Coastal Resilience Project – Tonga

Feasibility Assessment

2023

Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC)

Government of the Kingdom of Tonga

A report prepared for the Government of the Kingdom of Tonga with the technical support of the United Nations Development Programme (UNDP)

Executive Summary

This feasibility study provides the critical background information and guidance that informs the proposal and design for the 'Coastal Resilience Project for Tonga.' The feasibility study examines the current and projected climate change risks and likely impacts to affect the proposed project area, as well as the technical feasibility of proposed solutions to these and their design in the project framework. At the same time, considerations for gender responsiveness, impact potentials, sustainability potentials, and the possibility for transformational change for climate change resilience are included within the feasibility. Still, they are covered in the Annexes to the project proposal.

The Small-Island Developing State (SIDS) and South Pacific Polynesian Kingdom of Tonga comprises around 747km^2 of land across 176 islands, 36 of which are inhabited by a population of approximately 100,179 (TSD, 2021), spread across an estimated combined land and sea area of 720,000 km^2 (World Bank, 2021b). Tonga is one of the most vulnerable countries to climate change and disaster risks, ranking 6th most vulnerable and 5th most exposed (out of 185) globally (UND, 2023). Threats to human well-being and natural ecosystems include increased prevalence of heat waves, intensified cyclones, saline intrusion, wave-driven flooding, and permanent inundation.

Tongatapu is Tonga's most populous island and highest population density, holding around 74% (74,320) of the population (TSD, 2021), which is projected to grow over the next decade with Tongans commonly relocating from the outlying islands to Tongatapu. However, Tongatapu faces significant frequent flooding risks and permanent losses from rising sea levels (SLR) without future adaptation measures. On Tongatapu, there is clear evidence of the impacts of the rise in local sea levels. The permanent losses under a 0.5m SLR scenario are expected to be 6%, and under a 1.0m SLR scenario to be 25% (ADB, 2021a). Tonga has experienced a series of climate disasters in recent years: tropical cyclones Ian (2014), Gita (2018), Harold (2020), as well as non-climate related disasters with the Hunga-Tonga-Hunga-Ha'apai volcano eruption in 2022, which triggered tsunami waves throughout the Tonga archipelago. Combined, climate-induced and non-climate-related disasters affected up to 80% of the population and wiped out between 12% to 40% of the GDP (ADB, 2023c).

The **project objective** is to build the long-term resilience of vulnerable coastal communities to the direct impacts of climate change in Tonga, through an integrated approach that will enable transformational adaptation via climate-responsive and long-term climate risk informed land use and adaptation planning. The project therefore aims to build the long-term resilience of vulnerable coastal communities to the direct impacts of climate change in Tonga and build transformative adaptation capacities through strategic infrastructure work, long-term climate risk informed adaptation planning, and engagement on long-term adaptation solutions.

This objective will be achieved through the three inter-related Outputs. The outputs and associated activities are detailed below:

Output 1 Strengthened knowledge, capacity and engagement for incorporating climate risks into long-term adaptation planning supported through a multi-sectoral, multi-stakeholder engagement and dialogue platform

<u>Activity 1.1. Establish a national multi-stakeholder engagement platform for dialogue on co-creating long-term climate change adaptation strategies and solutions including voluntary retreat.</u>

The project will design a multi-sectoral and multi-actor stakeholder engagement plan and guidelines for a bottom-up national engagement process, by undertaking the following sub-activities:

- Sub-Activity 1.1.1 Design of a multi-sectoral and multi-actor stakeholder engagement plan and guidelines for a bottom-up national engagement process.
- Sub-Activity 1.1.2 Develop a Terms of Reference for a National adaptation planning engagement platform specifying memberships, responsibilities and results
- Sub-Activity 1.1.3 Undertake meetings of the national engagement platform on long-term climate change adaptation as per the Terms of Reference
- Sub-Activity 1.1.4 Develop policy options to incorporate climate resilience and land use principles into national frameworks

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Activity 1.2 Develop village and district level participatory climate risk informed plans

- Sub-Activity 1.2.1 Support a participatory process for developing village and district spatial plans to incorporate climate risk planning and adaptation strategies and incorporating principles of land-use.

Activity 1.3 Build the capacity of local government, village committees and NGOs to integrate climate risks and adaptation needs into community level planning, and inform future Community Development Plans (CDP)

- Sub-Activity 1.3.1 Develop an updated climate-responsive Community Development Plan Guideline to inform the development of future CDPs that includes including participatory vulnerability assessment and planning, gender needs assessment, and adaptation needs assessment and planning.
- Sub-Activity 1.3.2 Design and implement a capacity building package for the Ministry of Internal Affairs on utilising the new climate-responsive CDP guideline
- Sub-Activity 1.3.3 Strengthen capacities of key ministries for climate change risk informed planning and budgeting through trainings and materials
- Sub-Activity 1.3.4 Organize island events (Vava'u, Ha'apai, 'Eua, Tongatapu and Niuas) for sharing lessons for producing climate responsive CDPs

Output 2 Strengthened national and local capacities for effective monitoring and assessment of climate risks

Output 2 addresses the the limited capacity and available data to collect, analyse and use climate risk to inform considered strategic spatial planning and inform adaptation in policy design and decision-making processes regarding land use and coastal management. Four government agencies monitor coastal processes and maintain and manage coastal protection. These agencies, and the Government of Tonga in general, currently need access to the data and expertise to collect, manage, and analyze in-depth data on coastal climate change risks. Therefore, this activity aims to build capacity about climate risk data/interpretation to allow for better-informed coastal adaptation planning.

Activity 2.1 Strengthened mechanism for collecting and analysing data and information for better-informed climate risk monitoring and coastal adaptation planning

- Sub-Activity 2.1.1 Increase capacity of the Government to effectively collect, manage and analyse coastal monitoring data
- Sub-Activity 2.1.2 Collecting, interpreting and using data on climate risks for coastal adaptation planning to produce scenario-based coastal risk maps and knowledge material for use under Output 1.
- Sub-Activity 2.1.3 Improve multi-stakeholder coordination and collaboration on coastal adaptation and planning integrating climate change

Activity 2.2 Improve the knowledge base of multi-sectoral, multi-stakeholders on adaptation planning strategies for long-term resilient planning and transformative adaptation for Tonga based on climate risks and projections

- Sub-Activity 2.2.1 Support the use and interpretation of data collected in Output 2.1 by providing providing easily understood materials for multiple stakeholder types that consider strategic long-term coastal adaptation and inform the national multi-stakeholder adaptation planning engagement platform

Output 3 Reduced vulnerabilities of coastal communities in Hahake to climate hazards through coastal protection measures

Supplementing the work in Output 1 and 2, Output 3 will implement coastal protection measures in the Hahake region of north-eastern Tongatapu Island.

Activity 3.1. Coastal protection measures built along 4km of coastline in Hahake

- Sub-Activity 3.1.1 Detailed design and site-specific assessments of coastal protection measures finalized for Hahake
- Sub-Activity 3.1.2 Construct coastal protection measures in Hahake

Activity 3.2 Sharing of lessons learned and best practices in climate resilient coastal protection measures for scale-up at the national and regional level

- Sub-Activity 3.2.1 Technical evaluations of the design and effectiveness of the coastal protection measures conducted
- Sub-Activity 3.2.2. Production of and publication of a report on lessons learned
- Sub-Activity 3.2.3 Organize an international /regional conference for sharing lessons learned in climate resilient coastal protection and management

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1. Geophysical and socioeconomic risk profile of Tonga

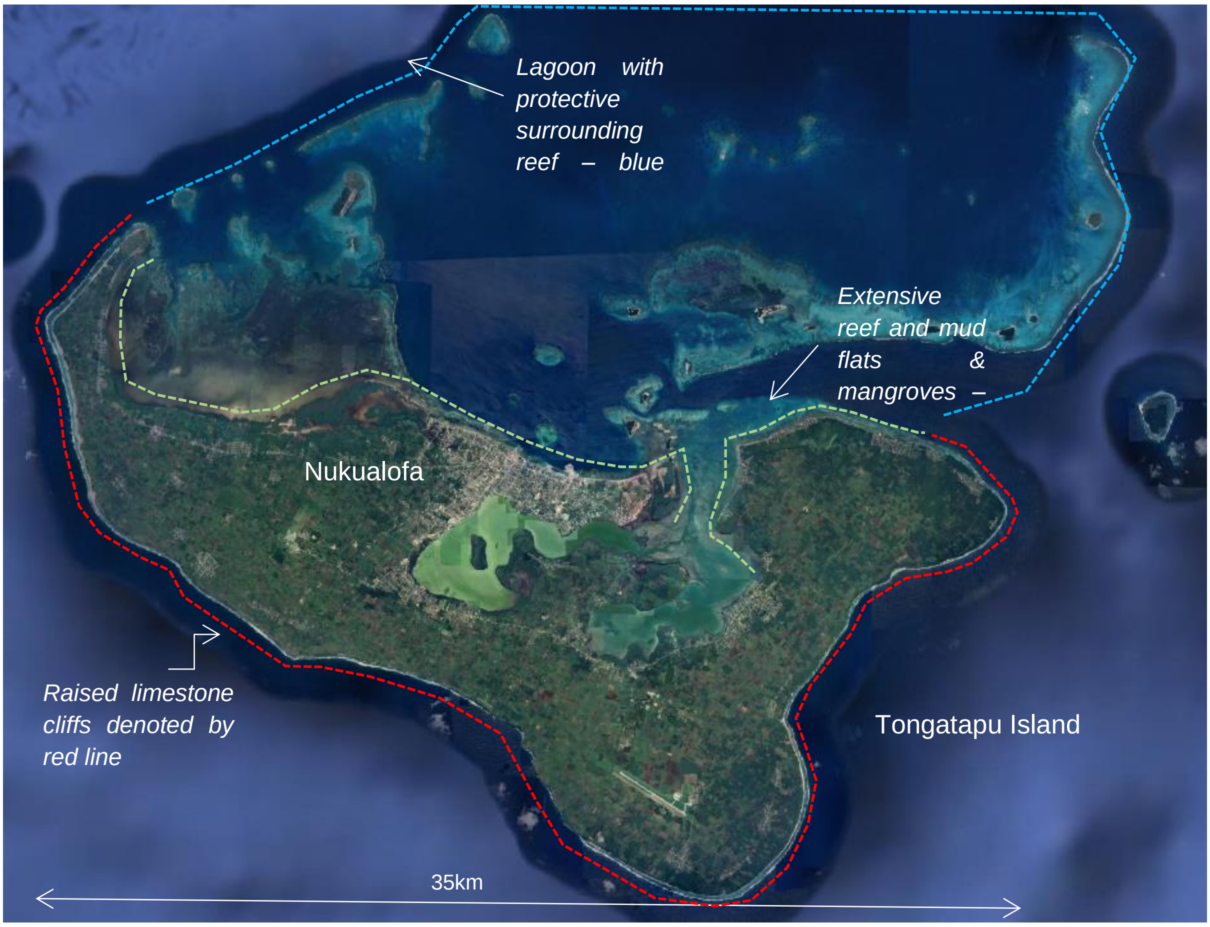
The South Pacific Polynesian Kingdom of Tonga spreads across over 170 small islands, many uninhabited. Located west of its nearest neighbour Niue, east of Fiji, and south of Samoa, Tonga covers around 747km^2 of land area, spread across an estimated combined land and sea area of 720,000 km^2 (World Bank, 2021b). Of the 176 islands, 36 are inhabited by a population of approximately 100,179 (TSD, 2021). Tonga is situated at the subduction zone of the Indian-Australian and the Pacific tectonic plates and lies within the Ring of Fire where intense seismic activities occur. The islands are formed on the tops of two parallel submarine ridges stretching from Southwest to Northeast and enclosing a 50 km wide trough (MEIDECC, 2019). The islands are divided into four main island groups: the Tongatapu group in the south including (74,320); Ha'apai group in the middle (5,665); the Vava'u group in the north (14,182); and the Niuas in the far north (1,148) (TSD, 2021).

Figure 1 Map of Tonga showing Tonga's main island of Tongatapu

1.1 Geographic and geophysical profile

The islands of Tonga are a mixture of geologically young steep volcanic islands, some of which remain so volcanically active they are ephemeral and uninhabitable (e.g., Hunga Tonga Island). The islands in Tonga are a mix of uplifted coral limestone (uplifted atolls), which may be capped with volcanic ash layers producing deep fertile soils. In contrast, others are steep, mountainous and volcanic in origin. Many of the nearshore communities are located on comparatively low-lying, marine hazard exposed land, exemplified by the national capital Nukualofa. Several volcanoes, some of which are still active, exist along the western ridge, while many coral islands have formed along the eastern ridge, amongst them are the Vava'u and Ha'apai island groups. Coral islands are in two categories, the low (true atoll islands) and raised coral limestone islands. (World Bank, 2021a). The geological history of Tonga is complex. Tongatapu Island with the capital Nuku'alofa, is a good example of this complexity; it is a former low-lying atoll that has been raised and tilted down towards the north (Schofield, 1967). The tilting has resulted in today's landscape consisting of a relatively flat island surface with inaccessible steep limestone cliffs tens of meters high on the southern shores and gradual shallowing towards the northern shoreline. However, the northern shore land/sea boundary differs as very low laying swampy nearshore land, protected by a large shallow lagoon and characterised by extensive intertidal reef and mud flats and mangrove wetlands.

Figure 2 Landform features of Tongatapu (showing also the location of the national capital Nuku'alofa on the low laying northern shore)



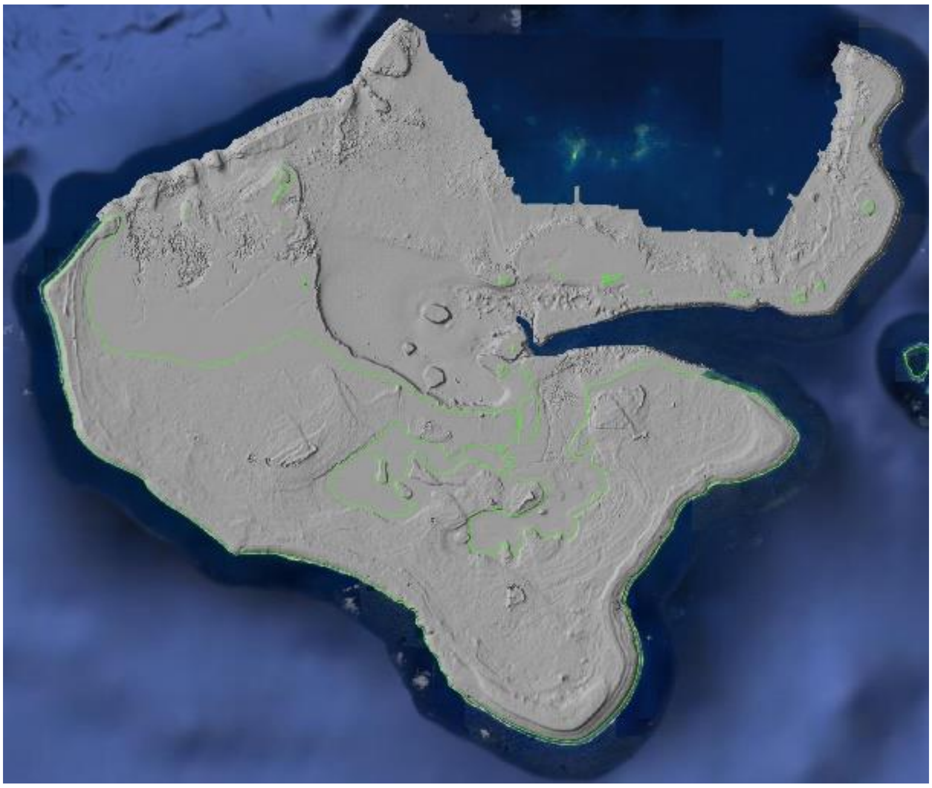
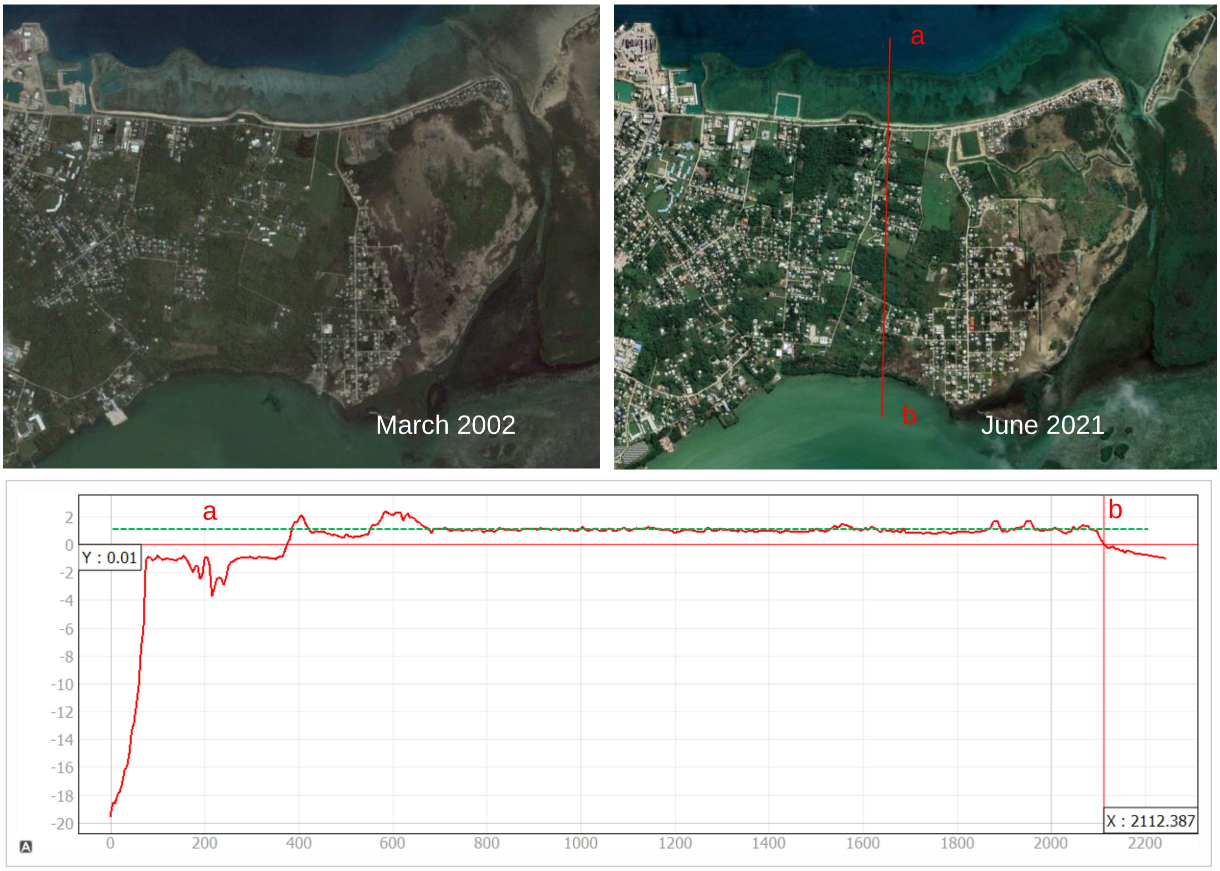


Figure 3 2016 LiDAR survey of Tongatapu Island

The green line denotes the island's shoreline. Note the raised land and steep cliffs to the south, southeast and southwest. In comparison, there is an imperceptible transition from land to sea on the northern shoreline, emphasizing the extremely exposed nature of the northern lagoon shore where over 50% of the National population is situated.

Figure 4 Land elevations of Tongatapu Island's Nuku'alofa (western side).



The images above show the western expansion of Nukualofa urban area with settlements, housing and infrastructure increasingly encroaching into mangrove wetland areas between 2002 and 2021. The red line in the image on the right (a – b) is a cross section transect, which shows the height (with sea level at '0') using the 2016 LiDAR topography data. Zero on the vertical axis (0 – red horizontal line) is equivalent to mean sea level (MSL).

The transect above (line a – b in the western side of Nuku'alofa) is typical of land elevations throughout Tonga's capital, Nuku'alofa and shows the extremely low laying nature of the north coast of the Island of Tongatapu. The tidal range at Tongatapu is 1.8m (BoM, 2023a), meaning clear weather tidal extremes will already reach close to the 1m level shown at the top of the graph (green line), this extremely marginal land height is a common feature throughout Nukualofa. Thus rising sea level, wave height or more intense rainfall can only increase the frequency, extent and damage caused by flooding into the future, and increase the incidence of over-topping in some sections of the coast line.

1.1.1 Reef mediated shoreline systems

The islands of Tonga have a mixture of both *hard* and *soft* shoreline systems that are either stable or dynamic systems accordingly. The hard shores are characterised by either raised limestone or volcanic cliffs and in some cases have narrow reef platforms (at approximately MSL) on their seaward edge. Where these hard reef platforms occur, they may have living coral reef ecosystems on their subtidal seaward slopes, which may influence wave energy. Correspondingly, Tonga's white sand, soft shoreline systems, are reef mediated shoreline systems that are often associated with low-lying depositional landforms where both the land and beach are comprised of once-living reef debris. Soft shorelines are often characterised by wider reef platforms or lagoons between the outer reef edge and the island shore. In these situations, deep ocean wave energy is controlled and mitigated by the outer fringing or barrier reef/lagoon systems.

