAPACITY [*2] Past	Future	PAST HISTORY 10yrs	30yrs	CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED [*3] Consequences	Operational Area(s)	Comments
				Higher Lower No Change	*More Less No Change*	*(See legend below)*				*Consequences (see list below)*	*Operational Area(s) (See list below)*	*Comments*
High Wind (e.g crane safety, navigability)	Major	Unlikely	Medium	Lower	Less	W	W	-	Higher	-	-	Even in high winds big ships would be asked to leave.
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)												
High Waves (e.g navigability, sea supply chain, breakwaters etc.)	-	-	-	Lower	Less	W	W	-	Higher	-	-	-
Temperature												
Sea Level Rise												
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Major	Possible	High	Lower	Less	A	A	-	Higher	1a-c, 1f-k, 1m	2a-j	High if a ship sinks in the harbour.

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

Likelihood	Consequence: Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	Medium	High	Very High	Very High	Very High
Likely	Medium	Medium	High	Very High	Very High
Possible	Low	Medium	Medium	High	Very High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences
1a Interruption/halt to logistics operations
1b Interruption to boat movements
1c Increased maintenance costs
1d Deferment of capital expenditure
1e Increased insurance costs
1f Adverse reputational impact
1g Environmental impact
1h Regulatory impact
1i Lost time due to staff or contractor injuries
1j Safety
1k Staff not able to attend work
1l Altered dredging schedule
1m Other business consequences

Operational areas
2a Vehicle Movements Inside Port
2b Demand, Trade Levels and Patterns
2c Goods Storage
2d Environmental Performance
2e Navigation and Berthing
2f Goods Handling
2g Environmental Performance
2h Inland Connected Infrastructure
2i Social Performance
2j Insurance

*Could be multiple (e.g 1a, 1b, 1h)
Please use these and/or other descriptions to comment on the impact of the climate event

General Operations Overview
Port Operations Manager

CLIMATE EVENT	EXISTING RISK*1 Consequence (Impact)	Likelihood	Risk	YOUR UNDERSTANDING OF FUTURE CLIMATE RISK Consequence (Impact)	Likelihood	ADAPTIVE CAPACITY *2 Past	Future	PAST HISTORY 10yrs	30yrs	CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED *3 Consequences (see list below)	Operational Area(s) (See list below)	Comments
				Higher Lower No Change	*More Less No Change*	*(See legend below)*						
High Wind (e.g crane safety, navigability)	Moderate	Likely	High	Higher	More	W	W			1a,b,j	2e	Tug boat most vulnerable. High wind - just shut down services/stay in port.
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)	Minor	Possible	Medium	Same	More	VW	W			1a,	2a-j	
High Waves (e.g navigability, sea supply chain, breakwaters etc.)	Moderate	Likely	High	Higher	More	W	A			1a-c,e,j	2a-j	
Temperature	Minor	Almost Certain	High	Higher	More	VW	W			1c,e-h,j	2d,g,i	
Sea Level Rise	Moderate	Almost Certain	Very High	Higher	More	VW	W			1c,e-h,j	2d,g,i	
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Possible	Extreme	Very High	Higher	More	A	A	2005	1987	1a-m	2a-j	Years of cyclones. Lines boat and crane can be done within a day if conditions are ok. Tug can be brought in later if a bigger boat required. Once tug back in water takes about 4 hours to ballast the tug. NB in regards to 2005 cyclone- opened straight away and mess had to be cleaned up. Roofing was an issue that needed to be cleaned up and rocks removed. 1987 cyclone - was like a 100 year cyclone, wiped everything on seaward part of wharf pushed into the harbour (none of it had been removed). Previous failings - all cargo needs to be taken off-site.

