CLIMATE CHANGE ASSESSMENT

I. BASIC PROJECT INFORMATION

Project Title:	Nuku'alofa Port Upgrade Project
Project Cost ($ million)**:**	45
Location:	Nuku'alofa, Kingdom of Tonga
Sector:	Transport
Theme:	Water Transport [Nonurban]
Brief Description:	The Queen Salote International Wharf (QSIW) at Nuku'alofa is Tonga's largest port. It handles 85 per cent of all cargo coming into Tonga, the vast majority of Tonga's international sea trade as well as providing a hub for inter-island trade. The project assessed as high risk based on a climate risk screening. A climate risk and vulnerability assessment (CRVA) has been prepared. QSIW is at risk from climate threats, particularly rising sea levels, intensity and frequency of cyclone events, storm surge and extreme rainfall events. These key climate risks will increase under climate futures projected for the Tonga region. Due to its location, the port is also exposed to the ongoing threat of natural disasters such as tropical cyclones, earthquakes and tsunami. The region experiences significant climate variability, and this contributes to the uncertainty in future climate projections.

Source: Asian Development Bank.

II. SUMMARY OF CLIMATE CHANGE FINANCE

Project Financing		Climate Finance	
Source	**Amount** ($ million)	**Adaptation** ($ million)	**Mitigation** ($ million)
Asian Development Bank			
Special Funds resources (ADF grant)	15.0	10.1	4.5
Special Funds resources (ADF grant - Concessional Resources Regional Pool)	30.0	5.0	1.6

ADF = Asian Development Fund.
Source: Asian Development Bank.

III. SUMMARY OF CLIMATE RISK SCREENING AND ASSESSMENT

A. Sensitivity of Project Component(s) to Climate or Weather Conditions and the Sea Level
Output 1 – Existing port infrastructure rehabilitated and
Output 2 – Existing international cargo wharves extended
Wharves (marine works):

- **Sea-Level Rise.** Vessel motions under high sea-level may cause safety issues during berthing and unloading/loading.
- **High-winds.** Inappropriate mooring under high-wind and lack of procedures may result in unsafe operations.
- **Intensity and Frequency of Tropical Cyclones.** Wind and wave forces associated to more intense and frequent tropical cyclones on wharves may cause damages to their structural component requiring regular repairs.

Yard (onshore works):

- **Sea-Level Rise.** Inundation will result in increased incidence of loss or damage of cargo.
- **Intensity and Frequency of Tropical Cyclones.** Wind forces associated to tropical cyclones on landside infrastructure cause damages and temporary disruption of operations to allow recovery.

- **Storm Surge.** Inundation of container yard due to wave overtopping will increase incidence of loss or damage of cargo.
- **Precipitations.** Regular flooding of the yard impacting port efficiency and representing safety hazards with sub-standard electrical services.

Access Road:

- **Precipitations.** Flooding of access roads impacting port efficiency by preventing connection of the yard to the road network.

Output 3 - Port operations and management improved

The development of the asset maintenance plan and trainings on maintenance need to consider changing needs on maintenance given climate changes impacts and the appropriate monitoring of these impacts.

B. Climate Risk Screening

- **Wharves.** The existing wharves length, lack of mooring points and fendering system are preventing the port to accommodate larger ships. Safety and efficiency of the operations are affected under high wind speed and high sea-level. Current Deck level of 2.6m Mean Sea Level (MSL) is adequate for operation to be undertaken with 2070 Sea-level Rise projection. Overtopping of the wharf will happen for storm surge with average recurrence interval (ARI) above 100 year (18% chance by 2040). Cyclones are regularly damaging the existing wharf 1 structure requiring maintenance and repairs.
- **Yard.** Some section of the existing yard level is lower than the wharves by 1m and the eastern revetment of the site is subjected to overtopping under small swell during high tide. Additionally, containers are washed away during cyclone event potentially damaging yard infrastructure. Cyclonic waves and storm surge overtopping the wharves (+2.68m) will potentially result in water been trapped on the yard preventing operations until removal.
- **Access Road.** Existing drainage is not adequate for 200mm monthly precipitation expected during wet season (November to March).