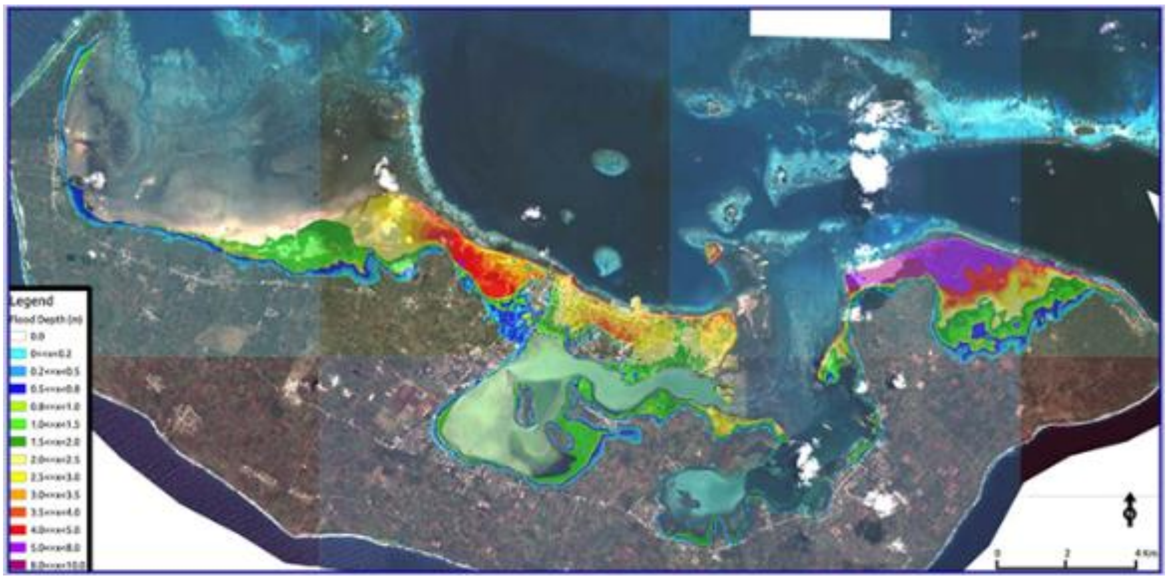
Reef-mediated shores occur throughout the Tongan archipelago and are frequently favoured as village settlement sites. Many of Tonga's islands have a mixture of shoreline types but nearly all of the inhabited islands of Tonga are at least in part dependant on uninterrupted reef structure and productivity to maintain their protective functional shorelines. Whilst such are entirely dependent on living coral ecosystems, any change in reef health, structure, productivity, or composition can potentially disturb sediment supply and/or wave energy, which can cause rapid change in shoreline function and position. Globally, reef systems are under increasing pressure due to climate change related sea surface temperature increase (coral bleaching) and ocean acidification and it follows that natural reef mediated shorelines are expected to become less capable of protecting islands as such stress increases. This is at a time when sea level rise and potential changes in storm intensities mean natural shoreline function is more important than ever.

1.1.2 Volcanism and tectonic hazards coupled with climate change

The islands of Tonga are associated with the Tonga-Kermadec Ridge and Tonga Trench, which is a large submarine subduction zone and also one of the fastest moving and most tectonically active on Earth, forming part of the “Pacific Ring of Fire” of intense seismic activity. Tonga has several active sites of volcanism, and is subject to frequent tremors and earthquakes. Individual and island groups have been subject to tectonic uplift, subduction and tilting, however, limited monitoring infrastructure make evaluation of these dynamics very hard to determine.

Tsunami inundation modelling shows that Tonga’s islands are critically exposed to tsunamis given their location along the Tonga Trench. Tsunami modelling undertaken for Tongatapu Island in 2011 (Damlamian et al., 2011) and then in 2021 (Borrero et al., 2021) shows that tsunami is also likely to impact the northern coastal areas of Nuku’alofa, and particularly Nukuleka, Talafo’ou, Navutoka, Manuka and Kolonga. Though not directly related to climate change, tsunamis pose an additional coastal hazard that is exacerbated by sea level rise and requires a similar adaptive response. In this regard there are significant co-benefits from sound coastal adaptation in response to climate change. Ultimately, long-term adaptation to sea level rise and coastal hazards associated with climate change will also assist in reducing exposure to tsunami in Tonga.

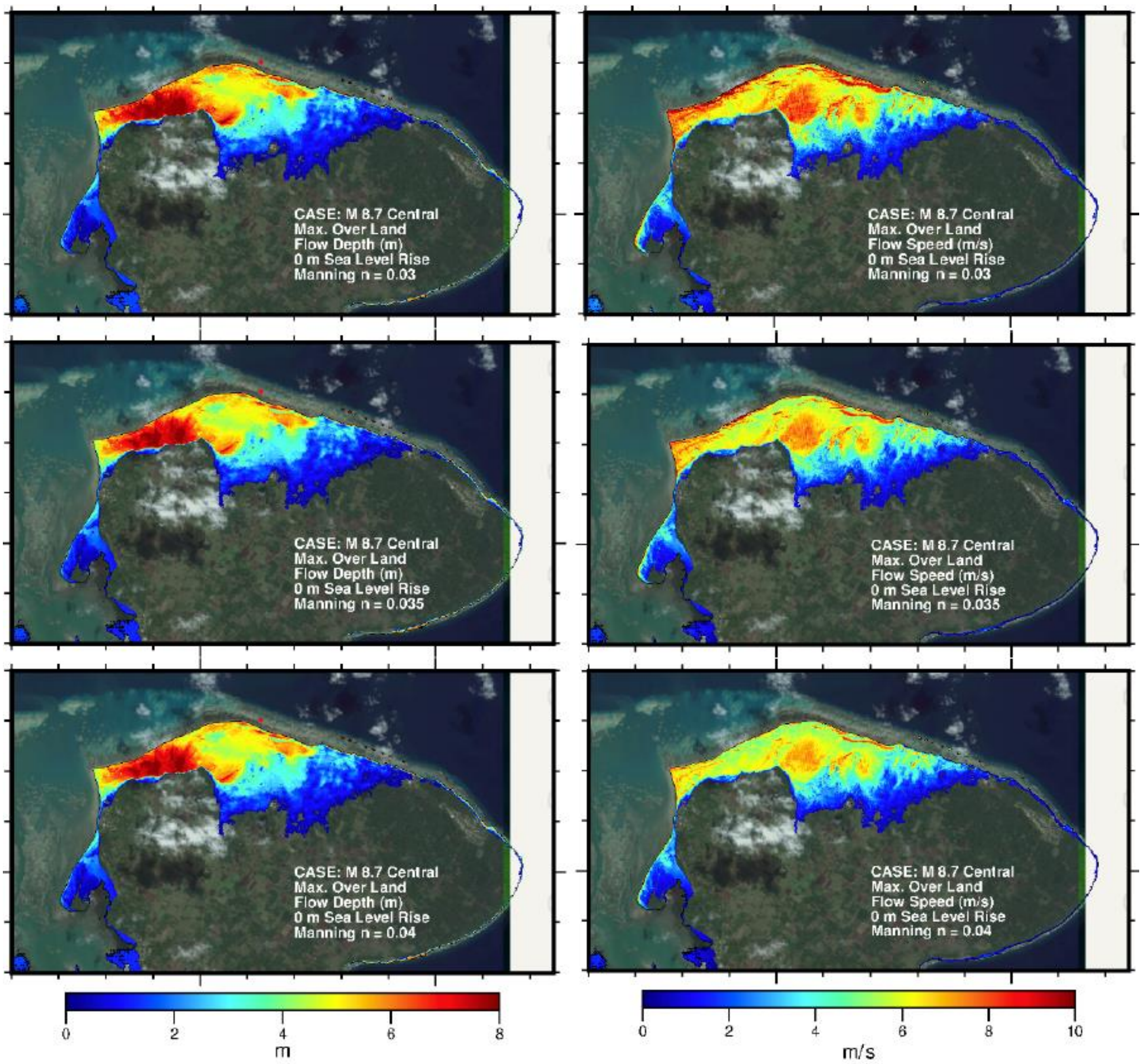
Figure 5 Inundation modelling of Tongatapu for a magnitude 8.7 tsunamigenic earthquake occurring in the Tongan Trench directly east of the island



Source: (Damlamian et al., 2011)

The figure below shows modelling outcomes for the eastern side of Tongatapu with maximum tsunami flow depth on the left and flow velocity over land on the rights, for Manning friction values of 0.03, 0.035 and 0.04 (top to bottom) for the eastern part of Tongatapu Island.

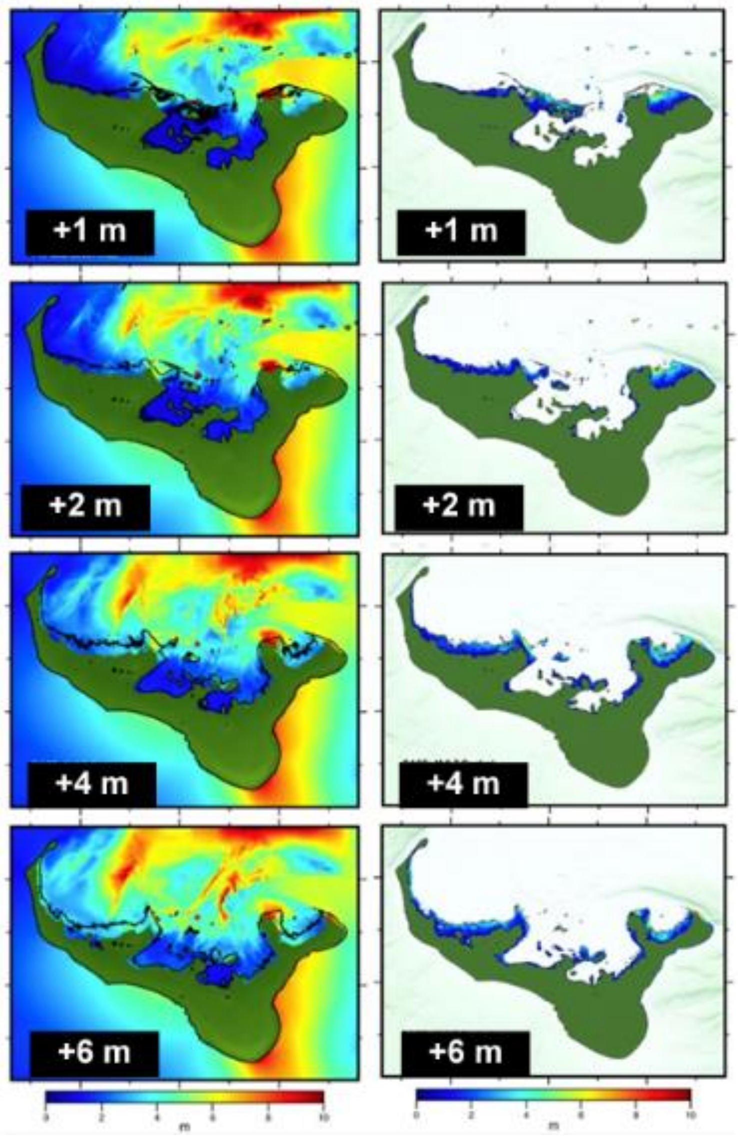
Figure 6 Maximum tsunami flow depth overland with flow velocity for eastern Tongatapu with an 8.7MW earthquake



Source: (ADB, 2021b)

When combined with predicted levels of sea level rise (SLR), tsunami modelling shows severe inundation potential throughout much of Nuku'alofa and the northern coast. The below figure shows these predicted impacts according to modelling for four sea level rise scenarios with tsunami heights generated of either +1m, +2m, +4m and +6m. The maximum tsunami amplitude is shown on the left, and the overland flow depth on the right, for an 8.7 magnitude earthquake.

Figure 7 Maximum tsunami amplitude and overland flow depth considering sea level rise (SLR) for a magnitude 8.7 earthquake



Source: (Borrero et al., 2021)

Critically, Tonga's seismological activity resulted in the January 2022 violent eruption of the Hunga Tonga-Hunga Ha'apai submarine volcano 65km north of Tonga's capital Nukuʻalofa, which produced a tsunami affecting Tongatapu and other islands of Tonga, as well as affecting Fiji, American Samoa, Vanuatu, New Zealand, Japan, the US, far-eastern Russia, Chile and Peru. Hunga Tonga–Hunga Haʻapai's plume reached a peak height of 58kms into the atmosphere and sustained heights greater than 30km. The eruption generated ocean-wide tsunamis, never before recorded in the Pacific instrumental record, and which were also undetected by tsunami warnings, given that volcanically generated tsunamis still remain a 'blind spot' in our understanding of tsunami hazards (Terry et al., 2022). Tsunami waves with run-up heights up to 45m struck the uninhabited island of Tofua in Tonga, and a 1.2m tsunami struck Nuku'alofa on Tongatapu (BoM, 2022).

The tsunami and ashfall following the eruption directly affected 85 per cent of the Tongan population, causing widespread damage to houses, schools, roads, and power and water supply networks (World Bank, 2023). In terms of loss and damage, the damage to the economy from the eruption and tsunami was estimated to be equivalent to US$182 million (approximately 421 million Tongan *Pa'anga*), or more than 36 percent of Tonga's GDP (World Bank, 2023). According to World Bank with the Government of Australia and Tonga phone surveys in April-May (World Bank, 2022a) and July-August (World Bank, 2022b) 2022, the tsunami disrupted livelihoods and access to health care; food insecurity, and loss of assets, where Tonga's poorest and most-vulnerable families were hit the hardest (World Bank, 2023).

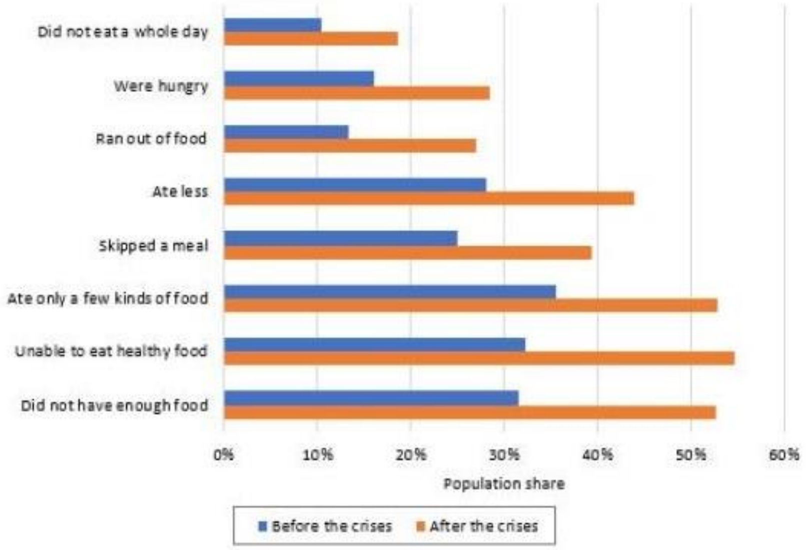


Figure 8 Hunga Tonga-Hunga Ha'apai tsunami's immediate impact on food security

Overall, 2507 people (770 men and 828 women, 390 boys and 351 girls along with 168 babies under the age of 5) were directly affected by the tsunami generated by as a result of the HTHH volcanic eruption (NEMO, 2022).

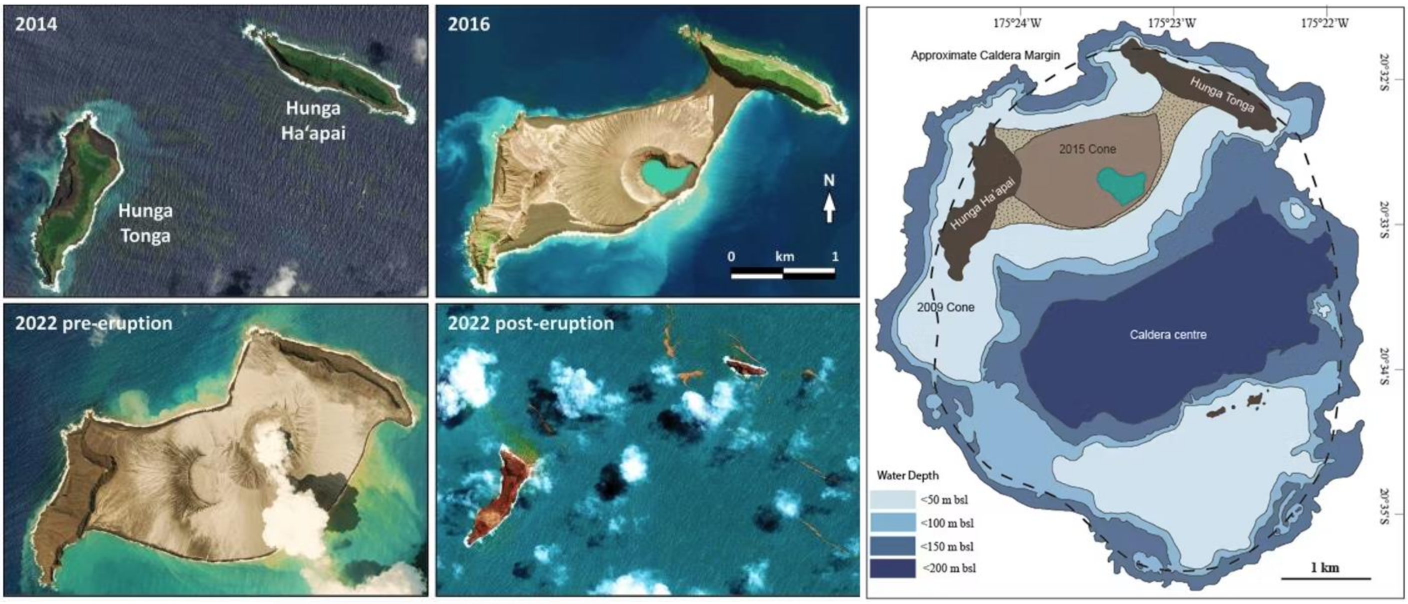
Source: (NEMO, 2022)

Among the affected people were identified total of 61 people, 18 female and 43 male as having some form of disability. There were four deaths (3 females and 1 male) reported, three as a direct result of the tsunami, and one reported as due to the trauma of the event and 10 people were officially reported injured (NEMO, 2022). The tsunami also displaced coastal communities throughout Tongatapu, 'Eua and Ha'apai who evacuated their homes for safer areas, with around 1.9% of the total Tonga population displaced immediately following the event (NEMO, 2022).

The tsunami waves largely affected the western coastal areas of Tongatapu and Ha'apai divisions, with Mango Island (Ha'apai) and 'Atataa Island displace, residents relocated to Tongatapu (NEMO, 2022), while 'Eua, Vava'u and Niuas were less affected (FAO, 2022). In total 29 houses were damaged and1,525 people were displaced by the impacts of the volcanic eruption and resulting tsunami (OCHA, 2022). Of the houses affected or damaged, the majority (174) were in Tongatapu, followed by 'Eua (75), Fonoifua and Pangai (16 each) and Mango (12). Limited flooding affected 3.5 percent of the total land area in the four priority divisions inundated in the days immediately following the tsunami (FAO, 2022). These households were based in low lying coastal areas and low lying islands. Out of total damaged houses, 113 houses, around 35%, are women headed houses (NEMO, 2022).

Prior to the 2022 explosion, the Hunga Tonga-Hunga Ha'apai volcano rose only 100m above sea level, however, was a massive volcano, around 1800m high and 20km wide. The Hunga Tonga-Hunga Ha'apai eruption was possibly equivalent to VEI 5, therefore of an order of magnitude greater than the 1991 eruption of Pinatubo in the Philippines and potentially represents the largest submarine eruption since Indonesia's Krakatau eruption in AD 1883 (Terry et al., 2022).

Figure 9 Changes in the Tonga-Hunga Ha'apai volcano from 2014



Source: Adapted from (Terry et al., 2022) and (Cronin, 2022)

The 2014/15 eruption created a volcanic cone, joining the two old Hunga islands to create a combined island about 5km long island (Cronin, 2022). Although the Hunga Tonga-Hunga Ha'apai volcano has previously erupted, these eruptions were dwarfed compared to the January 2022 eruption. The two earlier eruptions on December 20, 2021, and January 13 2022, were of moderate size. They produced clouds of up to 17km elevation and added new land to the 2014/15 combined island (Cronin, 2022). Of note is also the May 3, 2006 earthquake with Magnitude 8.0 (USGS, 2006) that occurred approximately 100 km northeast of Nuku'alofa along the Tonga Trench Subduction Zone. The earthquake only caused minor damage to Tongatapu but caused moderate damage in the Ha'apai Islands to the north, including the destruction of a hospital. This earthquake also caused the island of Lifuka (Ha'apai's main population centre) to subside by 230mm (Cummins et al 2006). The 2006 study expected this was a rare event and had reason to expect the island may "rebound" to its former elevation. Still, if not, approximately 40 years' worth of sea level rise (at current local rates) occurred instantaneously. These impacts from seismological events highlight the complexities of disaster impacts and the need for efforts to build greater resilience to events to tackle both climate and non-climate-induced threats. In the case of Tonga, addressing climate-related marine hazards in Tonga as adaptation strategies has co-benefits when well-considered and designed and assists in reducing exposure to seismological hazards.

The last large damaging tsunami prior to Hunga Tonga-Hunga Ha'apai, was caused by the 2009 Samoan Earthquake (29th September 2009), which impacted the northern island of Niuatoputapu. Tsunami wave flow heights from this event were estimated between 4 and 7m above mean sea level on Niuatoputapu (see below) and depending on location extended up to 500m inland from the shore (Clarke et al. 2019), it caused widespread destruction and loss of life.

1.2 Demographic profile and migration

Tongatapu is Tonga's most populous island, with the highest population density. Of Tonga's total population of 100,179 people, around 74% (74,320) reside on Tongatapu Island, approximately half of which are concentrated within Tonga's capital city in the greater Nukualofa area (TSD, 2021). The Island of Tongatapu has the largest land area of Tonga's islands (approximately 270km^2) and given the location of the main city of Nuku'alofa, Tongatapu also has the largest accumulation of built assets and infrastructure, including the main airport and seaport. Despite being a raised atoll, Tongatapu Island is agriculturally highly productive land with an upper layer of volcanic soils derived from ancient volcanic ash falls.

Of 31,000 employed in the country, approximately 19.4 per cent work in agriculture, 30.9 per cent in industry and 49.8 per cent in services. However, remittances from families overseas (most often in Australia and New Zealand) have been the largest contributor to Tonga's Gross National Product and are a major source of its foreign exchange year-by-year (Base, 2022). In Tonga, the number of workers participating in the seasonal schemes in Australia and New Zealand is so considerable that it has led to a shortage of agricultural labour in some sending communities, especially during peak harvest times (IOM & ILO, 2022). However, remittances are critical to strengthening resilience at the household, community and national levels and potentially constitute an alternative source of climate finance to build climate-resilient houses, improve the general quality of houses, purchase water tanks, improve seawalls at their property, and increase the overall resilience of households as well as climate-proof community infrastructure (IOM & ILO, 2022). Still, while international migration (out of Tonga) is significant, with the Tongan diaspora estimated to be 126,540 (more than the population residing within Tonga) (TWG MSDP, 2021), the population continues to grow with an annual average population growth of 0.3 per cent per annum over the last decade (ILO, 2022).