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

Likelihood	Consequence: Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	Medium	High	Very High	Very High	Very High
Likely	Medium	Medium	High	Very High	Very High
Possible	Low	Medium	Medium	High	Very High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences	**Operational areas**
1a Interruption/halt to logistics operations	2a Vehicle Movements Inside Port
1b Interruption to boat movements	2b Demand, Trade Levels and Patterns
1c Increased maintenance costs	2c Goods Storage
1d Deferment of capital expenditure	2d Environmental Performance
1e Increased insurance costs	2e Navigation and Berthing
1f Adverse reputational impact	2f Goods Handling
1g Environmental impact	2g Environmental Performance
1h Regulatory impact	2h Inland Connected Infrastructure
1i Lost time due to staff or contractor injuries	2i Social Performance
1j Safety	2j Insurance
1k Staff not able to attend work	
1l Altered dredging schedule	
1m Other business consequences	

*Could be multiple (e.g 1a, 1b, 1h)
Please use these and/or other descriptions to comment on the impact of the climate event

Tug Boat
Port Operations Manager

CLIMATE EVENT	EXISTING RISK[*1] Consequence (Impact)	EXISTING RISK[*1] Likelihood	EXISTING RISK[*1] Risk	YOUR UNDERSTANDING OF FUTURE CLIMATE RISK Consequence (Impact)	YOUR UNDERSTANDING OF FUTURE CLIMATE RISK Likelihood	ADAPTIVE CAPACITY[*2] Past	ADAPTIVE CAPACITY[*2] Future	PAST HISTORY 10yrs	PAST HISTORY 30yrs	CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3] Consequences	CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3] Operational Area(s)	CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3] Comments
				Higher Lower No Change	*More Less No Change*	*(See legend below)*				*(see list below)*	*(See list below)*	
High Wind (e.g crane safety, navigability)	Major	Possible	High	Higher	More	W	VW	High	High - Solid steel tug and underpowered			Safety factor with the wind. Bigger tug would be good, but would not be able to get it out of the water in the event of a cyclone warning. Could you modify the trailer to bring tug on trailer and bring it out up ramp - if so tehn could get a steel body tug. What about if had two tugs (same capacity)? Worthwhile practically for operational capacity but not economically. 30t capacity would allow for towing (not preference)
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)												
High Waves (e.g navigability, sea supply chain, breakwaters etc.)	Moderate	Likely	High	Higher	More	W	VW	High	Very high. Breakwater built approx 27 years ago.			E.g. what was the capacity of the tug (from dredging) - 30t bollard pull
Temperature												
Sea Level Rise												
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Extreme or Minor	Likely	Very high	Higher	More	A	A	High	Very High			Assuming if still in water. Medium - assuming not in the water/off site

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

Likelihood	Consequence: Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	Medium	High	Very High	Very High	Very High
Likely	Medium	Medium	High	Very High	Very High
Possible	Low	Medium	Medium	High	Very High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences
1a Interruption/halt to logistics operations
1b Interruption to boat movements
1c Increased maintenance costs
1d Deferment of capital expenditure
1e Increased insurance costs
1f Adverse reputational impact
1g Environmental impact
1h Regulatory impact
1i Lost time due to staff or contractor injuries
1j Safety
1k Staff not able to attend work
1l Altered dredging schedule
1m Other business consequences

*Could be multiple (e.g 1a, 1b, 1h)

Operational areas
2a Vehicle Movements Inside Port
2b Demand, Trade Levels and Patterns
2c Goods Storage
2d Environmental Performance
2e Navigation and Berthing
2f Goods Handling
2g Environmental Performance
2h Inland Connected Infrastructure
2i Social Performance
2j Insurance

Interface - Slipways and Wharves
Port Operations Manager

CLIMATE EVENT	EXISTING RISK[*1]			YOUR UNDERSTANDING OF FUTURE CLIMATE RISK		ADAPTIVE CAPACITY[*2]		PAST HISTORY		CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3]		
	Consequence (Impact)	Likelihood	Risk	Consequence (Impact)	Likelihood	Past	Future	10yrs	30yrs			
				Higher Lower No Change	*More Less No Change*	*(See legend below)*				*Consequences (see list below)*	*Operational Area(s) (See list below)*	*Comments*
High Wind (e.g crane safety, navigability)												
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)												
High Waves (e.g navigability, sea supply chain, breakwaters etc.)												
Temperature												
Sea Level Rise												
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Moderate	Possible	Medium	Higher	More	A	A	High	High	1b, 1c, 1e	2e	Medium. Fenders - 6 week lead time to delivery and 3 months total to install