Climate Risk Classification: High

C. Climate Risk and Adaptation Assessment

Methodology

The following approach has been adopted:

- Review of the literature on:
  - climate in Tonga and climate change projections,
  - previous technical investigations and design reports,
  - the impacts of climate change on ports;
- Analysis of available data on climate (temperature and rainfall data), metocean (water levels, waves, local wind) and geophysical hazards to provide current climate and disaster setting and exposure of QSIW. The analysis has been done utilising measured data where possible;
- Undertake targeted metocean monitoring and topographic and bathymetric survey campaigns to fill data gaps and inform the early stages of the project including the climate and disaster setting and exposure of QSIW;
- Internal workshops with the TRTA team and key stakeholders on the existing issues at QSIW, proposed design philosophy, strategic options evaluation, engineering feasibility, and proposed approach to climate resilience;
- Assessments of climate vulnerability and risk for the existing and the proposed port upgrade to identify which elements of the design require specific consideration;
- Incorporation of adaptation measures into the design and assessment of residual climate risk (e.g. due to uncertainty in projections);

Climate Risk Assessment

- **Sea-Level Rise -** A 25-year dataset of hourly water levels recorded at the Nuku'alofa (QSIW) tide gauge was attained through the BoM online data portal. Very high emissions scenario RCP8.5 was used in combination to tide record to define a 0,57m sea-level rise by 2070.

- **High-Wind -** The closest long-term wind record to QSIW has been collected at Fua'amotu International Airport Meteorological Station. Hourly sustained wind speed data since 1993 was obtained from this station. The available sources do not currently provide the climate change projections of wind for the Tonga region. It is therefore not possible to make any meaningful allowance for climate change in the specification of winds for design.
- **Tropical Cyclones -** An extreme value analysis (EVA) was undertaken based on the 1,000-year synthetic tropical cyclone dataset (i.e. the 656 events) to estimate the annual recurrence intervals (ARI) of cyclonic wind speeds. Based on Knutson et al (2010), a 11% wind speed increase expected by 2100.
- **Storm Surge -** A calibrated spectral wave model was used to transform the offshore wave hindcast information from the deep-water offshore extraction point to the port location. The tracks of 48 historical tropical cyclones were used to force the spectral wave model to provide estimates of ARI wave heights. A Surge level of 2.31m MSL is to be adopted for 2070.
- **Precipitations -** The IPSL-CM5AMR model was used as an indicator of the upper limit of rainfall changes. The model projects increasing rainfall into the future with annual rainfall projected to increase by 593mm in 2070.

Adaption measures

- **Wharves –** The existing structures were not designed to withstand additional loads required to provide a higher deck level. The only alternative to provide a raised the deck level was to demolish the existing wharves structures and rebuild them to the adequate level. The current deck level is adequate for 2070 SLR for normal day to day operation. The potential impact of an extreme surge in the long-term is not sufficient to justify the adoption of a costly and very disruptive measure of the existing operations. Allowance for additional load associated with potential future deck level rise to account for storm surge by 2070 will be included in the design of the new structures.
- The current fender system is located around Mean Sea Water level. Under current tide level, this system does not provide adequate support to ships during off-loading operations resulting in excessive rolling motions. Sea level rise will amplify this issue. Adoption of a new fender system with fender panel projecting above the deck was therefore adopted to allow for efficient and safer operations.
- The most efficient measure for the high-winds which consists in providing additional dolphin pilled structures and extending the main wharf was adopted. Alternative measures consisting in lowering the wind speed threshold for operations or installing larger bollards on existing structure will not provide significant improvements and therefore were not to be adopted.
- To mitigate the impact of cyclone on structures, the provision of a breakwater was considered. However, given the orientation of the main berth to the north, the 20m of water depth at the site and the potential obstruction caused to the ship manoeuvring, this measure was not further developed because of its low efficiency and implementation cost.
- Wharf 1 slab and sheet pile wall are regularly damaged by cyclone events due to the orientation of the berth. Upgrade of the deck system and installation of a waler beam system is adopted to provide added resilience. A full refurbishment of the wharf is not required to resist cyclone event and existing substructure will only be protected against further deterioration with installation of a cathodic protection system. The new structures will be designed to accommodate cyclones wind and waves.
- **Yard –** The Eastern side of the yard is the lowest point and there is currently no pavement or drain present at this location. Additionally, the remaining of the yard surfacing is in poor condition and require replacement. The measure adopted consists in adopting a higher level for the new pavement. Inclusion of a new drainage system as part of the pavement will prevent flooding under rain event and overtopping.
- **Seawall –** The level of the existing rock revetment on the Eastern and Northern section is currently too low to provide protection against waves. The measure adopted consists in building a new seawall

(concrete barrier) and adding rocks to the existing revetment. Alternative consisting in extending the existing Naval Base breakwater was not judged efficient and would have constraint the access of Patrol boats.

- Existing substation is in poor condition representing a safety hazard. As part of the measure adopted against cyclone impact, a new building provided will be designed to withstand adequate wind speed.

Access Road – The road will be resurfaced, and an additional surface drain will be provided on the Eastern side of road to prevent ponding and flooding.