The population of Tongatapu is projected to grow over the next decade, with Tongans commonly relocating from the outlying islands to Tongatapu. While all forms of internal migration occur in Tonga (rural to urban, rural to rural, urban to rural and urban to urban) the predominant trend in Tonga (and indeed globally) is rural to urban (TWG MSDP, 2021). Comparisons from the 2016 Census data, for example, showed this trend of in-migration (11,153) to be far greater than out-migration (3,717). While in Vava'u, in-migration (1,713) was much lower than out-migration (6,039), and a similar trend was found in Ha'apai in-migration (1,551) and out-migration (5,003), 'Eua in-migration (1,739) and out-migration (1,535) and Ongo Niua in-migration (382) and out-migration (244) (TWG MSDP, 2021). Paid work, education, health care and other opportunities associated with the capital city, drive relocation from other less well-developed or productive parts of the archipelago. At the same time, communities from other smaller, low-laying islands and settlements are expected to be increasingly challenged by meteorological-ocean hazards associated with climate change, which in turn is expected to drive relocation increasingly. Displacement has also been an issue due to disaster impacts, and is likely to continue, with significant and long-term displacements clearly requiring multi-stakeholder and cross-ministerial response in the delivery of public services and the management of community interests and expectations. Before the 2022 tsunami, the need for government agencies to plan for the continued increase in the population of Nukualofa and Tongatapu and the implications of internal migration shifts for land use, spatial planning, housing and Government services was well-noted within Tonga's Migration and Sustainable Development Policy (TWG MSDP, 2021). At the same time, aside from fast-hitting climate and non-climate related disaster events, climate-induced slow onset processes like coastal erosion, ocean acidification and other forms of environmental degradation in the medium term will drive both forced and voluntary internal movements in Tonga (TWG MSDP, 2021). In extreme cases, destruction of habitat and agricultural viability reduces the prospects for return to the home environment and increases the impetus for long term internal and/or outward migration which may also be perceived as displacement (TWG MSDP, 2021). The influx of new settlers to Tongatapu is resulting in ever greater strain on land resources around the capital Nukualofa and increasing patterns of settlement into marginal, low-lying and highly flood exposed areas.

1.2.1 Economic profile

World Bank data shows that Tonga has one of the world's smallest economies, as measured by GDP (World Bank 2023, 2023).

Table 1 World's smallest economies ranked by GDP

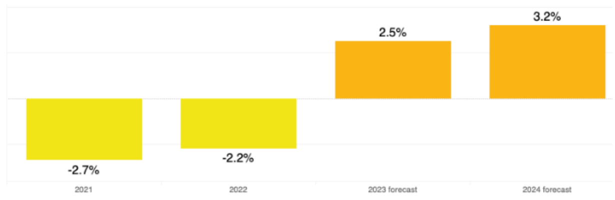
GDP (current US$) ranked from smallest		
Country	**Most recent Year**	**Most recent value (millions)**
Tuvalu	2022	60.35
Nauru	2022	150.92
Palau	2021	217.80
Kiribati	2022	223.35
Marshall Islands	2022	279.67
Micronesia (FSM)	2022	427.9
Tonga	**2021**	**469.23**
Sao Tome and Principe	2022	546.68
Dominica	2022	612.05
American Samoa	2021	709

Source: Adapted from (World Bank 2023, 2023)

As noted in Section 1.2, remittances have been the largest contributor to Tonga's Gross National Product and a major source of its foreign exchange year-over-year (Base, 2022), comprising around USD 194 million or

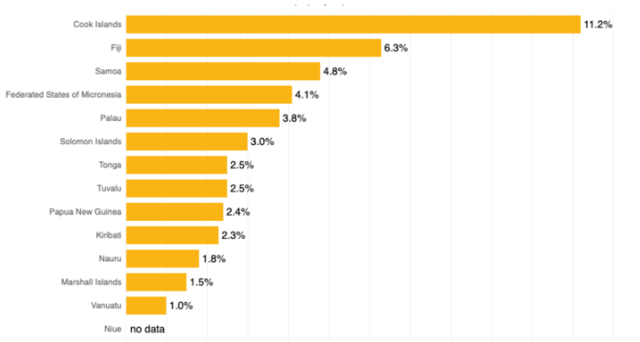
37.7% of GDP in 2020, the highest in the world (IOM & ILO, 2022), but which increased to 46.2% of GDP in 2021 (World Bank 2023, 2023). Tonga's GDP decreased to 469 million USD in 2021, down from 485 million USD in 2020 (World Bank 2023, 2023). GDP growth was 0.7% in 2019 and was subsequently adversely affected by COVID-19, with GDP falling to -1.2% in 2020 (GoT, 2022). The Hunga Tonga-Hunga Ha'apai volcanic eruption and tsunami reduced GDP growth to -2.5% (GoT, 2023). However, forecasts suggest that real GDP will grow with Tonga's GDP growth expected at 2.5% in 2023, and 3.2% in 2024 according to the ADB (ADB, 2023b), although Government of Tonga figures put this at a projected annual average growth of 3.4% for 2023 through to 2025 (FY) (GoT, 2023).

Figure 10 GDP growth rate for Tonga (% by year)



Source: (ADB, 2023b)

Figure 11 GDP growth rate forecast for 2023



Source: (ADB, 2023b)

Overall, aside from the contribution from remittances, which were 46.2% of GDP in 2021 (World Bank 2023, 2023), Tonga's economy is highly dependent on climate-sensitive sectors such as agriculture, fisheries and tourism and a limited resource base that is sensitive to external shocks (World Bank, 2021a). In 2022, agriculture contributed 19.93% of GDP, industry contributed 19.44%, and services 60.63% (ADB, 2023a). The Services sector employs most of Tonga's population at 43%. However, the agricultural sector, which includes fisheries and forestry, is then the leading productive sector in Tonga. The agricultural sector supports the majority of the population for subsistence and for cash income, employing a third of the labour force and accounting for at least 50% of the export earnings (World Bank, 2021a). A large share of agricultural production is for subsistence and employs around 30% of the population, followed by industry which engages 27% (World Bank 2023). Climatic conditions, concern for food security, availability of labour and technology, lack of technology and innovative practices, and market access are all issues affecting agricultural production. The performance of the fisheries sector has fluctuated over time according to the boom-and-bust cycles due to the migration of the tuna species, market access, fish prices, and policy.

Although incidence of absolute poverty is low in Tonga, many experience economic hardship. Economic hardship occurs for some when they do not have sufficient opportunities to access financial resources to cover basic needs, such as medical and education expenditures, due to the high economic cost of the country's smallness. The national revenue base is heavily influenced by the fluctuations of the global economy, relying heavily on remittance payments and foreign donor aid. Remittances are vulnerable to the economic fluctuations in countries where the Tongan diaspora mostly live (e.g., the US, Australia, and New Zealand), when downturns occur in these countries, remittances reduce and have a negative impact on Tongans both at the family level and for the broader economy. For example, remittances declined sharply, by USD 28 million from 2007 to 2009, due to the impacts of the global economic crisis (Fonua, 2012).

Donor funds also contribute significantly to the government budget and are primarily used for funding developmental projects and programmes that the government does not have sufficient resources to implement. The total development budget for FY 2022 amounted to USD 248.95 million, which was 40% of the total government budget (GoT, 2022) and in the FY 2022-2023 this was USD 327.7 million (GoT, 2023). However, Tonga is also rated 'high' in terms of the overall risk of debt distress (World Bank-IMF, 2021), with a high level of public debt, around half of which is owed to China, with a sharp spike in debt repayments due from FY2024 onwards. This heavy reliance on donor funds increases Tonga's vulnerability to external shocks as donors frequently reduce foreign aid in budget downturns.

Tonga's economic instability has been further compounded by its exposure to natural disasters. Although Tonga is not classified as a least developed country (LDC), its environmental and economic vulnerability has previously been higher than the LDC average compared to other SIDS, largely due to its proneness to disasters (Benfield, 2014). Overall, Tonga is considered highly vulnerable to disasters and climate change impacts, requiring higher capital spending on climate-resilient infrastructure projects that could increase resilience to disasters faster (World Bank-IMF, 2021). The Global Climate Risk Index 2020 cited Tonga as one of the countries experiencing the highest levels of climate-related loss as a percentage of GDP over the period 1999 - 2018 (Eckstein et al., 2019). In recent years, Tonga's economy has been affected by climate and non-climate-related disaster impacts, with a downtrend in GDP following the Hunga Tonga-Hunga Ha'apai volcanic eruption and tsunami in 2022. Similarly, Tonga's economy previously suffered from climate-related impacts in the form of severe devastation from Tropical Cyclone (TC) Gita in 2018, and TC Harold in 2020. Tonga's tourism sector, for example, was badly affected by the Hunga Tonga-Hunga Ha'apai volcanic eruption and tsunami, as well as COVID-19, with visitor numbers 'falling to zero' in 2020, while the fisheries sector was also affected by lack of transport access to markets (GoT, 2020).

Table 2 Global ranking of climate-related GDP % loss

Climate-related loss (% GDP) 1999-2018		Climate-related loss (% GDP) 2018	
Country	Rank	Country	Rank
Dominica	1	Tonga	1
Tuvalu	2	Samoa	2
Grenada	3	Oman	3
Tonga	4	Madagascar	4
Puerto Rico	5	Sri Lanka	5
	...		...
Colombia	90	Kazakhstan	90
	...		...
Brunei Darussalam	180	Zambia	135

Source: (Eckstein et al., 2019)

1.2.2 Sustainable development progress

Tonga has made good general progress towards achieving the Millennium Development Goals (MDG's). According to the measure of extreme poverty being the percentage of the population living below USD1.90 per day, Tonga's population living in extreme poverty has dropped to less than 1% in 2022, from 2.8% in 2011, 1.1% in 2009 and 3,1% in 2016 (TDS, 2023). However, eradicating poverty, gender equality, and HIV/Aids remain three areas of concern. The 2021 global Sustainable Development Report (Sachs et al., 2021) indicated that Tonga faces 'major challenges' to SDGs 2 (zero hunger), 3 (Good health and well-being), 5 (Gender equality), 9 (Industry innovation and infrastructure), 10 (reduced inequalities and 14 (life below water).

Building upon a consensus approach, Tonga's National Statistic Office developed its own multidimensional poverty measure to reflect the nuanced picture of poverty in Tonga (TDS, 2023). Using this indicator, poverty is measured by combining both low income, and material and social deprivation. Income is measured at the household level, reflecting the sharing of resources among household members in order to take into account both monetary (e.g. wages) and non-monetary sources (e.g. self-production, social capital). Deprivation is captured through an index of socially perceived necessities, items and activities that the majority of people in Tonga consider that no-one should go without. This equates to 20,661 people considered poor in 2021. The poverty rate is derived from comparing consumption per adult equivalent (AE) with a poverty line estimated at an annual amount of TOP $6,058 (approximately USD $2,532). This poverty line is calculated as the cost of basic needs for living, based on Household Income and Expenditure Survey (HIES) 2021 data. The proportion of Tonga's population considered poor due to low living standards, known as the "cost of basic needs poverty headcount ratio", is estimated to be 20.6%, reflected in the table below with the breakdown between adults and children. Multidimensional poverty in Tonga declined from 27% in 2015 to 24% in 2021 (TDS, 2023). By breakdown, however, child poverty rates are higher than adult poverty rates, with 28% of children living in poverty compared to 21% of adults. Overall, those in rural areas (rural Tongatapu and the outer islands) have higher rates of multidimensionally poverty (affecting 29%) compared to in Urban areas (20%) (TSD, 2020).

Table 3 Multidimensional poverty for adults and children in Tonga %

Multidimensional poverty by age group (%)

	Population	Adults	Children
Poor	**24**	**21**	**28**
Vulnerable deprivation	15	15	15
Vulnerable income	20	18	22
Non-poor	41	46	35
Total population (N)	100,179	62,949	37,230

Source: (TDS, 2023).

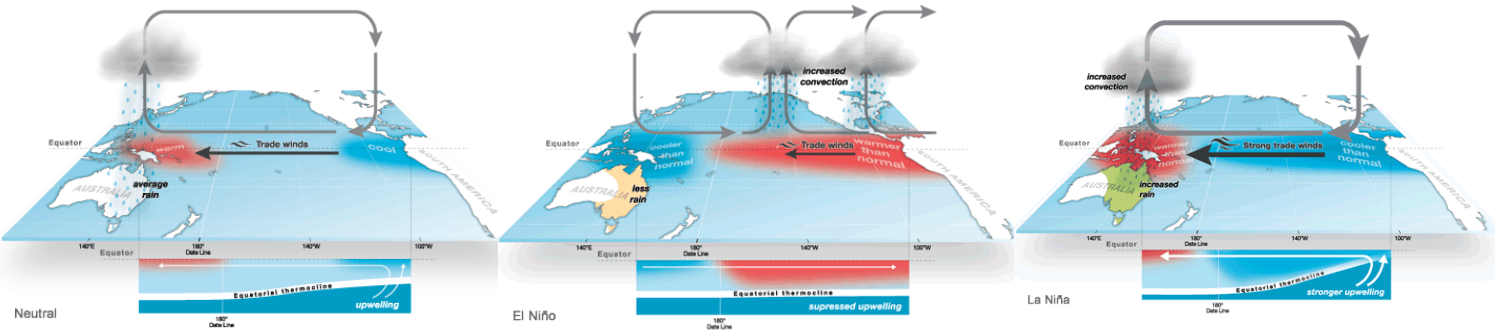
2. Climate Risk Profile of Tonga

Tonga is one of the most vulnerable countries to climate change and disaster risks. The country ranks 6th most vulnerable and 5th most exposed (out of 185) globally (UND, 2023). The ND-GAIN Index score (out of 100) summarises a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience scores Tonga on the ND-GAIN Index as 41.1, and its overall rank is 140 out of 185 (UND, 2023). Tonga's population already lives in a dynamic ecosystem, to which it has adapted, but climate change is likely to increase variability, pose new threats, and place stress on livelihoods. Communities are likely to need support to adapt and manage disaster risks facing their wellbeing, livelihoods, and infrastructure (World Bank, 2021a). Geographic isolation and economic vulnerabilities, including dependence on remittance and foreign aid, will increase the challenges faced by communities and decision makers (World Bank, 2021a). The largest island Tongatapu, where 74 per cent of the population resides, faces significant frequent flooding risks and permanent losses from sea level rise (SLR) in the absence of future adaptation measures. The permanent losses under a 0.5m SLR scenario are expected to be 6 per cent , and under a 1.0m SLR scenario to be 25 per cent (ADB, 2021a). Tonga has experienced a series of climate disasters in recent years; tropical cyclones Ian (2014), Gita (2018), Harold (2020), as well as non-climate related disasters with the Hunga-Tonga-Hunga-Ha'apai volcano eruption in 2022, which triggered tsunami waves throughout the Tonga archipelago. Combined, climate-induced and non-climate related disasters affected up to 80 per cent of the population and wiped out between 12 per cent to 40 per cent of the GDP (ADB, 2023c).

2.1 El Niño-Southern Oscillation (ENSO) implications for Tonga

The Pacific Ocean covers almost a third of the Earth's surface and plays an important role in shaping the world's climate. The presence of large-scale climate features and different sized land masses leads to profound regional variations in climate. Of these large-scale features, the El Niño-Southern Oscillation (ENSO) is the major cause of year-to-year climate variations (WMO, 2018). The extent and timing of the influence of ENSO varies between countries. ENSO is a natural cycle of the climate system, with two extreme phases: El Niño and La Niña. Interestingly, some studies have found support for an El Niño-like response in the year following large volcanic eruptions (Zhu et al., 2022). ENSO affects the year-to-year risk of droughts, floods, tropical cyclones, extreme sea levels and coral bleaching throughout the region. El Niño and La Niña events usually begin to develop between May and June and last until the following March to May. During an El Niño event, trade winds weaken or may even reverse, allowing the area of warmer than normal water to move into the central and eastern tropical Pacific Ocean. During a La Niña event, the Walker Circulation intensifies with greater convection over the western Pacific and stronger trade winds (BoM, 2023c). While such events tend to follow a typical pattern of development, the strength and timing of each event is different, as is the exact pattern of sea-surface temperature, wind, and impacts. If neither phase is apparent conditions are termed ENSO neutral. In its neutral state (neither El Niño nor La Niña), trade winds blow east to west across the surface of the tropical Pacific Ocean, bringing warm moist air and warmer surface waters towards the western Pacific and keeping the central Pacific Ocean relatively cool (BoM, 2023c).

Figure 12 El Niño-Southern Oscillation (ENSO) in 1. Neutral ENSO phase, 2. El Niño phase, and 3. La Niña phase



Source: (BoM, 2023c).

El Niño and La Niña events have distinct impacts on the rainfall of most Pacific Island countries. Changes in sea-surface temperature and winds associated with El Niño and La Niña cause largescale shifts in rainfall patterns. ENSO also profoundly influences sea level and the risk of tropical cyclones in the region and Tonga's climate pattern is very much affected by the El Niño phenomenon (MEIDECC, 2019). As the warm sea surface temperatures move east during El Niño, moisture and water vapour required for cloud formation also migrate eastward, influencing drought conditions in Tonga (World Bank, 2021a). The last three major droughts that have occurred in Tonga in 1983, 1998 and 2006 have been directly linked to El Niño events around the same time. Temperatures are also affected; year-to-year temperature variations along the equator can be larger than the average variations between the seasons. For Tonga, in the Southwestern Pacific Ocean, when there is the warm El Niño phase of ENSO (a deeper thermocline and decreased westward transport of water), the sea surface temperature increases to greater than normal in the Eastern Pacific. This shifts the prevailing rain pattern from the normal Western Pacific to the Central Pacific (as shown in the middle graphic). An El Niño brings warmer than average ocean temperatures to the central to eastern Pacific and a weakening of the trade winds. The South Pacific Convergence Zone (SPCZ) typically stretches northwest to southeast from the Solomon Islands, across Fiji and Samoa, to Tonga. The Intertropical Convergence Zone (ITCZ) and SPCZ tend to move closer to the equator, so rainfall increases near the equator and decreases in the north-west and south-west Pacific. In a La Niña the opposite changes to ocean temperatures occur and the trade winds strengthen. La Niña occurs when there is an increase in the strength and intensity of trade winds, which then enhances the warm pool in the Western Pacific, causing sea surface temperatures in the Central and Easter Pacific to become cooler resulting in above normal rainfall in the West (Malsale, 2023). The ITCZ and SPCZ tend to move away from the equator, reducing rainfall near the equator and increasing it to the north of the equator and south-west Pacific. Although the future ENSO changes due to climate change are uncertain, any shift in the frequency, intensity, and duration of El Niño / La Niña episodes would profoundly affect coastal risks in the region. In Tonga this includes the wind and wave effects on shoreline processes and the resilience of reef mediated shorelines, as well as potential influence on the frequency of extreme events.

Recently, the Pacific has come out of a triple-dip La Niña event, whereby La Niña was declared in 2020, 2021 and 2022 (Malsale, 2023). However, an El Niño alert was already issued in June/July 2023 for Tonga, with implications for Tonga of cooler nights, less rainfall over the next 6-12 months, and more tropical cyclones in the next cyclone season (1 November 2023-30 April 2024) (TMS, 2023). Climate change is likely to accentuate the spatial and temporal variations in weather and climate in the Pacific, including the differences from normal that result from ENSO events. Generally, there is clear evidence that atmospheric temperatures, sea levels, and ocean acidification have risen in the last several decades. It is more challenging to conclude general trends for other parameters such as the annual total rainfall, extreme rainfall, and the number and intensity of tropical cyclone.

2.2 Climate change impacts for the Pacific and Tonga

For the Pacific climate change is expected to bring more heavy rainfall events severe tropical cyclones and extreme sea level events, which will require adaptation for people, infrastructure, and coastal ecosystems (ICEDS, 2022b). For example, through the raising of dwellings and critical infrastructure to reduce flood impacts, through planned inland relocation of communities and infrastructure, and; through mangrove planting and beach nourishment to protect coastal infrastructure (ICEDS, 2022b).

Figure 13 Overview of climate change impacts in the Pacific

Source: (ICEDS, 2022a)

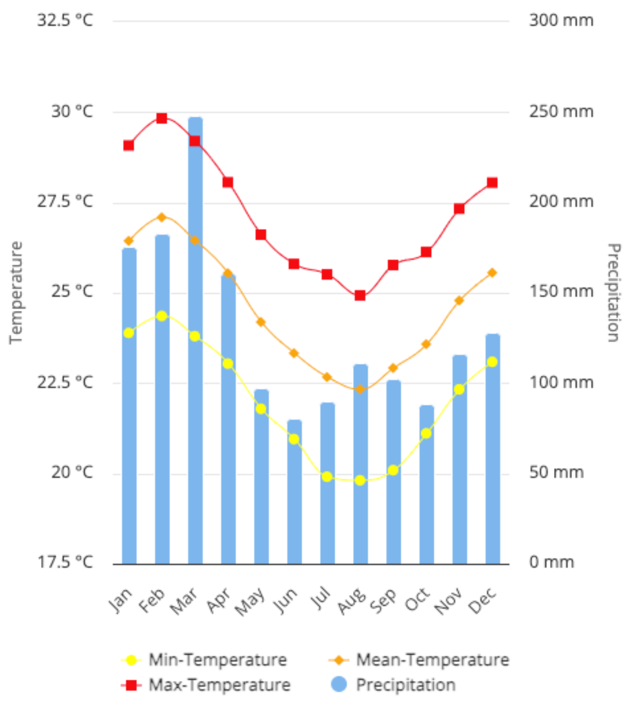
Currently, changes in rainfall patterns have resulted in almost annual flood events that damage major assets and threaten livelihoods. Categories 4 and 5 tropical cyclones are increasing as a proportion of all cyclones, severely impacting Pacific infrastructure. Rising sea levels will continue to increase the frequency of coastal inundation, damaging coastal infrastructure and settlements.