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

Likelihood		Consequence: Insignificant	Minor	Moderate	Major	Extreme
	Almost Certain	Medium	High	Very High	Very High	Very High
	Likely	Medium	Medium	High	Very High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences

1a Interruption/halt to logistics operations
1b Interruption to boat movements
1c Increased maintenance costs
1d Deferment of capital expenditure
1e Increased insurance costs
1f Adverse reputational impact
1g Environmental impact
1h Regulatory impact
1i Lost time due to staff or contractor injuries
1j Safety
1k Staff not able to attend work
1l Altered dredging schedule
1m Other business consequences

Operational areas

2a Vehicle Movements Inside Port
2b Demand, Trade Levels and Patterns
2c Goods Storage
2d Environmental Performance
2e Navigation and Berthing
2f Goods Handling
2g Environmental Performance
2h Inland Connected Infrastructure
2i Social Performance
2j Insurance

*Could be multiple (e.g 1a, 1b, 1h)
Please use these and/or other descriptions to comment on the impact of the climate event

Land Based Facilities - (Storage Sheds, Storage Areas, Office)
Port Operations Manager

CLIMATE EVENT	EXISTING RISK[*1]			YOUR UNDERSTANDING OF FUTURE CLIMATE RISK		ADAPTIVE CAPACITY[*2]		PAST HISTORY		CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3]		
	Consequence (Impact)	Likelihood	Risk	Consequence (Impact)	Likelihood	Past	Future	10yrs	30yrs			
				Higher Lower No Change	*More Less No Change*	*(See legend below)*				*Consequences (see list below)*	*Operational Area(s) (See list below)*	*Comments*
High Wind (e.g crane safety, navigability)												
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)												
High Waves (e.g navigability, sea supply chain, breakwaters etc.)												
Temperature												
Sea Level Rise												
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Moderate - Major	Possible	High	Higher	More	A	W	High	Very high	1a, 1c-j	2a-2j	High. Only had one folklift, now have two and have budget for third in next financial year. Would you respond better if had different plant/equipment? - on track with that right now in aiming to have additional plant - more adaptive unit (container handlers, 20ft-40ft spreader, 45t) - therefore greater capacity. Note - storage sheds and facilities more resilient after recent port upgrade.

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

		Consequence				
		Insignificant	**Minor**	**Moderate**	**Major**	**Extreme**
Likelihood	**Almost Certain**	Medium	High	Very High	Very High	Very High
	Likely	Medium	Medium	High	Very High	Very High
	Possible	Low	Medium	Medium	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
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P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences
1a Interruption/halt to logistics operations
1b Interruption to boat movements
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1d Deferment of capital expenditure
1e Increased insurance costs
1f Adverse reputational impact
1g Environmental impact
1h Regulatory impact
1i Lost time due to staff or contractor injuries
1j Safety
1k Staff not able to attend work
1l Altered dredging schedule
1m Other business consequences

Operational areas
2a Vehicle Movements Inside Port
2b Demand, Trade Levels and Patterns
2c Goods Storage
2d Environmental Performance
2e Navigation and Berthing
2f Goods Handling
2g Environmental Performance
2h Inland Connected Infrastructure
2i Social Performance
2j Insurance

*Could be multiple (e.g 1a, 1b, 1h)
Please use these and/or other descriptions to comment on the impact of the climate event

Land Based Equipment
Port Operations Manager

CLIMATE EVENT	EXISTING RISK[*1] Consequence (Impact)	Likelihood	Risk	YOUR UNDERSTANDING OF FUTURE CLIMATE RISK Consequence (Impact)	Likelihood	ADAPTIVE CAPACITY[*2] Past	Future	PAST HISTORY 10yrs	30yrs	CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED[*3] Consequences (see list below)	Operational Area(s) (See list below)	Comments
				Higher Lower No Change	*More Less No Change*	*(See legend below)*						
High Wind (e.g crane safety, navigability)												
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)												
High Waves (e.g navigability, sea supply chain, breakwaters etc.)												
Temperature												
Sea Level Rise												
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Moderate - Major	Possible	High	Higher	More	A	A	High	Very high	1a, 1c-j	2a-2j	High. Only had one folklift in the past, now have two and have budget for third in next financial year. Would you respond better if had different plant/equipment - on track with that right now in aiming too have additional plant - more adaptive unit (container handlers, 20ft-40ft spreader, 45t) - therefore greater capacity. Adaptation to cyclones 30 years ago took about 1 week to remove most/all off port. May not have even removed everything.