D. Climate Risk Screening Tool and/or Procedure Used

The high and medium risks identified in the AWARE report were used as initial framing for the more comprehensive CRVA undertaken in this study. The following climate risk were highlighted from the AWARE tool:

- Sea level rise: High
- Wind speed increase: High
- Onshore Storms: High
- Precipitation increases: Medium
- Air temperature increases: Medium
- Water availability: Low

Source: Asian Development Bank.

IV. CLIMATE ADAPTATION PLANS WITHIN THE PROJECT

Adaptation Activity	Target Climate Risk	Estimated Adaptation Costs ($ million)	Adaptation Finance Justification
Allowance in new structure for future deck level raise	Sea level rise resulting in increased overtopping	1.1	Design of the new wharf extension structure with an allowance from adoption of higher of deck level adequate for 2070 Storm Surge.
New fender system	Sea level rise resulting in unsafe and inefficient operations	1.0	Provide new fender with extended panel providing support above deck level to reduce ship motion for high-tides in 2070.
Raising Yard Level	Sea level rise resulting in inundation	0.1	Raise lowest point of the yard with new pavement for 2070 SLR.
Provision of a Seawall	Sea level rise resulting in inundation	1.8	Top up of existing rock revetment seawall with provision on concrete barrier to provide additional protection against 2070 SLR.
Provide Additional Dolphins	High-Winds resulting in unsafe operations	5.6	Two additional dolphins per wharf providing transverse restrain to the ships against high-winds.
Partial rebuilt of existing wharf 1	Cyclone wind and waves	2.0	Slab replacement and repairs on sheet pile wall and waler beam to provide additional support against waves.
Design New Structures to adequate wind speeds	Cyclone wind and waves	1.9	Marine (wharf extension, dolphins, wharf 1 Deck, gangway) and Onshore (Substation, Reefer towers, Lighting) to be designed to latest codes.
Provide Drainage	Precipitations and Storm Surge	0.9	Adequate drainage to be provided as part of the yard pavement and to be designed for heavy rain

Adaptation Activity	Target Climate Risk	Estimated Adaptation Costs ($ million)	Adaptation Finance Justification
			event and inundation due to overtopping.
Rainwater Harvesting	Drought	0.4	Firefighting system to be collecting rainwater with connection to water main as back-up
Cathodic Protection (CP) system	Sea temperature/ acidification	0.3	CP system install on submerged structures (existing and new) to prevent further damage.

Source: Asian Development Bank.

V. CLIMATE MITIGATION PLANS WITHIN THE PROJECT

Mitigation Activity	Estimated GHG Emissions Reduction [a]	Estimated Mitigation Costs ($ million)	Mitigation Finance Justification
LED Lighting and New Electrical Substation	40 tCO_2e/year	1.3	Provision of additional Masts and replacement of existing lighting with LED and dimmable control. A more efficient cabling and switchgear will be installed part of the refurbishment of the substation and services of the yard. In addition reduction turn around will be achieved through a efficient yard organization achieved by relocation of the substation.
Fuel Tank and new pavement	61 tCO_2e/year	0.3	Double hull tank with consumption monitoring kit will allow implementation of eco-driving strategy. New pavement will reduce roughness which in conjunction with adequate tyre pressure will reduce fuel consumption of handling equipment and trucks.
Wharf 2 Extension	27,989 tCO_2e/year for 2029-2034	4.5 [b]	Provision of additional length of wharf allowing larger ships and therefore larger amount of cargo to bring at once resulting in CO2 emission reduction for ships calling at the upgraded facility.
	40,203 tCO_2e/year for 2035-2037		
	69,465 tCO_2e/year for 2038-2043		
Total	**45,987 tCO2e/year[C]**	**6.1**	

GHG = greenhouse gas, tCO_2e = tons of carbon dioxide equivalent.

[a] Energy savings/year x emission factor = GHG emissions reduction.

[b] Cost of the mitigation measure includes only the section of the extension required to received larger ship which corresponds to 20m only.

[C] Annual average

Source: Asian Development Bank.