This section discusses the key climate change drivers that affect coastal resilience in Tonga and play a crucial role in the functioning and resilience of the reef-mediated shoreline systems that predominate in Tonga, particularly in North-western Tongatapu. Tonga faces a diverse set of risks from climate change but data and reliable model projections are lacking, presenting challenges for decision makers (World Bank, 2021a).

2.2.1.1 Observed climate trends for Tonga

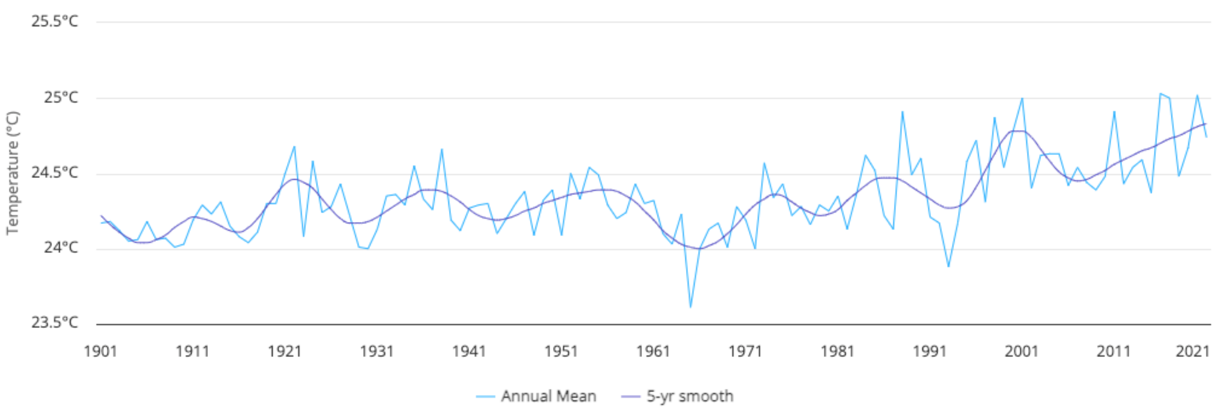
Tonga's climate is tropical with a wet season usually from November to April that has both moderate and variable rainfall, and dry season from May to October (World Bank, 2021b). Mean annual precipitation has averaged 1,666 millimetres (mm) over the period 1901–2019 (World Bank, 2021b). While, mean annual temperature in Tonga varies from 23°C to 26°C (World Bank, 2021b). Tonga's weather is governed by a number of factors that include the trade winds and the movement of the South Pacific Convergence Zone (SPCZ), a zone of high-pressure rainfall that migrates across the Pacific south of the equator (World Bank, 2021a). Year-to-year variability occurs under the influence of the El Niño Southern Oscillation (ENSO) in the south-east Pacific, which can bring prolonged drought conditions and contribute to a depletion of potable water, and tropical cyclones that occur during the wet season, causing extensive damage to local infrastructure, agriculture, and major food sources (World Bank, 2021a). Overall, the Tonga archipelago has observed a historical warming of around 0.6°C between 1979 and 2018 and future trends are obscured by the inability of climate models to accurately simulate trends at sufficiently small spatial scales (World Bank, 2021a).

Figure 14 Monthly climatology of min-temperature, mean-temperature, max-temperature and precipitation 1991-2020



Source: (World Bank, 2021b)

Figure 15 Observed average annual mean-temperature for Tonga for 1901-2021



Source: (World Bank, 2021b)

2.2.1.2 Temperature projections

On the highest emissions pathway (RCP8.5) warming of around 2.6°C is projected by the end of the century for Tonga (World Bank, 2021a). Potential threats to human well-being and natural ecosystems include increased prevalence of heat wave, intensified cyclones, saline intrusion, wave-driven flooding, and permanent inundation. As a result, biodiversity and the natural environment of Tonga are likely to face extreme pressure, as well as the losses of some species of fish, coral, birds, and terrestrial species.

Figure 16 Projected mean-temperature anomaly for 2020-2039 for Tonga (Reference period 1995-2014) SSP1-1.9 and SSPS 8.5 Multi-model ensemble

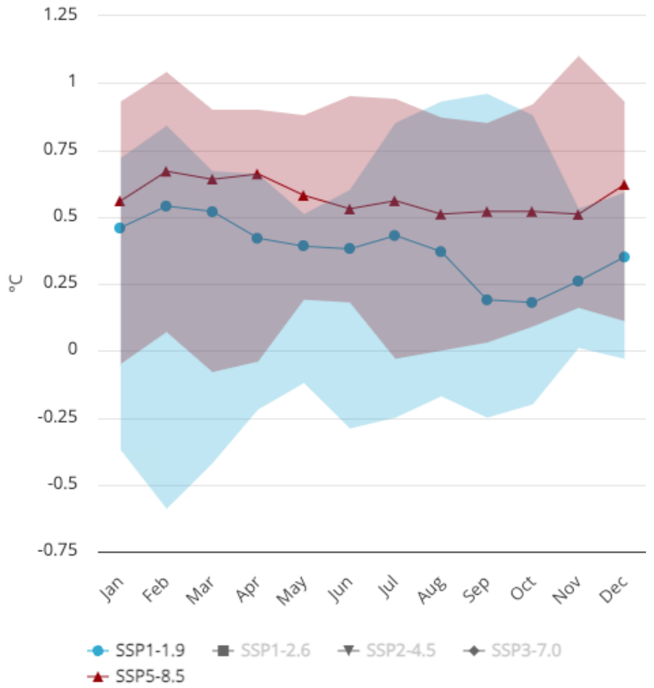
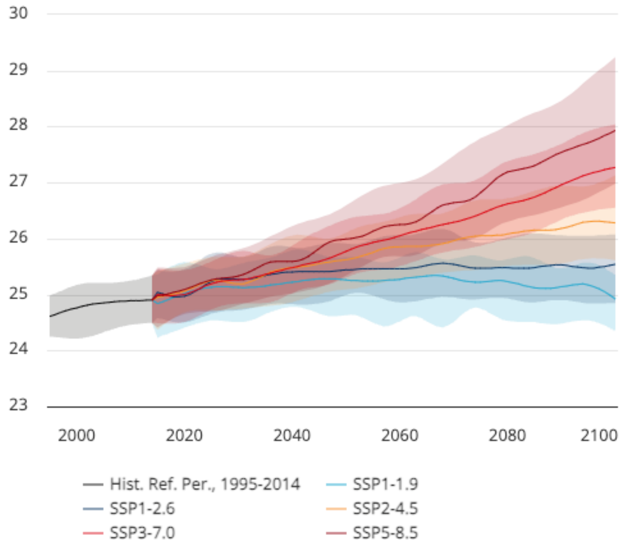


Figure 17 Projected mean temperature for Tonga (Reference period 1995-2014), multi-model ensemble



Source: (World Bank, 2021b)

2.2.2 Increasing sea surface temperatures

Changes in air temperature from season to season are relatively small and strongly linked to changes in the surrounding ocean temperature. Tonga has two distinct seasons – a warm wet season from November to April and a cooler dry season from May to October (McGree et al., 2022). However, Annual and seasonal air temperatures at Nuku'alofa increased over the period 1951–2020 and surface air temperature and sea-surface temperature are projected to continue to increase over the course of the 21st century (CSIRO, 2015; McGree et al., 2022). There is very high confidence in this direction of change because:

- Warming is physically consistent with rising greenhouse gas concentrations.
- All climate models agree on this direction of change.
- Observational evidence confirms projected rates of change.

Projections for all emissions scenarios indicate that the annual average sea-surface temperature (*with medium confidence*) will increase in the future in Tonga. Under all RCPs, the warming of up to 1.0°C is predicted before 2030; but after 2030 there is a growing difference in warming between each RCP. In Tonga by 2090, RCP8.5 results in a warming of 1.8–4.1°C while RCP2.6 gives a warming of 0.2–1.1°C.

2.2.3 Precipitation projections

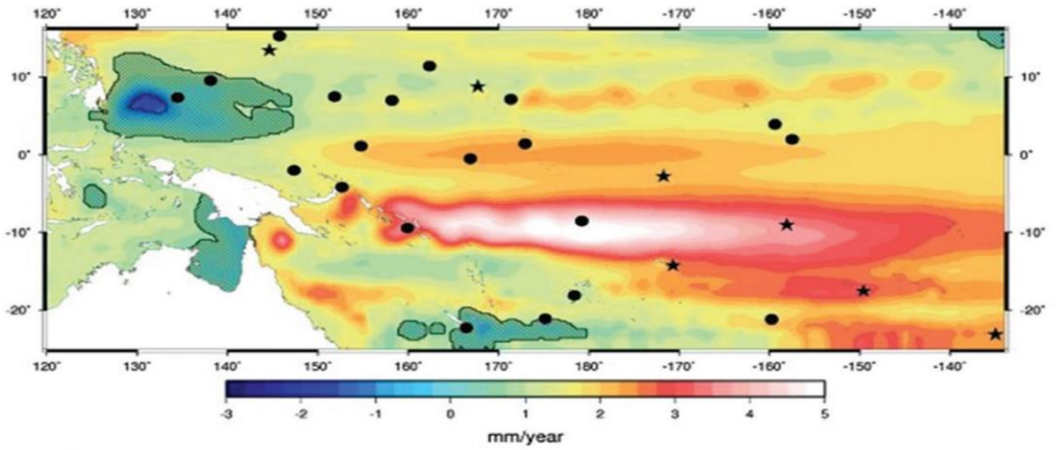
Due to the spatial distribution of the islands of Tonga, there is a disparity in the nature of rainfall in the country. Tonga's Third National Communication to the UNFCCC reports the annual mean rainfall at the five meteorological stations in Tonga between 1971–2007: Tongatapu reported an average of 1,721 mm, Vava'u an average of 2,150 mm, Ha'apai an average of 1,619 mm, Niua Fo'ou an average of 2,453 mm and Niua Toputapu an average of 2,374 mm (MEIDECC, 2019). All of the Tongan archipelago islands therefore receive significant annual rainfall.

2.2.4 Sea Level Rise and inundation

According to its Third National Communication to the UNFCCC, Tonga has already witnessed general sea level rise of 6.4 mm per annum when compared with historical records from 1993–2007 (MEIDECC, 2019). The 2021 IPCC 6th Assessment Report indicates global mean sea level has risen approximately 20cm since 1901 (IPCC, 2021). Rates are accelerating and between 2006 and 2018 global average rates were 3.7mm /

year. There is significant variability between locations. However, many countries in the Western Tropical Pacific including Tonga face pronounced accelerated sea level rise. Sea level rise hotspots, present greater impacts in certain areas or regions over others, including the South Pacific Convergence Zone (SPCZ), with greater warming projected in the areas in and around Tonga (the Southwest SPCZ and the Northeast SPCZ) (IPCC, 2022b). By the 2090s, sea level rise is estimated to increase about 60 cm using historical records only, or within the range of 40 cm–87 cm under RCP8.5 projections (World Bank, 2021a). Uncertainty in the projections of changes in the Antarctic ice sheet limit the certainty of knowledge of the range of this mean sea level change (World Bank, 2021a). Nonetheless, it is important to note that in 2022 the IPCC 6th Assessment Report included as an unlikely but plausible sea level rise scenario Antarctic Ice Sheet break up projections approaching 2m by 2100 (IPCC, 2022a). Additionally, for long-term near-shore infrastructure projects (i.e., with a design life greater than 30 years), the ADB (2022) recommends a scenario of 2 m SLR by 2100 be considered.

Figure 18 Interannual Sea-level trends in the Pacific Islands Region 1950-2009



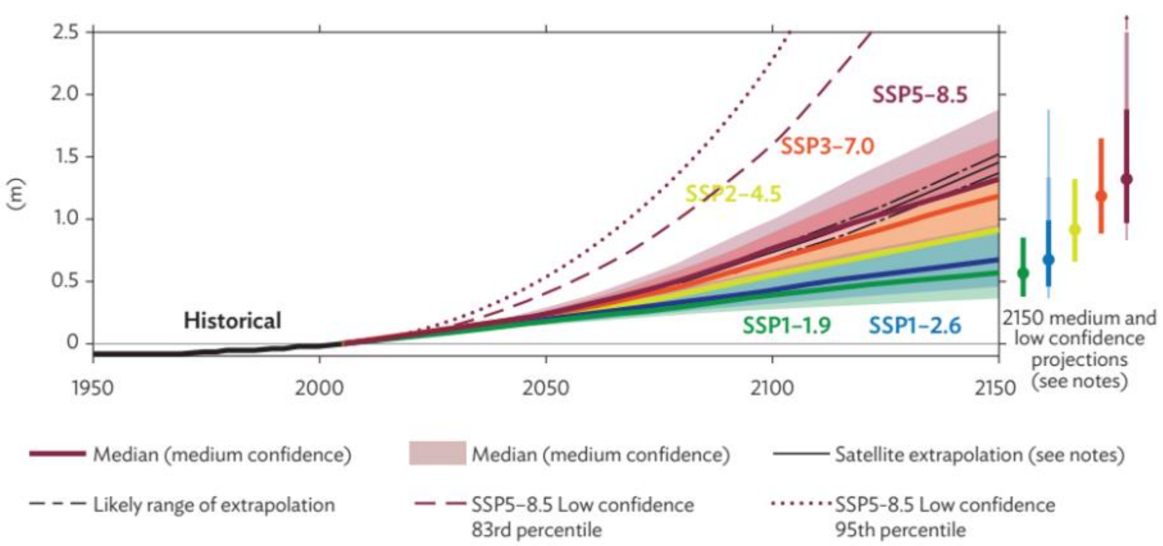
mm = millimeter.

Source ADB 2022

Note: Black circles and stars indicate the locations of the 27 tide gauges used in the study; stars correspond to the 7 tide gauges used to reconstruct global sea-level trends from 1950-2009. Hatched areas have nonsignificant trends (p-value > 0.1).

Tonga faces a potential long-term threat from permanent inundation and wave-driven flooding, and some studies have suggested that significant displacement of communities could occur (World Bank, 2021a). In combination with potential tectonic disturbances and cyclone activity, the risk to human communities of coastal submergence and wave inundation is among the highest in the world (Becker et al., 2019).

Figure 19 Sea Level Rise (SLR) for Tonga according to AR6 Projected Global Mean Sea-level Change Projections under different SSP Scenarios

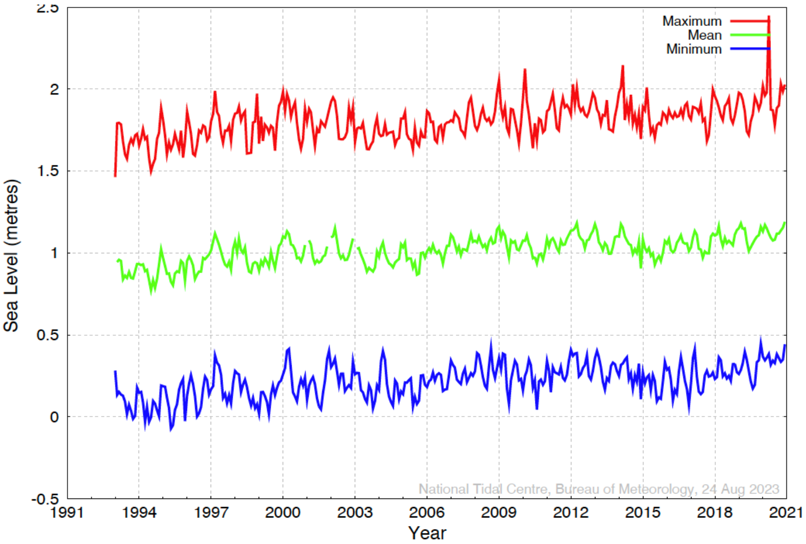


Source: (IPCC, 2021)

Above: solid lines present the median (-50 percentile) sea-level rise for each SSP, with corresponding shading reflecting the likely range (17-83 percentile) of potential sea levels. H + represents a low confidence high-confidence scenario. Extrapolated sea level based on historic satellite-derived sea level rise rates are shown in black. Upper 'likely' and 'very likely' (95 percentile) low confidence SSP5-8.5 H + sea level projections are shown as brown dashes.

Under the recent AR6 IPCC projections (IPCC, 2021) shows that even under relatively optimistic emissions reduction scenarios (mid-range SSP1-2.6, blue bar) sea level will continue to rise for hundreds of years into the future and is likely to be 2m above current levels by 2300. Given current evidence, trajectories more consistent with SSP5-8.5 (red bar) are more realistic; these indicate several meters (mid-range around 4.5m) above current levels by 2300. The IPCC (2021) has also included catastrophic sea level rise scenarios associated with plausible ice sheet instability for the first time. This could mean global mean sea level greater than 1.5m higher than present-day levels by 2100. These extremely high rates can no longer be ruled out based on science that has become available.

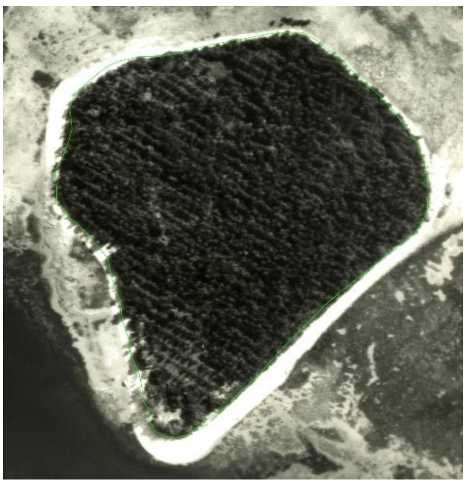
Figure 20 Monthly sea level at Nuku'alofa, Tonga from 1993-2021



Source: (BoM, 2023b)

On Tongatapu there is clear evidence of the impacts of local sea level rise. The Pacific Sea level and Geodetic Monitoring Project's Tongatapu gauge shows a "raw" rate of 7.1mm / year from Jan 1993 to Dec 2022 (BoM, 2023b). This 29 year time series is still too short to account for long-term seasonal fluctuations in sea level, but it is the relative rate over a meaningful monitoring period and is consistent with research (Becker et al., 2019) that has found consistently higher rates of sea level rise in the western tropical Pacific Islands. The Pacific Sea level and Geodetic Monitoring Project gauge lies within Tongatapu Island lagoon, where several coral sand cays (analogous to the atoll islands) lay on the reef platform surrounding the lagoon. Dominant wave direction for Tonga is typically from 60° (NE), with an average significant wave height of 1.30 m and an average wave period of 13.48 s (McGree et al., 2022).

Figure 21 Image comparisons from 1968 (left) and 2021 (right) show the same island in the Sand Cays of Tongatapu Lagoon over time



Source: (Webb, 2021)

The images above show the same island in the Sand Cays of the Tongatapu Lagoon over time, comparing 1968 (left) and 2021 (right). Notably, the gradual loss of the interior low-laying areas of the island to marine water incursion has occurred (red circle), pre-dating the Hunga Tonga-Hunga Ha'apai tsunami in 2022. Recent research (Webb, 2021) analysing these islands shows that these have been relatively stable for decadal, possibly centennial timeframes, many of them appearing on early navigation charts drafted by Cook in 1773. Until the 1960's, these islands remained relatively stable and persistent, with dense vegetation. The larger islands supported modest agriculture, fresh groundwater resources and small populations. Today, however, sea level rise is gradually destroying these islands due to the unprecedented and permanent incursion of tidal marine waters into their terrestrial environments. Contrary to popular understanding, islands do not necessarily erode away. Their shores may still be functional, but irrespective, low-lying areas within the interior succumb to tidal marine flooding as sea levels rise. This permanently degrades groundwater, soil and vegetation, rendering the island uninhabitable. Eventually, such land will be transformed entirely from terrestrial to marine intertidal, in this case mangrove. These destructive processes are occurring throughout the low-laying islands and nearshore areas of the Tongan archipelago.

Figure 22 Inundation modelling in Tongatapu under RCP8.5 / 2100

Source: (Webb, 2021)

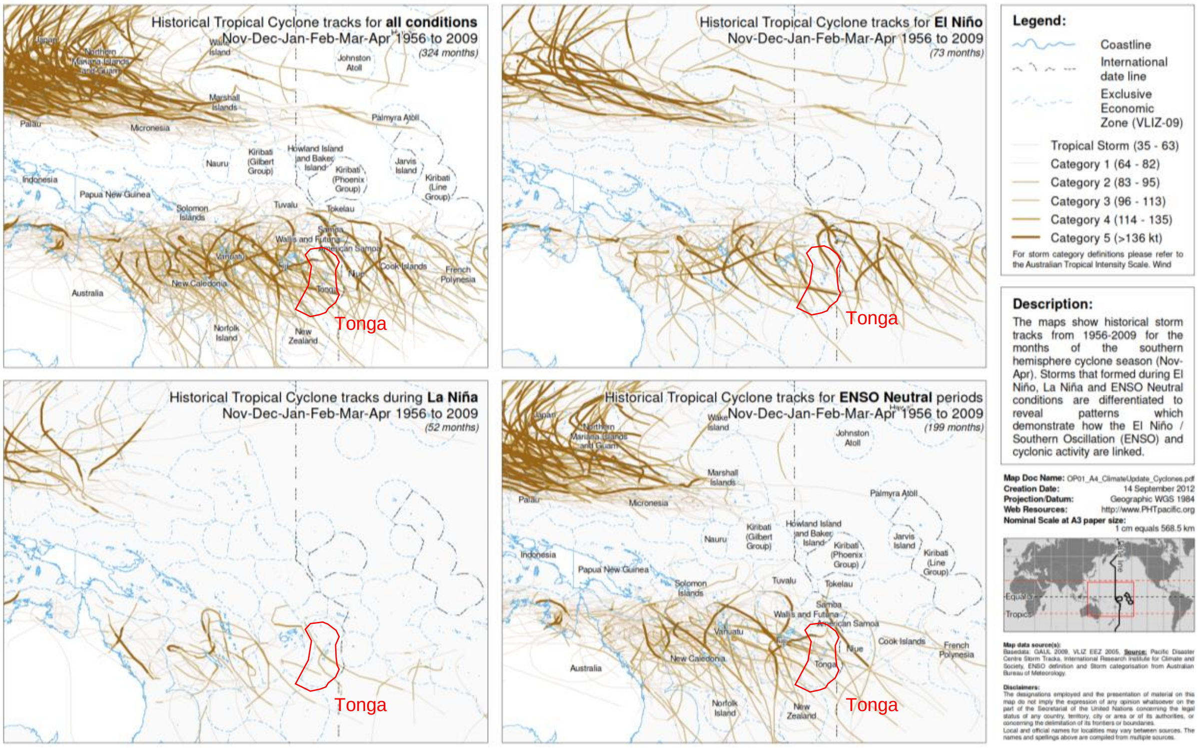
Above: inundation modelling in Tongatapu under RCP8.5 / 2100. The orange zones show the potential extent of routine tidal inundation with 1m of sea level rise. Note these areas extend through much of the densely populated capital Nukualofa (1) and include the shoreline areas targeted for remedial work by this Project (2 and 3). Without adaptation, by 2100 those areas shaded in orange will no longer be terrestrial habitat, they will have become intertidal marine environment and would not be tenable for established modes of settlement or development in Tonga (Webb, 2023).