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

Likelihood	Consequence: Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	Medium	High	Very High	Very High	Very High
Likely	Medium	Medium	High	Very High	Very High
Possible	Low	Medium	Medium	High	Very High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences
1a Interruption/halt to logistics operations
1b Interruption to boat movements
1c Increased maintenance costs
1d Deferment of capital expenditure
1e Increased insurance costs
1f Adverse reputational impact
1g Environmental impact
1h Regulatory impact
1i Lost time due to staff or contractor injuries
1j Safety
1k Staff not able to attend work
1l Altered dredging schedule
1m Other business consequences

Operational areas
2a Vehicle Movements Inside Port
2b Demand, Trade Levels and Patterns
2c Goods Storage
2d Environmental Performance
2e Navigation and Berthing
2f Goods Handling
2g Environmental Performance
2h Inland Connected Infrastructure
2i Social Performance
2j Insurance

*Could be multiple (e.g 1a, 1b, 1h)

Power and Communications - (Go together as they interact, power supply to the port)
Port Operations Manager

CLIMATE EVENT	EXISTING RISK*1 Consequence (Impact)	Likelihood	Risk	YOUR UNDERSTANDING OF FUTURE CLIMATE RISK Consequence (Impact)	Likelihood	ADAPTIVE CAPACITY *2 Past	Future	PAST HISTORY 10yrs	30yrs	CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED *3 Consequences	Operational Area(s)	Comments
				Higher Lower No Change	*More Less No Change*	*(See legend below)*				*Consequences (see list below)*	*Operational Area(s) (See list below)*	*Comments*
High Wind (e.g crane safety, navigability)	Moderate	Possible	Medium	Higher	More	W	VW	Medium	High	1a, 1i, 1j	2h	
High Wind (e.g crane safety, navigability)						A	W					In relation to Category 5 cyclone and since redevelopment of port
High Rainfall (e.g flash flooding in surrounding districts or site drainage issues)												
High Waves (e.g navigability, sea supply chain, breakwaters etc.)												
Temperature												
Sea Level Rise												
Tropical Cyclone (e.g combination of high winds, waves and storm surge)	Moderate	Likely	High	Higher	More	W	W	Medium	High	1a-m	2b, c, h, j	
Tropical Cyclone (e.g combination of high winds, waves and storm surge)						A	W					In relation to Category 5 cyclone and since redevelopment of port

KEY FOR COLUMNS ABOVE

1. EXISTING RISK

Likelihood	Consequence: Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	Medium	High	Very High	Very High	Very High
Likely	Medium	Medium	High	Very High	Very High
Possible	Low	Medium	Medium	High	Very High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

2. ADAPTIVE CAPACITY

RATING	ADAPTIVE CAPACITY DESCRIPTION
VW	Very well (no significant disruption)
W	Well (minor disruption – normal work resumes in hours)
A	Adequate (moderate disruption – normal work resumes in 3-5 days)
P	Poorly (major disruption – normal work would not resume for weeks)

3. CONSEQUENCE(S) AND OPERATIONAL AREA(S) IMPACTED

Consequences

1a Interruption/halt to logistics operations
1b Interruption to boat movements
1c Increased maintenance costs
1d Deferment of capital expenditure
1e Increased insurance costs
1f Adverse reputational impact
1g Environmental impact
1h Regulatory impact
1i Lost time due to staff or contractor injuries
1j Safety
1k Staff not able to attend work
1l Altered dredging schedule
1m Other business consequences

Operational areas

2a Vehicle Movements Inside Port
2b Demand, Trade Levels and Patterns
2c Goods Storage
2d Environmental Performance
2e Navigation and Berthing
2f Goods Handling
2g Environmental Performance
2h Inland Connected Infrastructure
2i Social Performance
2j Insurance

*Could be multiple (e.g 1a, 1b, 1h)
Please use these and/or other descriptions to comment on the impact of the climate event