VI. ASSESSMENT OF RESIDUAL RISKS AFTER THE PROJECT

Measure	Residual Risk	Measure Cost	Justification Not to Be Included Within the Project
Raising Deck of Existing Wharves against SLR and Storm Surge	None for the wharf – However yard level is still subject to flooding.	30	The current deck level is adequate for 50-year ARI Storm Surge and 2070 SLR. The existing structures will need to be rebuilt if higher Return Period are considered as they were not designed to withstand additional loads associated with a higher elevation.
Lower operational wind speed threshold lower to match existing wharf bollards capacity	Risk of mooring line break if sudden change in wind occurred and no regular monitoring of wind condition.	None	Mitigation measure is not adopted due to low efficiency of the measure and residual risk for the port operators.
Increase existing wharf bollards capacity to provide added restrain to the ship under high-winds	Risk of overloading existing structures if no regular monitoring of wind condition. Current mooring arrangement remains inefficient.	0.5	Mitigation measure is not adopted due to low efficiency of the measure and residual risk for the undersized structure.
Provision of a Breakwater to protect the facility against large waves potentially generated by cyclone.	A breakwater structure could be efficient against cyclonic wave if located directly north of the site. Extension of the existing Naval Base breakwater will not provide any substantial protection.	70	Mitigation measure is not adopted due to water depth (>20m) and obstruction for ship berthing at optimal location. Extension of the existing breakwater will not be efficient, will require a large investment and will affect the access of patrol boat to the Touliki Naval Base.
Raise lowest point of the yard with new pavement and inclusion of adequate drainage system.	Potential for inundation under 50-year ARI Storm Surge remains but yard level and drain system are designed to 2070 SLR to prevent interruption of operation.	0.5	Adaption will lower dust emission at site. Rising the yard level to 100-year ARI storm surge level will be efficient unless if a complete rebuild of the access road is done. Disruption created during construction while be significant as the road is the only mean access to the yard.
Top up of existing rock revetment and provision of a concrete barrier to provide additional protection to the most exposed location.	Seawall will add protection against inundation during high-tide and future SLR. However, the measure will not remove risk of overtopping during cyclone and 100-year ARI storm surge.	2.0	Adaption will provide additional protection against inundation associated with sea-level. This measure in combination with upgrade of pavement and drainage will provide some resilience against cyclone.
Allowance for additional load associated with potential future deck	None for the wharf – However yard level is still subject to flooding.	1.0	Adaption will provide future proofing opportunity to raise the wharf extension level by 2070 if found necessary.

Measure	Residual Risk	Measure Cost	Justification Not to Be Included Within the Project
level rise will be included in the design of the new structures.			
Provide new fender with extended panel providing support above deck level to reduce ship motion at future high-tides.	Inundation of the yard associated with sea-level and high-tide remains.	1.0	Adaption will provide safer operations under 2070 SLR.
High winds/large waves cause safety issues to port staff during berthing, unloading/loading.	The extension to berth 2, additional dolphins and new fender system will significantly decrease any risk during operation.	5.0	Adaption will additionally reduce ship motions during off-loading. In addition, revision and implementation of the existing operational manual will be undertaken.
Excessive wave and wind load on wharf deck structure due to tropical cyclone	Wharf 1 is the most affected marine structure by cyclone due to its exposure and type of construction. Wharf 1 is currently condemned due to deteriorated slab soffit. Design of the new deck system for wharf 1 will be based on latest international standard.	2.0	Adaption will provide a secondary wharf with added resilience against cyclone, minimize post-disaster recovery and routine maintenance.
Marine and Onshore infrastructure) will be designed to latest international standard to provide adequate resilience against cyclone.	Prevalence of forces on structures will not be reduced as there are no protective structures (breakwaters, etc.). However ultimate wind speed threshold will be raised for the new structures and improved for the yard with the inclusion of lashing points.	2.0	Adaption will provide a secondary wharf with added resilience against cyclone and minimize post-disaster recovery. In addition, revision and implementation of the existing operational manual will be undertaken.
Adequate drainage to be provided as part of the yard pavement and to be designed for heavy rain event.	Potential inundation under tsunami and overtopping remains	1.0	Adaptation will additionally include oil separator due minimize impact on environment.
Resurfacing of the access road will include provision of additional drainage, re-grading of road	Potential inundation under tsunami and storm surge remains	0.5	Adaptation will additionally provide safe pedestrian access to site and clearly signed evacuation route.

Measure	Residual Risk	Measure Cost	Justification Not to Be Included Within the Project
surface and cleaning of existing drain.			
Firefighting system to be collecting rainwater with connection to water main as back-up	Minimal – consumption of water within QSIW are primarily based on rainwater with connection to public water as back-up.	0.5	Adaptation will additionally Reduce operating cost.
CP system install on submerged structures (existing and new) to prevent further damage associated with rise of water temperature (ocean acidification)	Efficiency of the measure relies on regular monitoring and routine maintenance been undertaken.	0.5	Adaptation will additionally reduce maintenance cost.
Relocation the port to prevent the facility been isolated during coastal inundation	None for the facility – However the whole north coast of Tongatapu will remain severely impacted.	200	Building of a new facility will be expensive and will be efficient only if road network is raised to provide access during inundation. The scope of this measure is beyond current project boundaries.