This Tonga Coastal Resilience Project considers that RCP8.5 is appropriate in estimating future SLR impacts and adaptation since no evidence is available at this time showing tangible reductions in global GHG emissions below a 2100 / RCP8.5 trajectory (IPCC, 2022a; Le Cozannet et al., 2019; UNEP, 2022). Even if large reductions in emissions are achieved over the coming 80 years and sea level trajectories are reduced, sea level rise of 1m and more will almost certainly still occur further into the future thus developing adaptation strategies based on RCP8.5 / 2100 is a sound "no regrets" approach.

2.2.5 Tropical storms and cyclones

For Tonga, tropical cyclones were most frequent in El Niño years and least frequent in La Niña years. Year-to-year variability is large, ranging from no tropical cyclones in some seasons to six in 2015/16 (McGree et al., 2022). The entire Tongan Archipelago is subject to direct land fall of tropical cyclones. These can generate locally raised sea levels and large wave conditions, heavy rainfall, and wind speeds more than 200km/h. Given that the greater proportion of Tonga's population live in near the shore, on low laying land, when large cyclone events combine with high spring tides it can cause catastrophic flooding and wave damage. Additionally, heavy precipitation associated with such storms also increases flood risk as low laying back shore areas become inundated with fresh water which cannot drain to the sea because of high wave / sea level conditions.

Figure 23 Historical storm tracks for the months of Nov-April during 1956-2009 compared under the different ENSO conditions



Source: ENSO status data from IRI archive converted to ENSO cycle using the El Niño and La Niña definition of the Australian Bureau of Meteorology: 5 month average SOI above 8 and below 8 respectively

The Tonga Climate Risk Country Profile (World Bank, 2021) indicates there were 85 cyclones developing within or crossing the Tongan archipelago between the years 1969 – 2011 with an approximate average of 20 cyclones per decade. The report outlines there were 55 cyclones since 1981 and 19 of these were Category 3 or higher. There have been only three Category 5 tropical cyclones ever recorded in Tongan waters, TC Ron (1997) and TC Ian (2014), and TC Harold (2020); it is notable that these have all occurred in the last twenty-five years, and two within the last decade.

Table 4 The seven most destructive tropical cyclones to have affected Tonga in the last 65 years[1]

No	Name	Category	Month/Year	Area Affected
1.	Severe Tropical Cyclone (un-named)	Category 4	March 1961	Vava'u
2.	Severe Tropical Cyclone "Isaac"	Category 4	March 1982	Vav/Hap/Tongatapu

[1] Adapted from Final MET Report for TNC.docx

3.	***Severe Tropical Cyclone "Ron"***	***Category 5***	***January 1998***	***Niuafo'ou***
4.	Severe Tropical Cyclone "Waka"	Category 4	January 2002	Vava'u
5.	***Severe Tropical Cyclone "Ian"***	***Category 5***	***January 2014***	***Ha'apai***
6.	***Severe Tropical Cyclone "Gita"***	Category 4	February 2018	Tongatapu
7.	**Severe Tropical Cyclone "Harold"**	**Category 5**	**April 2020**	**Eua/Tongatapu**

Hihifo Road, post TC Gita, Nuku'alofa 13 February 2018. Source "Matani Tonga Online".

TC Gita (Cat 4; February 2018) was the most damaging event to have ever been recorded in Tonga, it was estimated to have impacted some 80% of the national population as it passed just south of the capital Island Tongatapu. The storm caused widespread damage estimated at US$164.1 million (equivalent to 38% of the Tongan GDP)[2]

The Multihazard Assessment for Tongatapu (ADB, 2021a) assessed multi-hazard risks for Tongatapu, reporting (amongst other things) that:

- Coastal inundation hazard intensity and the influence of SLR generally reduce with distance from the northern shoreline and the shoreline of Fanga'uta Lagoon. The extent and depth of inundation on the southern shoreline is generally minor, even under significant return period events or 2.0m of SLR
- Climate change impacts on inundation risk were considered through 0.5m, 1.0m, and 2.0m SLR with increased intensity of precipitation also considered. Permanent losses from SLR are significant in comparison to the return period scenarios and AAL losses, with up to 50% of the asset value impacted in the 2.0m SLR scenario. It is important to note that as the SLR scenarios will not occur for a number of years, further development over this time frame, both through increased urbanization and/or new flood protection infrastructure, would alter the expected losses from what has been presented here.
- An indirect comparison of extreme hazard scenarios (200-year return period) and permanent loss for SLR scenarios provides some indication of relative impact across the events. This comparison shows that losses in the 200-year pluvial flooding scenario (7% of total asset value) are similar the permanent losses under a 0.5m SLR scenario (6%). The 200-year seismic scenario (19% of total asset value) is similar to the permanent losses under a 1.0m SLR scenario (25%). It is important to

[2] Tonga: Rapid Damage Assessment and Recovery Framework for Tropical Cyclone Gita, ACP-EU Natural Disaster Risk Reduction Program, 2018

differentiate between the probabilistic occurrence of a single hazard event and the gradual impact from projected SLR.

2.3 Climate change impacts on Tonga's critical sectors

Tonga is highly vulnerable to coastal inundation/erosion through extreme weather events. Figures on sea level rise show that Tonga has experienced an accelerated rate of SLR compared to the global average and that this is projected to continue in future decades. Tonga is already experiencing coastal inundation affecting communities, infrastructure, and livelihoods. For example, the total loss of coastal agricultural land from sea level rise has been estimated to be 43 km^2; about 8% of the total land area (GoT, 2018). The World Bank (2021a) has recorded that 'noting that the land is particularly low near the capital, at Nuku'alofa, and sea level rise increases of 0.3 m and 1m could cause potential land losses of 3.1 km^2 and 10.3 km^2, respectively, or 1.1% - 3.9% of the total area of Tongatapu Island', potentially displacing people and adversely affecting infrastructure and livelihoods (World Bank, 2021a). There is a compelling case for the need for a comprehensive approach in Tonga towards the management of climate change risks, especially in relation to coastal vulnerability and future land use. At the same time, urgent protection is needed for highly vulnerable coastal areas in Tongatapu. The following section summarises sectoral vulnerabilities to climate change in Tonga, on human habitation and settlements, marine ecosystems and reef systems, agriculture and fisheries, economy, energy and infrastructure, and water resources.

2.3.1 Human habitation and settlements

The population of Tongatapu is projected to grow over the next decade with Tongans commonly relocating from the outlying islands to Tongatapu as discussed in section 1.2. While all forms of internal migration occur in Tonga (rural to urban, rural to rural, urban to rural and urban to urban) the predominant trend in Tonga (and indeed globally) is rural to urban (TWG MSDP, 2021). Comparisons from the 2016 Census data, for example, showed this trend of in-migration (11,153) to be far greater than out-migration (3,717). While in Vava'u, in-migration (1,713) was much lower than out-migration (6,039), and a similar trend was found in Ha'apai in-migration (1,551) and out-migration (5,003), 'Eua in-migration (1,739) and out-migration (1,535) and Ongo Niua in-migration (382) and out-migration (244) (TWG MSDP, 2021). Paid work, education, health care and other opportunities associated with the capital city, drive relocation from other less well-developed or productive parts of the archipelago. At the same time, communities from other smaller, low-laying islands and settlements are expected to be increasingly challenged by met-ocean hazards associated with climate change, which in turn is expected to drive relocation increasingly. Most notably, the influx of new settlers to Tongatapu is resulting in ever greater strain on land resources around the capital Nuku'alofa and increasing settlement patterns into marginal, low-lying and highly flood exposed areas such as Nukuleka. The influx of new settlers to Tongatapu results in ever greater strain on land resources around the capital Nukualofa and increases the risk of settlement into marginal, low-lying and highly flood exposed areas. Because of the lack of data-based planning and policy around climate change impacts, infrastructure and settlements will continue to expand into vulnerable locations. Displacement has also been an issue due to disaster impacts, such as the 2022 tsunami, and is likely to continue, with significant and long-term displacements clearly requiring multi-stakeholder and cross-ministerial response in the delivery of public services and the management of community interests and expectations. Prior to the 2022 tsunami, the need for government agencies to plan for the continued increase in the population of Nukualofa and Tongatapu and the implications of internal migration shifts for land use, spatial planning, housing and Government services was well-noted within Tonga's Migration and Sustainable Development Policy (TWG MSDP, 2021). Aside from fast-hitting climate and non-climate related disaster events, climate-induced slow onset processes like coastal erosion, ocean acidification and other forms of environmental degradation in the medium term will drive both forced and voluntary internal movements in Tonga (TWG MSDP, 2021).

In extreme cases, the destruction of habitat and agricultural viability reduces the prospects for a return to the home environment. It increases the impetus for long term internal and/or outward migration which may also be perceived as a displacement (TWG MSDP, 2021). Internal displacement and resettlement is further complicated by land ownership complexities in Tonga whereby under the Constitution of Tonga (the Constitution and the Land Act), all land in Tonga belongs to the King of Tonga. Land allotments are then inherited through families, but only to the eldest 'legitimate' son, and not to 'illegitimate' eldest sons or to women or younger male heirs. Notably, the influx of new settlers to Tongatapu is resulting in ever greater strain on land resources around the capital Nuku'alofa and increasing patterns of settlement into marginal, low-lying and highly flood-exposed areas such as Nukuleka. This reality underpins the urgent need for improved understanding of climate change impacts and consultation with all stakeholders regarding safe long term adaptation plans. Aside from fast-hitting climate and non-climate-related disaster events, climate-induced slow-onset processes like coastal erosion, ocean acidification and other forms of environmental degradation in the medium term will drive both forced and voluntary internal movements in Tonga (TWG MSDP, 2021).

2.3.2 Marine ecosystems and reefs

Biodiversity conservation is one of the most difficult environmental issues facing Tonga. The combined impacts of climate change and disasters on biodiversity only compound the scale of the challenge. it takes 5 to 10 years for a coral reef which was destroyed by cyclone to recover. Climate change directly impacts coral reef ecosystems via increasing heat stress (coral bleaching) and increasing concentrations of CO_2 in ocean surface waters (acidification). Both stressors are understood to present enormous challenges to continued reef function and the potential synergistic impacts of both acting in tandem are of urgent concern. Projected heat-related bleaching in Tongan waters based on the 1982-1999 average, shows that a mean sea surface temperature change of +1.5 ^{0}C increases the risk of reef bleaching from a 1 in 30-year event to a 1 in 1, or an annual event.

Additionally, the duration of the event under +1.5 ^{0}C would approximately double (CSIRO, 2015). Observational reef monitoring data is scarce for Tonga, but the 2002 Coral Reef Status Report (Lovell & Palaki, 2002) indicate widespread bleaching had been recorded in 2000, affecting both the southern and northern reaches of the archipelago with 10 – 100% of some coral species being impacted. A more recent study (Smallhorn-West et al., 2020) also indicated extensive recent evidence of coral bleaching in the Ha’apai (central) Tongan archipelago. Elsewhere, the IPCC AR5 (Field et al., 2014) indicates, that increased coral bleaching and reduced reef calcification rates due to thermal stress and increasing carbon dioxide (CO2) concentration are expected to affect the functioning and viability of living reef systems. Unprecedented bleaching events have been recorded in the remote Phoenix Islands (Kiribati), with nearly 100% coral mortality in the lagoon and 62% mortality on the outer leeward slopes of the otherwise pristine reefs of Kanton Atoll during 2002–2003 (Alling et al., 2007).

There is also mounting evidence that ocean acidification impacts the health, productivity and structure of coral reef ecosystems (Cantin et al., 2010; De’ath et al., 2009; Mollica et al., 2018). In summary, increased CO_2 concentration associated with greenhouse gas emissions decreases water pH and reduces the aragonite saturation state in surface ocean waters. This negatively impacts the ability of hard corals and many other marine organisms to build their skeletons. The Australian CSIRO (CSIRO, 2015) indicates that in Tonga aragonite saturation state declined from approximately 4.5 in the late 18th century to about 4 by 2000 (Kuchinke et al., 2014) and that the aragonite saturation state will continue to decline as sea surface CO_2 concentrations increase over time, impacting coral reef growth rates. Projections under RCP8.5 show aragonite saturation will decline to less than 3.0 by mid-century (2050 – 2070 see figure); this is the level at which coral reefs are expected to show serious declines in structure and productivity. The threat posed to coral reef ecosystems via climate change stress of sea surface temperature increase and acidification is well established. The third global coral reef bleaching event occurred between 2014 and 2017 and was the longest and most extensive event on record (Eakin et al., 2019). The potential for these impacts to result in shoreline dysfunction and decline in “reef mediated shoreline systems” of Tonga are direct and threaten the natural protective or building properties of the natural shoreline systems, which the great majority of Tonga’s coastal communities rely on. As discussed in previous sections (Section 1.1.1), Tonga’s shores are living reef-mediated shores. Thus, any degradation of Tonga coral reef ecosystems is expected to negatively impact the shoreline process and their ability to continue to protect human assets. Significant coastal vulnerability stress has been indicated in the target shoreline of Hahake where this proposal intends to implement coastal protective works. Thus, this planned infrastructure is a response to current and projected impacts.

2.3.3 Agriculture and fisheries

Tropical cyclones have significantly affected the agriculture and fisheries sectors. They have experienced immediate and long-term damage on crops, trees, fishing (boats, motors, and gear), livestock, tools and equipment for agriculture, buildings, and other infrastructure used to support the agriculture and fisheries sectors. Tonga’s Third National Communication notes that diversification of agricultural crops allows for some buffering against these impacts – e.g. In the event of a storm, for example, tree crops, including coconut, breadfruit and banana may be damaged, but root crops, such as yam, taro, sweet potatoes, cassava, may be relatively less affected. In times of drought, root crops may also feel the effect in the short term while tree crops may have more of a delay in impact. However, severe events affect both type of crops, making the economy and livelihoods quite vulnerable (World Bank, 2021a). For instance, in 2010, Tropical Cyclone Renee severely affected Tongatapu, Vava'u and Ha'apai groups of islands, damaging agricultural root crops, fruit trees and vegetables. Impacts on the agricultural sector because of the storm were estimated at US$8.4 million (in current conversion), and the effects likely lead to further declines in local agricultural production and economic contribution (World Bank, 2021a). Similarly, Tropical Cyclone Ian (2014) severely damaged food crops and fruit trees, including yam, cassava, sweet potato, colocasia, bananas and other root and vegetable crops. The average percentage damage to food crops ranged from 75% for yams, to 99% for the banana family and cassava 96%, second only to bananas. Total losses to the fruit trees sector were valued at more than US$2 million. The loss is estimated to be the value of a missing fruiting season (the second season after the cyclone) when trees are expected not to fruit or a minimal harvest is expected due to the trees' ongoing recovery from the cyclone. Some fruit trees are expected to start fruiting immediately after the cyclone event. There was extensive damage to coconut, breadfruit, mangoes and other fruit trees some of which were at peak season when TC Ian struck. Mangoes, breadfruit, and avocado were in early harvest, as such, the whole harvest was lost. Crops of paper mulberry and pandanus will fully recover within 12 months after the cyclone and no extra loss is expected apart from the damage caused. In the fisheries sector, the largest cyclone losses were incurred to fishing equipment, including boats and outboard motors, as well as critical fishing gear such as nets and diving gear. These losses prevent those who rely on the fishing industry from earning a living, whether that is from fishing, or from boat and equipment service. It was estimated that it took between 3 and 6 months for operations to return to pre-cyclone production. Loss of public facilities servicing/supporting the fisheries sector is estimated at $600,000. Additionally, losses were incurred to government-managed facilities at the Ha'apai Fisheries Division compound. This includes damaged offices and furniture, workshop buildings, staff living quarters, buoys, markers, anchors, and government boats (FAO, 2014).

Damage in the livestock sector includes the death of cattle, pigs, horses and poultry, as well damages to housing, pig pens, cattle fences and tethering ropes for larger animals. Damage due to the death of livestock is estimated at $237,500, while damage to fencing and livestock equipment is estimated at $176,700. In the aftermath of the cyclone, with severe destruction to fencing and enclosures, herds of roaming escaped pigs and cattle caused further damage to the remaining viable food crops, as pigs dug and fed on tubers while cattle grazed on any remaining and sprouting shoots (FAO, 2014). Further to cyclones, severe droughts in 1983, 1998, 2006 and 2015 stunted growth in both sweet potatoes and coconuts (World Bank, 2021a). When droughts have occurred, farmers have seen their production of food reduced, or in some instances completely lost. This has created food security issues as well as loss of income which has further adversely impacted the economy and socio-economic development. Previous severe droughts have caused stunted growth in sweet potatoes, coconuts and most of the traditional root crops such as taro, yams, and cassava which make up a significant portion of people's diets. Droughts have adversely affected livestock, freshwater fisheries, and the health of people in the smaller islands of Ha'apai and Vava'u because is heavily dependent on rainwater (as groundwater has high levels of salinity).

In general, with increasing population and land pressures for urban development, the fallow periods have shortened and fertility has declined, further highlighting future vulnerability to agriculture production under increased drought periods and more El-Niño weather (World Bank, 2021a). Also, the predicted climate change impacts will create a new pest and disease regime, and therefore the need to develop improved pest and disease management program. A changing climate seems likely to further affect both the economy and people (through effects on livelihoods, food security and customary obligations) of Tonga (World Bank, 2021a). At the same time, an increase in sea surface temperatures will affect the fisheries resources dependent on the functioning of the reef ecosystem. If severe bleaching risk events occur more often than the projected recurrence interval, the long-term viability of coral reef ecosystems becomes threatened. The wider regional sea temperature and climatic changes also affect the migratory patterns of key food species such as tuna.

2.3.4 Infrastructure and water resources

Most buildings and major infrastructure developments in urban and rural areas throughout Tonga occur on vulnerable, low lying coastal areas that are at risks to climate change. Tonga's road and other drainage systems remain underdeveloped and ill-suited to cope with intense and frequent rainfall, or storm surge. The lack of appropriate drainage on some roads in Vava'u, for example, also causes large amounts of sedimentation to flow into coastal waters during heavy rain.

A rise in sea level will cause seawater intrusion, particularly in low lying coastal areas. Saltwater intrusion will be disastrous if it increases salinity in the groundwater lens therefore reduces the ability of sufficient freshwater for drinking purposes. A reduction in the area of freshwater lens due to erosion and subsequent land loss also exists.

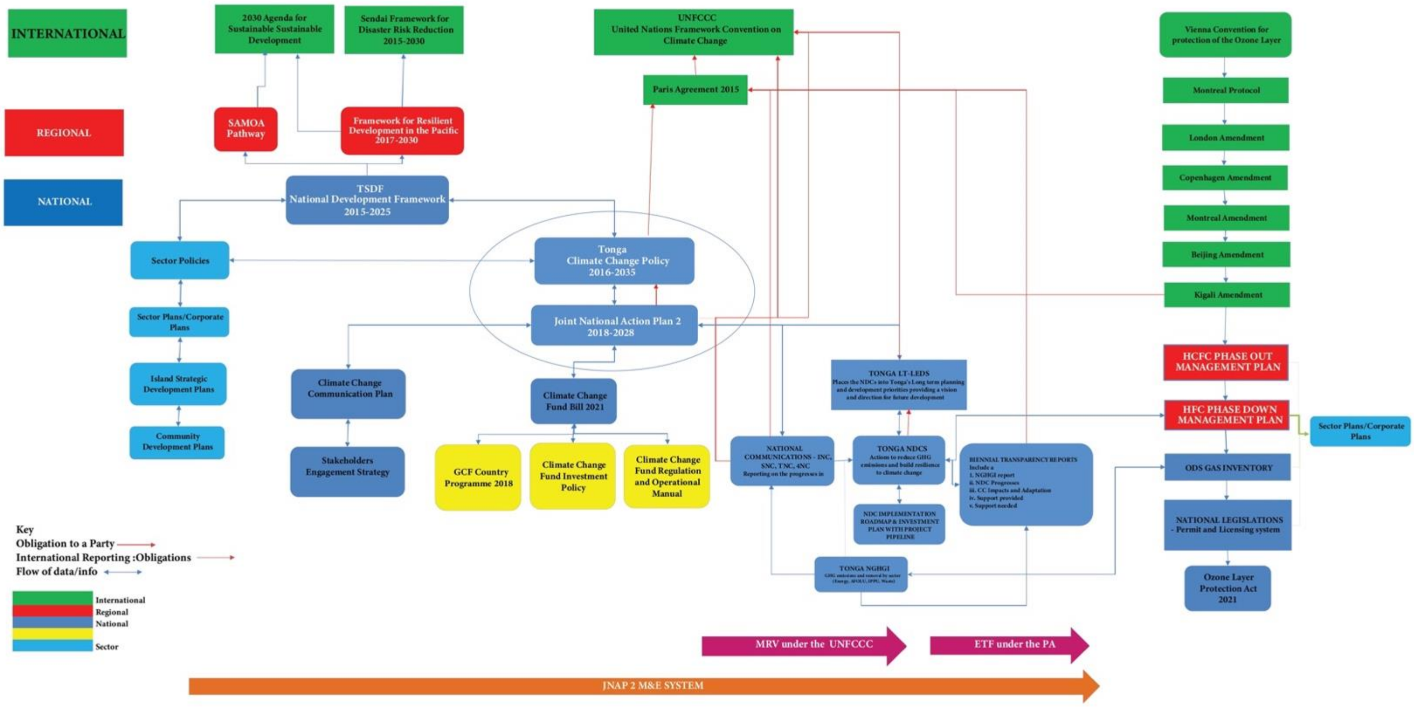
3. Policy and Institutional Frameworks related to climate-resilient development

The following sections set out the policy and institutional frameworks for climate resilient framework, and policy and strategy supporting sustainable and climate-resilient development for Tonga.

3.1 Climate Change-Related Policy Environment in Tonga

The Government of Tonga prioritises addressing vulnerability to the negative impacts of climate change on the sustainable development of the country and considers climate change and disaster risks to be of the highest priorities. The Government of Tonga has subsequently developed policy and planning instruments for managing disasters and addressing climate change. However, capacity and resource constraints undermine the delivery of integrated approaches across development sectors. This led to the Government of Tonga realizing that there was a real need for an integrated, comprehensive and whole of government approach to managing risk and addressing community-based issues. Ultimately these policies and strategies contribute to Tonga's broader objectives:

Figure 24 Chart of climate change policy landscape in Tonga



<u>National Climate Change Policy of 2006 and 2016:</u> The government's first effort to address climate change via government policy was in 2006 with the development of the National Climate Change Policy (NCCP). Since then, there has been significant changes to both Tonga's policy and regulatory landscape on CCDRM. The increasing priority of CCDRM has seen the emergence of numerous CCDRM-related policies and legislation. The NCCP of 2006 did not set out a process or timetable for achieving its strategies, which could be considered to be aspirational and broad statements of intent. The policy also does not contain specific outcomes or targets and does not refer to the role of sector plans in implementing climate change activities. That said, this policy was considered a major step forward and defined the position, direction, and responsibilities of the government and other stakeholders for the short and long term. The 2016 Tonga Climate Change Policy – A resilient Tonga by 2035, however, provided clear vision, goal, and objectives to direct responses to climate change and disaster risk reduction over the five years between 2016 and 2021/2. In 2016, the GoT made a comprehensive update to its initial National Climate Change Policy of 2006 to address the nation more fully is challenges with regard to climate change and disaster risks. Extensive consultations were held across Tonga and included all relevant stakeholders, including government ministries, NGOs, civil society organisations, and various special interest groups. These efforts resulted in the GoT publishing of the "Tonga Climate Change Policy - A Resilient Tonga by 2035". Building on the Climate Change Policy of 2006, a "Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management

2010-2015” (JNAP) was developed to ensure that the priorities of the policy were addressed and implemented at all levels. Tonga was the first country in the world to develop a JNAP. The Climate Change Policy 2016, also aligned with the revised JNAP.

The Climate Change Policy 2016 had three strategic goals:1). Strengthened integrated risk management to enhance climate and disaster resilience; 2). Low carbon development, and; 3). Strengthened disaster preparedness, response and recovery. The strategy also succeeded the existing separate regional frameworks on disasters and climate change (respectively, the Pacific Disaster Risk Reduction and Disaster Management Framework for Action, commonly referred to as the Regional Framework for Action or RFA, and the Pacific Islands Framework for Action on Climate Change (PIFACC)), which both ended in 2015 (MEIDECC, 2016). A ‘Resilient Tonga’ means an integrated approach to adaptation, mitigation and disaster risk reduction. The policy in particular sets out:

- The Vision statement: “A Tonga that is resilient to the impacts of climate change and climate-related disaster risks, and is able to protect and safeguard its present and future citizens.”
- The mission statement: “To develop a resilient Tonga through an inclusive, participatory approach that is based on good governance; builds knowledgeable, proactive communities, and supports a strong, sustainable development pathway.”
- The Policy goal: “The goal of the policy is to achieve the vision of a Resilient Tonga by 2035. This will be realized through the achievement of specific targets.”

Furthermore, it is intended to provide a guiding framework for the development of sector strategies. To achieve the goals, multi-sector coordination will be required. Notably, this policy clearly pronounces that the GoT “recognizes that climate change is the single biggest issue that will determine to future of Tonga and will require a ‘whole of Tonga level of cooperation and coordination” (MEIDECC, 2016). It is important to note that the policy is multi-faceted, cross-sectoral, gender-inclusive, equitable and strongly focused on community ownership with strong governance support. As building resilience to climate change cannot be achieved in a fragmented manner, a purposely holistic approach is being pursued.

<u>Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management 2010–2015; 2018-2028 (JNAP1 and 2)</u>: Tonga was the first country in the world to develop a Joint National Action Plan for Disaster Risk Management and Climate Change Adaptation combining both climate change adaptation and disaster risk management which was originally envisioned to be different plans (MEIDECC, 2016). The JNAP emerged when Tonga was simultaneously considering developing a Disaster Risk Management Action Plan while separately considering developing a National Adaptation Plan of Action for Climate Change (NAPA) under the UNFCCC and Pacific Islands Framework for Action on Climate Change. The Joint National Action Plan 2 on Climate Change and Disaster Risk Management (JNAP 2) 2018-2028 is Tonga’s National Adaptation Plan (NAP) for climate change, which sets out six policy objectives and targets and an implementation strategy for the country to achieve its vision of a Resilient Tonga by 2035. JNAP2 is aligned with the Tonga Climate Change Policy and covers both climate change adaptation and disaster risk management. The rationale behind combining climate change and disaster risk management was:

- An acknowledgment of the close linkages between climate change impacts and disaster risk management;
- The need to avoid/minimise duplication of efforts resulting from a plethora of standalone national policies, regional and international instruments;
- To increase efficiency in development efforts and maximise the use of limited resources.

The JNAP was developed within the context of Tonga’s national development and is aligned with its National Strategic Planning Framework which provides the overarching framework for development and resource allocation. More specifically, the JNAP highlights priority areas for Disaster Risk Management and Climate Change Adaptation over the next decade and provides directives to be taken. The six objectives of JANPA 2 are: 1) Mainstreaming for a resilient Tonga, 2) Implement a coordinated approach to research, monitoring and management of data and information, 3) Resilience-building response capacity, 4) Resilience-building actions, 5) Finance, and 6) Regional and international cooperation. These build on Tonga’s first Joint National Action Plan on Climate Change Adaption and Disaster Risk Management (JNAP 1) in 2010 and existing capacities and enhancing institutions already in place at national, sectoral, and community levels as well as the Outer Islands in planning processes for adaptation planning’. The JNAP is in alignment with the national, regional and international policy drivers, agreements and frameworks on climate change and disaster risk management. It highlights national and community priority goals and activities to be implemented to enable the people and environment of Tonga to adapt to the impacts of climate change and to mitigate disaster risks (GoT, 2018).

The JNAP 2 on Climate Change and Disaster Risk Management 2018-2028 Monitoring and Evaluation System Guide and the Monitoring and Evaluation Standard Operating Procedure (SOP) includes the monitoring of the extent to which resilience activities have been achieved via the assessment of process indicators; and the more evaluative exercise of determining if and how resilience activities changed vulnerability levels based on the assessment of outcome indicators. The outcome indicators' contribution to the achievement of the national sustainable development goals is identified as impact indicators and all three indicator classifications are mapped. Notably, the indicators most applicable to the Tonga Climate Resilience project are (and indicative selection are included below at Table 5):

- T1_2.2.3p: LIDAR surveys for all of Tonga complete
- T1_2.2.4p: Training on the management and use of the climate change portal and GIS-based systems completed (for all sectors)
- T1_2.3.2p: Monitoring system for currents, waves and ocean pH levels established
- T1,6&10_2.3.3p: Monitoring system for water, soil health and coastal erosion established
- T2&3_4.1.1p: *Tonga Coastal Resilience Project* replicated in outer islands;
- T3_3.6.7p: Strategies for the maintenance and adaptation of basic infrastructure and services (hospitals, roads, communication, water and sanitation, waste management) to climate stresses incorporated into CDPs
- T2&3_4.1.1p: *Tonga Coastal Resilience Project* replicated in outer islands;
- T12_1.4.1 Develop standard resilience guidelines for all community engagement activities;
- T12_1.4.3p: Resilient Tonga targets and vulnerability baselines11 incorporated into community development plans
- T12_1.4.4p Resilient Tonga targets and vulnerability baselines11 incorporated into all district and island development plans
- T12_1.4.3p: Resilient Tonga targets and vulnerability baselines11 incorporated into community development plans.

Table 5 - National indicators established for monitoring and evaluation under JNAP 2

Target 1 Indicators (Coast)

Process Indicators	(Proposed) Outcome Indicators	Impact Indicators
T1&4_1.3.1p: Vulnerability baselines for coastal sector developed. **T1_1.3.2p:** A costed and GESI factored resilient plan for coastal management developed. **T1, 4, 12_1.3.3p:** A multi-hazard disaster preparedness, response and recovery plans, including drill exercise for communities developed. **T1_1.3.6p** National coastal zone management plan and land use plan developed **T1,10,12_1.4.3p** Integrated water resource management plans for rural villages integrated with village specific national coastal zone and land-use **T1&4_2.1.5p:** Resilience indicators (process, outcomes and impacts) for the coastal sector developed. **T1_2.2.3p:** LIDAR surveys for all of Tonga complete **T1_2.2.4p:** Training on the management and use of the climate change portal and GIS-based systems completed (for all sectors) **T1_2.3.2p:** Monitoring system for currents, waves and ocean pH levels established **T1,6&10_2.3.3p:** Monitoring system for water, soil health and coastal erosion established **T1&8_4.1.5p:** Environmentally sensitive flood management response measures in 80% of coastal communities established	**T1_1o:** Number of people living below the poverty line that live in **flood prone** areas _T1/T12 **T1_1o:** Number of people living below the poverty line that live in **drought prone** areas _T1/T12 **T1_4o:** Number of businesses located in areas of flood/coastal erosion risk_T1 /T18 **T1_7o:** Number of properties lost due to coastal erosion per year _T1/T3/T12 **T4_6o:** Percentage of fisheries dependent households with livelihoods vulnerability reduced due to resilience-building activities.	**SDG 1.2.1** Proportion of population living below the national poverty line, by sex and age
T1_2o: Number of properties flooded per year _T3/T1/T12 **T1_3o:** Number of properties located in river/coastal floodplain_ T3/T1/T12 **T1_5o:** Number of hospitals located in areas at risk from flooding/coastal erosion _T1/T3/T21 **T1_13o:** Percentage of households at reduced flood risk due to construction of new or enhanced defences_T1/T3/T12 **T1_14o:** Reduction of flood damage and disaster relief costs due to increased standards for flood protection and improved flood emergency preparedness_T1/T3/T12 **T1_15o:** Number of new major infrastructure projects located in areas at risk_T1/T2/T3 **T1_16o:** Mangrove preservation and afforestation to improve a coastal community's resilience to disasters._T2/T8/T3 **T1_11o:** Number and magnitude *coastal* vulnerability problems perceived by local communities according to gender and age (T1/T12) **T1_12o:** Number and magnitude *coastal* vulnerability problems perceived by disabled and marginalized groups according to gender and age (T1/T12)	**SDG1.4.1** Proportion of population living in households with access to basic services	
T1_8o: Number of hectares of productive land lost to soil erosion _T1/T6	**SDG2.4.1** Proportion of agricultural area under productive and sustainable agriculture	

T1_10o: Total length of sewerage and drainage network at risk from climate hazards_T1/T3	**SDG 6.3.1** Proportion of wastewater safely treated
T1_9o: Acidification of marine water _T	**SDG14.3.1** Average marine acidity(pH) measured at agreed suite of representative sampling stations_T1/T8

Target 2 Indicators (Transport and Communications Infrastructure)

Process Indicators	(Proposed) Outcome Indicators	Impact Indicators
T2_1.3.1p: Vulnerability baselines for transportation and communications infrastructure developed. **T2_1.3.2p:** A costed and GESI factored resilient plan for transportation and communications infrastructure developed. **T2_1.3.3p:** A multi-hazard disaster preparedness, response and recovery plan for transportation and communications infrastructure developed. **1.3.11** Complete specific studies to determine the feasibility for Tonga to transition away from petrol and diesel (alternative sources) in the transport sector (shipping and vehicles); **T2_2.1.5p:** Resilience indicators (process, outcomes and impacts) for the transportation and communications infrastructure developed. **T2&3_4.1.1p:** *Tonga Coastal Resilience Project* replicated in outer islands; **T3_3.6.7p:** Strategies for the maintenance and adaptation of basic infrastructure and services (hospitals, roads, communication, water and sanitation, waste management) to climate stresses incorporated into CDPs **T2&3_4.1.1p:** *Tonga Coastal Resilience Project* replicated in outer islands;	**T2_1o:** Number and magnitude of *transportation and communications* related vulnerability problems perceived by local communities according to gender and age (T1/T12) **T2_2o:** Number and magnitude of *transportation and communications* related vulnerability problems perceived by disabled and marginalized groups according to gender and age (T1/T12) **T2_3o:** Percentage of climate resilient roads in the country	**SDG1.4.1** Proportion of population living in households with access to basic services

Target 12: Community Resilience

Process Indicators	(Proposed) Outcome Indicators	Impact Indicators
T12_1.3. 1p: Vulnerability baselines for community resilience developed. **T12_1.3.3p:** A multi-hazard disaster preparedness, response and recovery plan for community resilience developed. **T12_1.4.1** Develop standard resilience guidelines for all community engagement activities; **T12_1.4.3p:** Resilient Tonga targets and vulnerability baselines11 incorporated into community development plans	**T1_1o:** Number of people living below the poverty line that live in **flood prone** areas _T1/T12 **T1_1o:** Number of people living below the poverty line that live in **drought prone** areas _T1/T12 **T1_7o:** Number of properties lost due to coastal erosion per year _T1/T3/T12 **T4_6o:** Percentage of fisheries dependent households with livelihoods vulnerability reduced due to resilience-building activities.T4/T12	**SDG 1.2.1** Proportion of population living below the national poverty line, by sex and age
T12_1.4.4p Resilient Tonga targets and vulnerability baselines11 incorporated into all district and island development plans. **T12&T17_1.5.1p** Study to identify local knowledge regarding the distribution of responsibilities within the family in climate change adaptation and in preparation and response to natural disasters and climate stresses conducted12 **T12_1.5.2** Studies to estimate the cost of climate change and natural disasters impacts on community livelihoods. The case studies could be representatives of urban, rural and outer islands settings piloted12; **T1, T12 & T17_1.5.3** Study of scenarios of relocation due to climate change and natural disasters impacts taking into considerations gender perspectives conducted **T12_ 2.1.5p:** Resilience indicators (process, outcomes and impacts) for community resilience developed. **T12&22_2.1.7p:** Research on Traditional Knowledge on climate conducted and disseminated11 **T12_3.3.1p:** Community climate and disaster resilience awareness raising and behavioral change program for communities and households throughout Tonga developed and implemented **T12_3.3.2p:** Community climate and disaster resilience awareness raising and behavioral change program involving the arts and the media developed and implemented	**T1_2o:** Number of properties flooded per year _T3/T1/T12 **T1_3o:** Number of properties located in river/coastal floodplain_ T3/T1/T12 **T1_13o:** Percentage of households at reduced flood risk due to construction of new or enhanced defences_T1/T3/T12 **T1_14o:** Reduction of flood damage and disaster relief costs due to increased standards for flood protection and improved flood emergency preparedness_T1/T3/T12 **T1_15o:** Number of new major infrastructure projects located in areas at risk_T1/T2/T3 **T1_16o:** Mangrove preservation and afforestation to improve a coastal community's resilience to disasters._T2/T8/T3 **T1_11o:** Number and magnitude *coastal* vulnerability problems perceived by local communities according to gender and age (T1/T12) **T1_12o:** Number and magnitude *coastal* vulnerability problems perceived by disabled and marginalized groups according to gender and age (T1/T12)	**SDG1.4.1** Proportion of population living in households with access to basic services

T4_4o: Number and magnitude of *fisheries* related vulnerability problems perceived by local communities according to gender and age (T1/T12) **T4_5o:** Number and magnitude of *fisheries* related vulnerability problems perceived by disabled and marginalized groups according to gender and age (T1/T12)	**SDG14.7.1** Sustainable fisheries as a proportion of GDP in small island developing States, least developed countries and all countries_T4

Tonga Strategic Development Framework I (2011-2014) and Tongan Strategic Development Framework II 2015-2025: A more progressive Tonga: Enhancing Our Inheritance: The GoT initially developed a four-year Tonga Strategic Development Framework (TSDF I) with a vision for developing and promoting "a just, equitable and progressive society in which the people of Tonga enjoy good health, peace, harmony, and prosperity, in meeting their aspirations in life[3]". The Framework identified nine key outcome objectives and four enabling themes, with a series of strategies to achieve the vision. This has been updated with the second Tonga Strategic Development Framework (TSDF II). The second Tonga Strategic Development Framework (TSDF II) sets out the broad framework for Tonga's development over a 10-year period. The framework consists of the desired national impact, 7+1 National Outcomes and twenty-nine Organisational Outcomes, which, working together, will guide the development of Tonga until 2025. The Tonga Strategic Development Framework (TDSF) II, 2015–2025 guides the direction of infrastructure planning and development and sets out seven National Outcomes for a) a more inclusive, sustainable and dynamic knowledge-based economy; b) a more inclusive, sustainable and balanced urban and rural development across island groups; c) a more inclusive, sustainable and empowering human development with gender equality; d) a more inclusive, sustainable and responsive good-governance with law and order; e) a more inclusive, sustainable and successful provision and maintenance of infrastructure and technology; f) a more inclusive, sustainable and effective land administration, environment management, and resilience to climate and risk, and; g) a more inclusive, sustainable and consistent advancement of our external interests, security and sovereignty. TSDF II builds on recent developments and the lessons learned from TSDF I, reflecting an increasing understanding of future uncertainties and risks. Additionally, it builds on the ongoing reform process to build a more integrated planning and budgeting system and sets out a high-level integrated vision of the direction that Tonga seeks to pursue over the next ten years. In TSDF II, the GoT recognised that building greater resilience to existing and future extreme natural events and climate change impacts is essential to its sustainable development. These threats require Tonga to become better at planning as well as responding to the unexpected.

In TSDF II, the vision that was created in TSDF I has been simplified and merged into a more tightly articulated set of "National Outcomes" which are supported by clear "Organisational Outcomes". These Organisational Outcomes provide guidance to government Ministries, Departments and Agencies (MDAs), and other organisations on the Organisational Outputs they must deliver. Defining the Organisational Outputs to contribute to the Organisational Outcomes is the responsibility of sector and corporate planning. The Outputs should be fully articulated in MDA Corporate Plans, align with the Outcomes, and be fully in balance with the available funding in their Budgets. The GoT effort to build resilience to climate change is outlined in "Organisational Outcome 5.4: Improved national and community resilience to the potential disruption and damage to wellbeing, growth and development from extreme natural events and climate change, including extreme weather, climate and ocean events, with a particular focus on the likely increase in such events with climate change."[4] Also prioritised in TSDF II is a pillar on Infrastructure and Technology related to natural resources and the environment. TSDF II notes the need to build strong, knowledge-based, sustainable and inclusive institutions and that utilise a variety of technology and infrastructure inputs to protect the islands and particularly the coasts effectively.

Sub-National Policy Framework

Tonga's sub-national policy framework is currently subject to a major reform initiative lead by the Ministry of Internal Affairs (MIA). The MIA, as a ministry, was established in 2012 is currently working through a 'bottom-up' development planning process to improve government systems at the local government all the way down to the district and village level. The aim is to create an integrated government that is responsive to community needs. Historically, Tonga's approach to government planning has been top-down whereby the distribution of services and information is filtered downward from the national government to the provinces, districts, and communities. Policy and planning at the sub-national level in Tonga concerning CCDRM are relatively new. However, it has quickly emerged as a priority at provincial, district, and community levels. The success in establishing CCDRM as a priority at the local level is the result of numerous donor-funded initiatives on designing and mainstreaming CCDRM at these subnational levels. In general, these initiatives have been implemented by CSO and NGO groups. However, the CCDRM plans developed through these initiatives exist separately and independently of the mainstream community development plans at local government, district

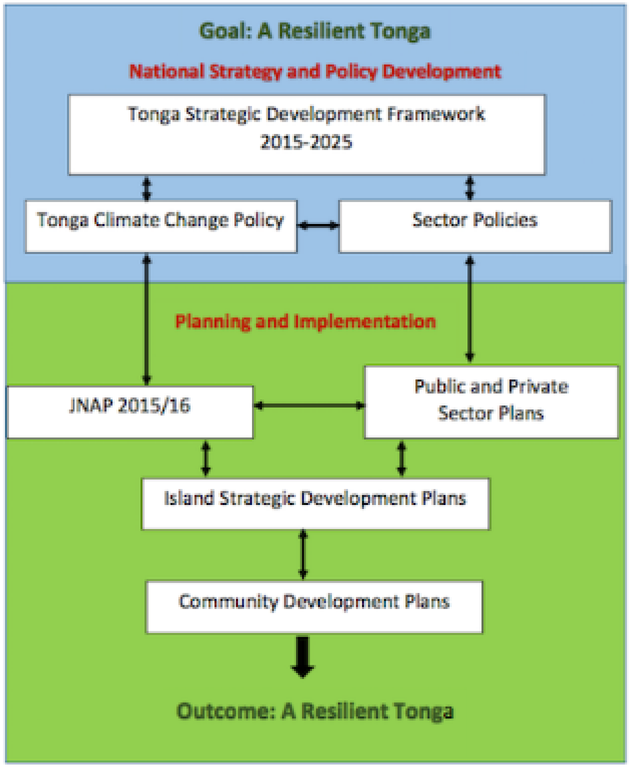
[3] Tonga Strategic Development Framework 2011-2014
[4] Tonga Strategic Development Framework II

and village level. As such, integration of CCDRM into sub-national and local level development planning (vertical integration) is an important response for improved risk governance in Tonga. The CCDRM has been integrated into 44 Community Development Plans across and 5 District's Development Plans across Tonga.

4. Institutional Framework

The government has recently made a strategic decision to evolve the policy planning to be a simultaneous top-down and bottom-up effort and process. This approach is believed to be more holistic and effective to mainstreaming and streamlining Climate Change and Disaster Risk Management (CCDRM) both horizontally across government, and vertically from parliament to the community, and from the community to parliament. Such a holistic approach not only advocates a 'whole of country' input into the planning and decision-making process, but also sets a platform from which improved consistency in the planning process can be achieved. A visual illustration of this process is below.

Figure 25 - National strategy and policy development, illustrates a simultaneous top-down and bottom-up approach to policy making.



Source: Tonga Climate Change Policy 2015

4.1 Institutional at National Level

Ministry of Finance and National Planning (Treasury): The Ministry of Finance and National Planning is the central institution responsible for managing and allocating the national budget.

Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC): MEIDECC is led by the Deputy Prime Minister of Tonga, illustrating the importance of the Ministry in the Government system. Their overall mandate is to provide policy advice on the administration of environment and climate change. MEIDECC comprises seven departments: the Department of Meteorology; the Department of Energy, the Department of Information; the Department of Disaster Management; the Department of Environment, the Department of Climate Change and the Department of Communications. The National Emergency Management Office (NEMO) is also housed within MEIDECC. The Department of Climate Change (DCC) will be appointed as the National Implementing Partner (UNDP Terminology) / Executing Entity (GCF Terminology) of the Project. The Department of Climate Change is mandated to coordinate and oversee all climate change-related activities in Tonga. The DCC also serves as the secretariat for the JNAP, which includes responsibility for coordinating Government and non-government entities to achieve, monitor, and evaluate JNAP objectives. As the proposed GCF project has been designed to respond to JNAP priority, DCC is best placed to provide the overall project ownership and oversee activities.

Ministry of Lands, Surveys, Natural Resources and Environment
The principal role of the Ministry of Lands, Surveys, Natural Resources and Environment is managing lands, mineral resources and energy for the benefit of all its stakeholders and developing and implementing programmes for the environment. The Ministry's activities are carried out through operations and technical support services such as survey, draughting, computing, physical planning, and geology. The Ministry of

Lands, Environment, Climate Change and Natural Resources in collaboration with the Ministry of Infrastructure, is responsible for compliance with the National Emergency Management Act, Implementation of National Disaster Plan and mainstreaming Disaster Risk Management through a Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management.

Ministry of Internal Affairs
Established in 2012, the Ministry of Internal Affairs is responsible for leading Tonga's sub-national policy framework and integrating government from the national to the community level. The MIA is the window to subnational communities and a gatekeeper to island development and community development plans. The MIA is an implementation partner for capacity development programs involving local governments and communities.

Ministry of Infrastructure
Ministry of Infrastructure is responsible for providing and maintaining Tonga's infrastructure, including all forms of transport infrastructure and building and construction codes. Its core objectives are: (i) to create an appropriate system of rules, regulations and enforcement, consistent with Tongan law and international standards, to guide the safe and secure operations of maritime services, civil aviation, and land transport; (ii) create and manage an appropriate system of rules, regulations and enforcement to guide safe and environmentally sound building and construction in Tonga; (iii) to provide vehicle maintenance, mechanical and engineering services, as well as quarry and heavy plant services for government and public use. The Ministry of Infrastructure, in collaboration with Ministry of Lands, Environment, Climate Change and Natural Resources, is responsible for compliance with the National Emergency Management Act, Implementation of the National Disaster Plan and mainstreaming Disaster Risk Management through the JNAP on Climate Change Adaptation and Disaster Risk Management. The Ministry of Infrastructure is both an operator and a regulator.

Tonga Meteorological Service
The Tonga Meteorological Service provides regional and national weather and climate forecasts, summaries, satellite imagery, aviation weather services, coast watch services and access to numerical models for meteorological and climatological purposes.

4.1 Institutional at sub-national and local levels

Community-based organisations (CBOs)
Community and faith-based groups and churches have long been a distinctive feature of civil society organizations in Tonga. Hence, the development of civil society in Tonga is closely aligned with the historical role of the country's churches, the changing nature of rank and the monarchy, and the transition toward democracy. Community-based organizations play a key role in governance and this GCF funding proposal in that they will support the implementation of JNAP and provide feedback to assist in monitoring and evaluation. Particularly, the Civil Society Forum of Tonga (CSFT), which was established in 2001 to address and coordinate the needs and collective roles of Civil Society Organisations (CSO's), and to better serve their communities. Sincit's establishment in 2001, the Government of Tonga has recognised the potential of CSFT in taking the lead role for the involvement of Non-Governmental Organisations on Political, Social and Economic activities that leads to sustainable development economic growth and income generation. CDFT recognizes the Rights of people-centered development through empowering participation, locally-led initiatives, inclusive partnership, equality participation & inclusive prosperity for all (people of Tonga) and endeavor to build accountable and transparent institutions that create self-reliance and opportunities for resource mobilization within CSO sectors and the communities.

Non-governmental organizations
The Tonga Community Development Trust (TCDT) is an indigenous, non-governmental development organization operating in the Kingdom of Tonga. TCDT's focus is on capacity building with special attention on the less developed, more disadvantaged communities of Tonga including the poorest of the poor. Their projects are focused on Family and Community Health; Rural Water Supply and Sanitation; Sustainable Development; Environmental Conservation; Disaster Preparedness; Women in Development; Human Rights; Good Governance, Civic Education and Voter Education.

The Private Sector

The Tongan economy has been underperforming for more than a decade. The productivity of both labour and capital has been low, resulting in poor returns on investment. Few new businesses have started, and existing ones have been slow to expand. Job creation has been insufficient to employ the growing number of new school leavers looking for work, and, after adjusting for inflation, wages and salaries have not risen. This has led many Tongans to seek opportunities overseas. As a result, more Tongans live in other countries than in Tonga. Since many emigrants are highly skilled, this is a serious loss to a country of only 100,000 people. The growth of Tonga's private sector has been hampered by a number of constraints, which have resulted in the low productivity of investment.

Institutional framework for decision making in land management

Tonga has a unique system of land ownership and management. Land in Tonga is administered by the laws as defined by the Land Act of Tonga which went into effect in 1875 but has been amended recently. The Minister of Lands, Surveys, Natural Resources and Environment is the representative of the Crown in all matters concerning land in the Kingdom of Tonga. According to the Land Act of Tonga, the Minister is responsible for granting leases and permits and does so with the consent of the Cabinet. The foreshore is the property of the Crown. Changes, additions, or developments to the foreshore must have the approval of the Minister of Lands. Tonga's people are divided into two main classes: the nobles and the commoners. These two classes have long differed in political and land rights. The two-class system has resulted in friction between the two groups. The friction lies primarily with the commoners who feel disenfranchised and disadvantaged by the system. The modern Tongan constitution also greatly restricts women's ability to lease land by reserving land ownership exclusively for the crown (Tecun & Ata Siuʻulua, 2023). There have been outbreaks of violence in the past, such as the riots of 2006 in Nukuʻalofa. Additionally, there have been commoner-led pro-democracy movements. The efforts of the commoners have led to the amending of the Constitution to allow commoners to vote for more of the members of the Legislative Assembly. The resulting government and the noblemen have not, however, shown a commitment to land reform in favour of commoners, and it is unlikely that the recent amendments will result in changes to the land tenure system. The rising population and declining land productivity within a context of insecure land rights have prompted individuals to engage in conflict with the government and nobility, both of which have become less powerful.

Institutional framework for decision-making for development

In Tonga, the decision-making framework has evolved over the last two decades as reforms have been implemented and as the national government has attempted to be more progressive and inclusive in decision making and planning.

The Local Government and Community Development Division of the Ministry of Internal Affairs (MIA) has responsibility for overseeing the development and integration of Community Development Plans (CDP's). Community Development Plans have evolved over the years and now require the incorporation of key priorities of climate change and disaster risk management (as well as gender and social inclusion). CDP's feed into District Development Plans, which subsequently are incorporated into Island Development Plans.

5 Past and ongoing efforts to improve climate resilience for coastal environments

Due to Tonga's high vulnerability, the GoT has been developing an institutional policy framework to respond to climate change threats effectively. For example, they have formulated the National Climate Change Policy, and JNAP (I and II) as the implementing tools for the policy and established the JNAP Secretariat within MEIDECC, later upgraded as the Climate Change Department. One of the GoT's primary intents for developing policies, action plans and institutions is to guide donors on where to concentrate development resources, as opposed to donors duplicating pre-existing efforts or, conversely, standalone efforts that are not supported or aligned by the national development priorities. Increasingly, donors are attempting to align their efforts with the JNAP structure. Recent projects and programs that aim at building resilience are, by and large, in line with various priorities in JNAP. Projects and programs listed in this section are some examples of those relevant to this proposed GCF-supported project or provide the foundation for this project by providing either data or investing in complementary vulnerability reduction measures and/or raising community awareness.

5.1 An overview of past and ongoing projects aimed at reducing coastal vulnerability

The Tonga Climate Resilience Sector Project (CRSP), Asian Development Bank, 2013-2019: This project was funded by the ADB (US$ 20 million) with co-financing from the Government of Tonga (GoT - US$ 3.88 million). The project aimed to implement the Strategic Program for Climate Resilience (SPCR) prepared by GoT under phase II of the Pilot Program for Climate Resilience (PPCR). The CRSP Project contributed some coastal protection measures in the Hahake area, and the current project will complement the earlier work and has adopted lessons regarding revetment design and community consultation. The Project was also focused on mainstreaming climate resilience into development planning and addressing country priorities, focusing on the most vulnerable sectors and communities. The project aimed to (i) build capacity in climate change adaptation and disaster risk management at community, sector and national levels; (ii) provide information, tools, and legislative frameworks needed to introduce climate change considerations into government and sector planning and budgeting processes; and (iii) provide access to resources (technical, human, financial) to implement appropriate adaptation infrastructure on the part of high a risk coastal areas on the Hahake area of Tongatapu. The proposed GCF project is complementary to CRSP investment by: Providing the policy underpinning for future decision-making on coastal / climate risks and; Complementing the CRSP investment by completing the most urgent coastal protection needs in Hakake peninsula through an additional 4 km of coastline adaptation/protection measures.

Under the Tonga Integrated Urban Resilience Sector Project (TIURSP), ADB plans to support the Government to manage current flood risk and increase the resilience of the Nuku'alofa urban area. For this purpose, a 'Climate and Disaster Resilient Urban Development Strategy and Investment Plan' is being developed, including a long-term adaptation pathway for Nuku'alofa which will enable continued development of the city in a manner resilient to natural hazards. To effectively prioritise components of the future strategy – e.g. investment in infrastructure for the most high-risk and/or ecologically sensitive locations, combined with other adaptation strategies such as changes in building policies, relocation or reclassification of urban areas, etc., the ADB and the GoT require a detailed assessment of hazard, exposure and risk for Tongatapu island. The project to complete these assessments is known as the Multi-Hazard Disaster Risk Assessment (MHDRA) provides the basis for decision-making by estimating the cost of damage and the number of people and assets at risk of inundation, tsunami, wind, and seismic hazards, including the impact of climate change, at a range of return periods.

The Asian Development Bank (ADB) Multihazard Disaster Risk Assessment (2021) of Tongatapu assessed multiple natural hazards in the capital city, Nuku'alofa, and the entire island where it is located, Tongatapu. This has provided a significant basis for providing the vulnerability assessments for Tongatapu.

The IFAD Tonga Rural Innovation Project completed in 2017, supported the development of 151 Community Development Plans (CDPs) between 2015 and 2017, supporting 13,238 direct beneficiaries.

The EU funded (€12 million) Intra-ACP GCCA+ Pacific Adaptation to Climate Change and Resilience Building (PACRES), 2018 – 2023, working with the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communication (MEIDECC), to build the capacity of Tongans to adapt to climate change and continue to build their resilience focused on the development of climate change and disaster resilience information and knowledge management products to enhance community awareness about the harmful impact of climate change. This includes under JNAP 1, Tonga's climate change portal, hosted by MEIDECC: https://www.climatechange.gov.to/ Output 2 supports the climate change information and knowledge management products to enhance community awareness about the harmful impact of climate change developed under PACRES by providing the critical technical capacity for tools and for climate information and knowledge management.

The Global Climate Change Alliance Plus Scaling Up Pacific Adaptation (GCCA+SUPA), 2019-2022: The project's overall objective is for a holistic approach to coastal protection in northern Tongatapu to be adopted by the government. The objective is to equip communities better to undertake small-scale coastal protection measures (hard and soft engineering). The three key result areas are (1) Conduct a coastal assessment, feasibility and conceptual design study for coastal protection along the entire north coast of Tongatapu (Niutoua to Ha'atafu); (2) Implement small-scale coastal protection and ecosystem-based measures in northwest Tongatapu (Sopu to Ha'atafu); and (3) Enhance awareness about the impact of climate change and natural disasters in Tonga.

Trialling coastal protection measures in Western Tongatapu Project, European Union, 2016-2018: was also funded by the European Union (EUR 550,000) and implemented by GIZ, this project has the overall objective of increasing the resilience of six coastal communities in western Tongatapu to climate change impacts and sustaining livelihoods in those communities. There are four targeted outcomes: (i) Reduced climate change vulnerability and enhanced adaptive capacity, focusing on coastal protection and management; (ii) Enhanced education and awareness on coastal management in the context of climate change; (iii) Effective monitoring of the coastal protection measures, in collaboration with key stakeholders and other related projects and programs; (iv) Strengthened partnerships of the project with communities. Building on the trials from the Eastern Tongatapu (see below), a suite of interventions was designed which included: (i) construction of bamboo groynes; (ii) two new mangrove nurseries protected by the groynes; (iii) construction of geosynthetic sandbag defences to form secondary flood barriers within the backwaters of the wetland lagoon areas.

Trialling Coastal Protection Measures in eastern Tongatapu, European Union, 2013-2015: This project was also funded the European Union (EUR 500,000) and executed by the Pacific Community (SPC) as part of the Global Climate Change Alliance: Pacific Small Island States (GCCA: PSIS) programming. The project focused on designing, building, and monitoring 'hard' and 'soft' engineering measures working in combination along two coastal stretches in eastern Tongatapu. One measure consisted of the construction of permeable groynes coupled with beach replenishment and coastal planting. The second measure involves constructing short offshore breakwaters combined with beach replenishment, and coastal planting. 'Trialling coastal protection measures in eastern Tongatapu' focuses on design, building and monitoring the success of 'hard' and 'soft' engineering measures working in combination along two coastal stretches. One measure consists of the construction of permeable groynes coupled with beach replenishment and coastal planting. The second measure involves constructing short offshore breakwaters combined with beach replenishment and coastal planting. Several villages, stretching from Nukuleka to Kolonga, in eastern Tongatapu, were identified as needing priority action in Tonga's JNAP. The project therefore responded to the identified need by trialling different engineering methods to prograde the coastline seaward by accumulating sediment. The idea was that a successful outcome will increase the amount of time that these affected villages have for planning for the projected impacts of climate change. The final evaluation report and its case study acknowledged that the initial monitoring data provided an indication of likely success, and yet, that the measures implemented "only provide short-medium term protection from coastal erosion and rising sea levels[5]."

The Australian Government's Governance for Resilient Development in the Pacific Program (Gov4Res) (Australian contribution $7.9 million, 2019-2023) supports national and local governments and communities, as well as regional organisations, to strengthen decision-making processes and governance systems towards risk informed and resilient development of which UNDP's proposed project will also support outcomes, given the enhanced access to technical capacity building and training for government staff, for climate-risk informed decision making under Output 2.

The Pacific Risk Resilience Programme (PRRP), Australian Govt, UNDP and Live and Learn Environmental Education, 2012-2018: The PRRP was a US $14 million program aimed at helping build the national and regional risk governance enabling environment to improve the resilience of Pacific communities to climate

[5] See for further information: Pritchard, M. & D. Sweeney. (2016). Global Climate Change Alliance: Pacific Small Island States Case Study – Best practice coastal protection in Tonga, p2.http://www.gcfund.org/fileadmin/00_customer/documents/Operations/5.3_Initial_PMF.pdf

change and disasters. Lessons learned from the project included identifying the need to: build on national and sub-national linkages, foster a network of skilled and experienced personnel in Tonga, and ensure the project work is 'anchored' and has a sufficiently footprint within government structures to be sustained over time (PRRP mid-term evaluation 2017). The Program is organized on three outcome areas for national implementation under one coordinated program: (i) CCDRM considerations are integrated into coherent cross-sectoral development planning, budgeting and performance frameworks; (i) participating countries integrate CCDRM considerations into sub-national and community needs assessment, planning, budgeting, and performance frameworks; and (iii) internal and external stakeholders use quality, credible information generated by the Programme to inform their readiness for, adoption of, or commitment to effective risk governance. The program is funded by the Australian Government through a partnership between UNDP and the international NGO, Live and Learn Environmental Education (LLEE).

The Climate resilient marine spatial planning project (2022-2026) is also underway to assist in developing marine spatial plans (MSP) informed by the best scientific information available, including climate change scenarios, paving the way to a sustainable, inclusive, and resilient ocean-based economic development.

The Integrated Environmental Management of the Fanga'uta Lagoon Catchment - As part of the GEF Ridge to Reef program and UNDP, 2015-2017:_This program (US$ 1.76 million) was part of the Pacific Islands Ridge-to-Reef National Priorities program (R2R) of GEF. The R2R program serves as a global test case and programmatic initiative involving multiple United Nations, Regional and National agencies, and Pacific Small Island Developing States (PacSIDS) to support and address national priorities and development needs while delivering global environmental benefits in line with GEF focal area strategies - Biodiversity, Land Degradation, Climate Change Adaptation and Mitigation, International Waters and Sustainable Forest Management. This GEF program was supported with US$ 91 million of GEF grants and US$ 333 million of co-financing from the participating countries and other development partners. The program's goals are to maintain and enhance the ecosystems of Pacific Island countries through integrated approaches to land, water, forest, biodiversity and coastal resource management that contribute to poverty reduction, sustainable livelihoods and climate resilience. The R2R aimed to maintain and enhance the ecosystem goods and services through integrated approaches to land, water, forest, biodiversity and coastal resource management that contribute to poverty reduction, sustainable livelihoods and climate resilience in Pacific Island countries. There is a second phase of the project Ridge to Reef Phase II funded by GEF (USD 16.25 million) under MIEDECC and UNDP's Implementation which implements the Fanga'uta Lagoon Stewardship Plan and replicates lessons learned from the Tonga R2R Phase I to priority areas in Vava'u. Phase II conserves the wetland ecosystems that support the lives and livelihoods of local communities, the project aims to implement an integrated strategy to prevent and manage unsustainable and destructive activities that reduces the risks to Tonga's indigenous marine species and ecosystems from threats such as habitat loss, degradation, overexploitation, invasive species, pollution, and climate change. The objective of the project is "to effectively implement the Fanga'uta Stewardship Plan (FSP) for strengthened, integrated and inclusive management of the Fanga'uta Lagoon, and replicate successful strategies and lessons learned from the Tonga R2R Phase I to priority areas in Vava'u".

Mangrove Ecosystems for Climate Change Adaptation and Livelihoods (MESCAL) Project, 2011-2014: This project was supported by the International Union for the Conservation of Nature (IUCN) and funded by the governments of Italy and Austria. This project focused on community livelihoods and mangrove conservation for an enhanced ecosystem and improved coastal resilience. The review found that the mapping of mangrove areas indicated mangrove coverage to be substantially larger than previously reported. Furthermore, 10 species of mangroves were confirmed to be in existence in Tonga, as opposed to eight as previously reported.

6 Current barriers and needs – constraints to improve climate resilience

This section describes key existing barriers in addressing climate change and coastal protection in Tonga that guide the project design.

6.1 Barrier 1: Lack of climate-informed land use planning, including dialogue and discussions regarding solutions to internal migration.

6.1.1 Lack of climate-informed land-use planning, including dialogue and discussions regarding solutions for internal migration

Climate-informed land use plans ideally consider various risks, such as future sea-level rise and storm surge risk areas under different climate scenarios and return periods. In Tonga, some coastal communities in highly exposed locations will likely have to move away before the sea level reaches their doorsteps, or more realistically, damages from extreme wave events become too frequent to bear. Yet, in Tonga, such an analysis of future risks and expected damages has not been undertaken and in many locations outside of the island of Tongatapu, and those that have been now out of date/not current, undermining the ability to develop a data-informed understanding of vulnerability or where safe locations may exist. Complex land ownership dynamics and other social and institutional reasons have also prevented a sound, consensus-driven, climate-informed intergenerational strategic land use plan from emerging. The process of informing all stakeholders and obtaining consensus necessarily needs to be a bottom-up, dialogue-based process but a platform for enabling such dialogue does not currently exist. Therefore, there is an urgent need to address this barrier to enable island-wide discussions on effective climate-informed land use planning that would provide a long-term solution for the vulnerable communities in Tonga.

Key national and external documents have highlighted the need for a broader planning approach to climate resilience and land-use:

- JNAP 2 identifies the need for 'fully coordinated and streamlined resilience planning approaches implemented across government ministries' and proposes the specific actions to 'develop a national coastal zone management plan and national land use plan integrating the adapted JNAP targets for a *Resilient Tonga'*

- The International Monetary Fund's (IMF) Climate Policy Assessment for Tonga (2020) recommends that Tonga 'improve, enact and enforce climate-informed building and <u>land-use codes</u>' in the short term (emphasis added).

6.1.2 Internal immigration – implications for use of coastal land

Migration, including planned resettlement, is increasingly occurring in small islands to intentionally respond to or prepare for climate change impacts (IPCC, 2021). However, strong cultural connection to land and uncertainty about life in receiving countries means that many remain opposed to permanent migration. Migrant agency and choice in decisions about whether to move, where, when and how is an important determinant of success for this strategy (ICEDS, 2022a). Furthermore, domestic relocation inland is often preferred over international migration. Two case studies of community relocation in Fiji highlight that including all social groups in the relocation planning process will strengthen adaptation outcomes. Government frameworks can also guide the relocation process and foster success as is seen in the Government of Fiji's relocation framework (ICEDS, 2022b). Tonga's Third National Communication[6] (TNC) identifies a clear trend of population movement into coastal and low-lying areas associated with people moving into Nuku'alofa from other areas of Tongatapu and from outer islands. This has changed the pattern of land use, for example through habitation and plantation agriculture in formally unoccupied areas and has a number of short term effects, including from fertilizer use and run-off that can impact adjacent ecosystems. The population of Tongatapu is projected to grow over the next decade with Tongans commonly relocating from the outlying islands to Tongatapu. While all forms of internal migration occur in Tonga (rural to urban, rural to rural, urban

[6] Third National Communication to the UNFCCC

to rural and urban to urban) the predominant trend in Tonga (and indeed globally) is rural to urban (TWG MSDP, 2021). Comparisons between the 2021 Census data from the 2016 Census data, for example, showed this trend of in-migration (11,153) to be far greater than out-migration (3,717). While in Vava'u, in-migration (1,713) was much lower than out-migration (6,039), and a similar trend was found in Ha'apai in-migration (1,551) and out-migration (5,003), 'Eua in-migration (1,739) and out-migration (1,535) and Ongo Niua in-migration (382) and out-migration (244) (TWG MSDP, 2021). Paid work, education, health care and other opportunities associated with the capital city, drive relocation from other less well developed or productive parts of the archipelago. At the same time, it is expected that communities from other smaller, low laying islands and settlements will also become increasingly challenged by met-ocean hazards associated with climate change, which in turn is expected to increasingly drive relocation. Displacement has also been an issue due to disaster impacts, such as the 2022 tsunami, and is likely to continue, with significant and long-term displacements clearly requiring multi-stakeholder and cross-ministerial response in the delivery of public services and the management of community interests and expectations. Prior to the 2022 tsunami, the need for government agencies to plan for the continued increase in the population of Nukualofa and Tongatapu and the implications of internal migration shifts for land use, spatial planning, housing and Government services was well-noted within Tonga's Migration and Sustainable Development Policy (TWG MSDP, 2021). At the same time, aside from fast-hitting climate and non-climate related disaster events, climate-induced slow onset processes like coastal erosion, ocean acidification and other forms of environmental degradation in the medium term will drive both forced and voluntary internal movements in Tonga (TWG MSDP, 2021). In extreme cases, destruction of habitat and agricultural viability reduces the prospects for return to the home environment and increases the impetus for long term internal and/or outward migration which may also be perceived as displacement (TWG MSDP, 2021). Most notably, the influx of new settlers to Tongatapu is resulting in ever greater strain on land resources around the capital Nuku'alofa and increasing patterns of settlement into marginal, low-lying and highly flood exposed areas such as Nukuleka.

More importantly, sea level rise will, in the foreseeable future, make the most vulnerable of these areas uninhabitable, and 'infrastructure and homes would be lost'. Consequently, there is a need to ensure that development avoids high risk areas prone to future SLR induced flood inundation. This is an issue that requires urgent consideration and must be delt with conclusively in respect to long term solutions. Any future Coastal Development Planning needs to acknowledge this in terms of its policy setting into the future. Furthermore, Tonga must address adaptation needs from the nuanced perspective of RCP8.5 sea level rise trends, interrelated risk of extreme waves and meteorological/oceanic events, and strategically consider contemporary shoreline stress issues considering future projections. Creating the regulatory and social framework to address this issue requires more than a 'coastal management plan' as this needs to be in a broader framework that also addresses use of land away from the coast to plan for alternative locations for housing and other uses. Further, there is a need to engage widely with communities to engender social acceptance of future changes to the regulatory / planning regime, especially considering the specific land tenure arrangements that apply in Tonga. This points to the need for a broad commitment to climate-informed land use planning.

6.2 Barrier 2: Technical capacity gap within government ministries to collect, analyse and use climate risk data that is required to mainstream climate risks into national policy design and coastal planning

Lack of capacity to collect, analyse and use climate risk data that is required to mainstream climate risks into national policy design and coastal planning: There is a lack of technical capacity in government agencies in relation to the establishment of baseline data, data management, and conducting monitoring and evaluation, to support coastal resilience adaptation and land use planning. This barrier prevents an empirical evidence-based decision-making process; as a result, adaptation decisions are often guided by budget availability rather than technical feasibility. The IMF Climate Policy Report (2020) states that 'efforts [to incorporate climate change risks in national planning] are generally ad-hoc and information is not comprehensively shared. Hazard and risk-informed land use planning information could usefully be strengthened and better disseminated. The information that does exist is scattered across several Ministries including MEIDECC, Ministry of Lands and Natural Resources and the Ministry of Infrastructure. Strengthening information and awareness of climate and disaster risks can help ministries prioritize, plan and potentially minimize costs of reconstruction, particularly for assets located in high-risk areas'. This project seeks to build Tonga's technical capacity in climate risk data collection and management, strengthening Tonga's ability to select long-term and medium-term adaptation interventions by prioritizing high-risk areas. Increased technical capacity will also build a central repository of empirical experience in ecosystem-based coastal adaptation in Tonga, and the surrounding islands of the Pacific, through the project interventions. An important downstream effect resulting from this lack of capacity/data, is that communities facing immediate and evident climate-related hazards find it difficult to make a case for resources to ensure coastal protection in their locality. This can create anxiety and a sense of helplessness among community members, and often prompts desperate actions that are not cost-effective (i.e. numerous attempts of community members piling sandbags along the foreshore) or, in the worst-case scenario, are maladaptive and potentially undermine the long-term resilience of the community.

6.3 Barrier 3: Limited capacity of local community actors to develop and design bottom-up community plans for implementing climate-responsive and climate risk-informed solutions

For building long-term resilience of the country to ever-increasing climate risks, it is critical that local communities' understanding, and capacities grow in concurrence with technical capacity strengthening efforts for the central government agencies. Yet, the efforts to build capacity in Tongan communities and community/district agencies, as well as mobilizing necessary funding for community actions, have only begun recently. The development of Community Development Plans (CDP) represents baseline efforts that the Ministry of Internal Affairs (MIA) has been leading and, to date, all rural communities have formulated, or in the process of formulating, a CDP. MIA intends to strengthen their support to communities in undertaking climate vulnerability assessments, adaptation and gender needs assessments and assisting communities in mobilizing funds from, for example, the Tonga Trust Fund, but local actors' capacities remain limited. Tonga's Joint National Action Plan 2 on climate change and disaster risk management 2018-2028 (JNAP 2), observed that there is 'no explicit consideration of CCA and DRM but many issues identified in the CDPs that are relevant within a resilience building context'. This highlights the need for support for specific inclusion of these issues into community planning.

6.4 Barrier 4: Weak institutional capacity and coordination to implement an integrated cross-sectoral approach to coastal resilience

6.4.1 Weak institutional capacity and coordination to implement an integrated cross-sectoral approach to coastline resilience

Past approaches to coastal vulnerability reduction (i.e. donor-dependent, isolated, engineering-oriented interventions), have required little coordination between ministries and between government and communities. Coastal assessments and construction have been typically outsourced to international technical agencies, leaving little need for agencies like MoLSNR, Department of Climate Change, Met Department and Department of Environment to coordinate with each other. The engineering-oriented approach typically leaves little scope for local community engagement in the maintenance of the structure. Yet, new coordination requirements emerge as Tonga embarks upon a new pathway to long-term vulnerability reduction and resilience building (in which the Government and community must take a much more proactive role in identifying and implementing solutions to their problems). For example, as the technical barrier for data collection on coastal parameters is simultaneously removed (see barrier #2), relevant agencies such as MoLSNR, Met Department and Department of Environment must work much more closely together to share information about coastal processes, climate models and ecosystem functions. However, mechanisms to facilitate such multi-ministerial coordination - such as a data-sharing protocol and community engagement beyond the project lifespan- are currently weak.

6.4.2 Technical / design models and capacity

Experience in Tonga has shown that the use of ineffective and poorly designed coastal protection measures. These can be costly (in terms of funding), increase community concerns about the immediate vulnerability of homes and infrastructure, and are potentially maladaptive in that they can create conditions that exacerbate localised coastal erosion. Therefore, there is a need to demonstrate and deploy coastal protection methods based on accurate baseline knowledge, sound design, use local materials as far as possible, and are acceptable to local communities. There is also a polarity in contemporary thinking in respect to coastal adaptation in that strategies implemented by a given Project are either soft, hard, resource-use orientated or rely on exclusion and protection. It is crucial to demonstrate in Tonga and elsewhere that model coastal adaptation approaches combine all available approaches simultaneously. And that not only social priorities and spatial heterogeneity guide the type of intervention and design, but crucially in a changing world, strategic temporal considerations are also made. For example, matching revetment design life to the expected horizon when a nearshore low-laying area becomes untenable for human habitation.

7. Recommendations for interventions, given current efforts, gaps and barriers

The project objective is to build the long-term resilience of vulnerable coastal communities to the direct impacts of climate change in Tonga through an integrated approach that will enable transformational change towards climate-responsive land use and long-term climate risk informed adaptation planning. The project therefore aims to build the long-term resilience of vulnerable coastal communities to the direct impacts of climate change in Tonga and build transformative adaptation capacities through strategic infrastructure work, long-term climate risk informed adaptation planning, and engagement on long-term adaptation solutions. The design of the proposed project is based on the best knowledge available on mainstreaming climate change adaptation into key community and national planning, and coastal protection in the face of sea level rise in Tonga. The approach is based on three areas of intervention that address the gaps identified in Section 6, as summarised in the table below.

7.1 Overall approach and addressing the gaps

The project will focus on a bottom-up development planning approach (community development plans, district plans and island strategic plans) to link development and spatial planning / land use management to promote transformative adaptation.

The overall objective is to support the transformative adaptation agenda setting through a participatory process and build policy consensus, and promote planning coherence. Towards this end, the project will focus on a bottom-up development planning approach (community development plans, district plans and island strategic plans) to link development and spatial planning / land use management to promote transformative adaptation.

<u>Key barriers in the baseline addressed by the project</u>: In the context of Tonga's existing programmes and commitments to reduce its vulnerability to climate change, there are several barriers that must be addressed in order to bring about transformational impact. Key barriers include:

Category	Barrier addressed	Proposed intervention (Output)
1. Policy / planning	1.Lack of climate-resilient coastal and land-use planning	1. Strengthened knowledge, capacity and engagement for incorporating climate risks into long-term adaptation planning supported through multi-sectoral, multi-stakeholder engagement and dialogue platform
2. Technical capacity	2. Lack of technical capacity for data collection / interpretation to inform climate-resilient planning	2. Strengthened national and local capacities for effective monitoring and assessment of climate risks
	3. Limited capacity of local community actors to develop and design bottom-up community plans	

3. Coordination / Implementation	4, Weak institutional capacity and coordination to implement an integrated cross-sectoral approach to coastal resilience	3. Reduced vulnerabilities of coastal communities in Hahake to climate hazards through coastal protection measures

Output 1 Strengthened knowledge, capacity and engagement for incorporating climate risks into long-term adaptation planning supported through multi-sectoral, multi-stakeholder engagement and dialogue platform

Activity 1.1 Establish a national multi-stakeholder engagement platform for dialogue on co-creating long-term climate change adaptation strategies and solutions including voluntary retreat.

Sub-Activity 1.1.1 Design of a multi-sectoral and multi-actor stakeholder engagement plan and guidelines for a bottom-up national engagement process.

Sub-Activity 1.1.2 Facilitate a national awareness campaign on climate change and disaster risks and transformative adaptation strategies for multi-stakeholder dialogue co-creating long-term adaptation strategies and solutions (using material developed under Output 2)

Sub-Activity 1.1.3 Develop a Terms of Reference for a National adaptation planning engagement platform specifying memberships, responsibilities and results

Sub-Activity 1.1.4 Undertake meetings of the national engagement platform on long-term climate change adaptation as per the Terms of Reference

Sub-Activity 1.1.5 Develop policy options to incorporate climate resilience and land use principles into national frameworks

Output 1 addresses the core issue of ensuring that climate change risks are included in land-use planning and decision-making. In addition to the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC), the key government institutions involved are the Ministry of Lands Survey and Natural Resources (MoLSNR), Ministry of Internal Affairs (MIA), Ministry of Finance and National Planning (MoFNP). The importance of this issue cannot be overstated, as it focuses on fundamental issues of land ownership, access, allocation and use in the Tongan cultural and legal context. This Output therefore responds to the lack of climate-resilient land use planning through instigating a process that will provide a soundly based long-term framework to guide development in the face of key climate change risks. The approach recognises that it is necessary to address the underlying economic, social and cultural challenges faced by communities (including knowledge of future sea level rise and its implications).

The national multi-stakeholder engagement platform for dialogue on co-creating long-term climate change adaptation strategies and solutions will involve a process with an array of stakeholder discussions that will touch on a number of sensitive areas, including land ownership, customary rights, and future threats to property, and potentially lives, from climate related hazards. It will involve a broad array of issues including legal aspects. In line with the Tonga Climate Change Policy, will need to consider principles including community ownership, participation, gender issues and equity/fairness.

Recognising the breadth and scope of the consultation required, the methodology will incorporate recognised consultation principles including:

- Ensuring meaningful, effective, informed participation of stakeholders.
- Conducting stakeholder engagement in a gender-responsive, culturally sensitive, non-discriminatory, and inclusive manner.
- Providing ongoing reporting to affected communities and individuals.[7]
- Offering multiple opportunities for consultation and engagement.
- Listening deeply; acknowledging people's concerns; summarising common ground and areas of disagreement; and being prepared to negotiate, change plans, and explore alternatives.[8]

These principles will be allied with culturally appropriate and participatory processes developed and well-practised in Tonga, as used in previous national initiatives, outlined in the Box[9] below.

[7] UNDP Social and Environmental Standards guidance Note on Stakeholder Engagement 2020
[8] GCF sustainability Guidance Note: Designing and ensuring meaningful stakeholder engagement on GCF-financed projects - 2019
[9] Content drawn/adapted from: JNAP, JNAP2, Tonga climate change Policy, draft national land use policy

Tonga Consultation Process High level commitment: Ensuring high level / political support for the process through some form of high-level advocacy such as an 'eminent persons group' Dedicated Support: Employing selected / representative teams with the skills and resources to support the process from outset to conclusion Research base: Basing consultations on a firm foundation of research and technical information (using external expertise where necessary) Stakeholders: Bringing a full range of stakeholders to the 'table' to ensure comprehensive and inclusive participation Engagement methods: Using a range of different methods, such as workshops, forums, community meeting, and supported by appropriate communications. Gaining Consensus: Managing the process to maximise the opportunity to gain consensus-based support for the outcomes

The process will also include a wide range of national and local stakeholders, including Members of Parliament, nobles and other landowners, village and island development committee members, NGO's CSOs, and the representatives of private sector businesses. The proposed project will use existing mechanisms for community engagement (such as the Fono, a Community meeting, usually called by the estate owners/nobles – two talking chiefs, town officers) to raise public awareness on climate change and disaster risks that the country is facing. Specifically, data and information will be simplified and made accessible to the wider population (closely linked to activities under Output 2).

The objective of Output 1 is to set the basis for consideration of impacts and responses to sea-level rise over decadal timeframes. This will allow for pro-active resilience planning that provides appropriate lead times for repositioning of key infrastructure (e.g., roads, utilities, buildings) in order to avoid the costs of future extreme events in coastal areas that are vulnerable to sea-level rise. The proposed process involves designing and implementing the national multi-stakeholder engagement platform for dialogue on co-creating long-term climate change adaptation strategies and solutions, including voluntary retreat – between government, coastal communities and other stakeholders about the current and projected sea level rise impacts. This will be informed by detailed topographic information delivered through Output 2, allowing communities access to modelling and imagery on sea level rise under different scenarios (rates and timescales). The topographic, bathymetric, and related surveys conducted under Output 2 will provide a rich data resource enabling a detailed assessment of climate-related hazards throughout Tonga. These will be developed into communication products that will be used to inform the national multi-stakeholder engagement platform for dialogue. With this information shared openly with stakeholders, the process will explicitly be evidence-based. In other words, decisions can be made with accurate knowledge of the geophysical and human environments, sea level projections and associated hazards. These processes in turn will inform village and district-level participatory climate risk-informed plans:

Activity 1.2 Develop village and district-level participatory climate risk-informed plans

Sub-Activity 1.2.1 Support a participatory process for developing village and district spatial plans to incorporate climate risk planning and adaptation strategies and principles of land use.

At the same time, Output 1 supports building the capacity of local government, village committees and NGOs to integrate climate risks and adaptation needs into community-level planning, and inform future Community Development Plans (CDP). Since 2012, the Government, under the leadership of the Ministry of Internal Affairs (MIA) has promoted the concept of community-led development planning processes. This led to communities/villages across Tonga completing their Community Development Plan (CDP) for the first time in 2016/2017. However, until now the CDPs have not incorporated the climate risk needed to address climate change adaptation priorities and propose solutions and opportunities to address the most urgent needs for building resilience. The national land-use plan will also assist in facilitating the transition to different land uses (including infrastructure and habitation) towards locations that are resilient to future sea level rise. Specific locality-based responses will be developed and incorporated into Community Development Plans as appropriate.

Activity 1.3 Build the capacity of local government, village committees and NGOs to integrate climate risks and adaptation needs into community level planning, and inform future Community Development Plans (CDP)

Sub-Activity 1.3.1 Develop an updated climate-responsive Community Development Plan Guideline to inform the development of future CDPs that includes including participatory vulnerability assessment and planning, gender needs assessment, and adaptation needs assessment and planning.

Sub-Activity 1.3.2 Design and implement a capacity building package for the Ministry of Internal Affairs on utilising the new climate-responsive CDP guideline

Sub-Activity 1.3.3 Strengthen capacities of key ministries for climate change risk informed planning and budgeting through trainings and materials

Sub-Activity 1.3.4 Organize island events (Vava'u, Ha'apai, 'Eua, Tongatapu and Niuas) for sharing lessons for producing climate responsive CDPs

Output 2 Strengthened national and local capacities for effective monitoring and assessment of climate risks will (2.1) strengthen the mechanisms for collecting and analysing data and information for better-informed climate risk monitoring and coastal adaptation planning and; (2.2) improve the knowledge base of multi-sectoral, multi-stakeholders on adaptation planning strategies for long-term resilient planning and transformative adaptation for Tonga based on climate risks and projections. This Output enhances the mechanism for collecting and analysing data and information for better-informed climate risk monitoring and coastal adaptation planning, providing key capacity building, training and mentoring for coastal adaptation planning and monitoring and developing climate risk-informed coastal plans. At the same time, Output 2 improves the knowledge base of multi-sectoral based, multi-stakeholders on adaptation planning strategies for long-term resilient planning and transformative adaptation for Tonga, which are based on risks and projects. This includes improving LiDAR coverage for Tonga's Islands, and capacities for interpreting key information, producing maps and knowledge material on scenario-based coastal risk maps, for decisions on long-term settlement patterns and climate risk for strategic long-term coastal planning while strengthening multistakeholder coordination and collaboration on coastal adaptation and planning integrating climate change.

Four government agencies have responsibilities in the broad areas of monitoring coastal processes and maintaining/managing coastal protection: the Ministry of Lands, Survey and Natural Resources (MoLSNR); under MEIDECC the Department of Environment (for ecosystem monitoring) and Meteorological Department (for climate modelling); and the Ministry of Fisheries for coral reef monitoring as part of the general fisheries/marine ecosystems monitoring responsibilities. These agencies, and the Government of Tonga in general, do not currently have access to the data and expertise to collect, manage and analyze in-depth data on coastal climate change risks. This activity therefore aims to build capacity in relation to climate risk data/interpretation in order to allow for better-informed coastal adaptation planning. Baseline data on coastal topography bathymetry and tide/wave behaviour will be procured from external providers.

Tonga has limited access to the fundamental baselines required to understand the impacts of sea level rise and marine hazards: high quality, accurate nearshore bathymetry (sea floor depth) and topography (land elevation). The relationship between sea level and land height must be characterised accurately if Tonga is equipped to make sound long term decisions regarding adaptation response and strategy. Likewise, the only way to accurately model wave impacts is if quality nearshore bathymetry + topography is available. In essence, it is not possible to design detailed adaptation to marine hazards at the engineering or strategic policy level unless these baselines are available as it is not possible to manage that which is not measured. Because of the need for high quality data for considering sea level rise or wave impacts, the Project intends to implement the necessary due diligence and collect this data via professional national survey design. This survey will complete gaps in current data coverage and will re-survey Tongatapu Island given existing data is older (2011) and comparatively course (up to 50cm vertical error) in comparison to contemporary techniques (better than 5cm vertical error). Additionally, Tongatapu houses over 60% of the national population and many of the island's settlements are located in exposed nearshore locations with little topographic relief. Accurately modelling must be undertaken to explain the spatial and temporal dynamics of inundation in these locations and do so in the most detailed way possible. Sea level rise projections are becoming increasingly robust (and alarming) and in order for Tonga to make informed decisions the best possible explanation of such impacts must be made available at the Government, community and household scale.

LiDAR survey work will capture outer island groups and selected areas of Tongatapu where covergage is either missing or outdated. In addition to this survey, the project will also support the purchase of selected equipment (hardware and software) that will remain with the Government of Tonga to provide capability to carry on supplementary survey work as needed throughout the project, and subsequently. Increasing capacity in analysis of the data will then bridge the current gap to enable these data to inform and guide climate risk driven modelling (coastal inundation, storm surge and hydrodynamic modelling), shoreline mapping, and vulnerability analysis of coastlines.

UNDP learning from recent similar work in Tuvalu, a nation widely recognised globally in respect to the impacts of sea level rise, showed conclusively that local understanding of the extent of inundation due to sea level rise and the likely timeframes involved, was still poorly understood prior to the collection of LIDAR and associated inundation modelling in 2019.[10] Only once a clear empirical understanding became available did the Government embark on extensive and ambitious long term adaptation plans commensurate with what the science explained was the precise impacts they faced. This Project will leverage this new data in the same way and will use this to inform the national dialogue process to guide discussion of impacts and potential adaptation strategy and response. LIDAR survey work will capture gaps in outer island groups where low-lying communities are predominant as well as the capital island Tongatapu where coverage is either missing or outdated. In addition to this survey, the project will also support the purchase of selected equipment (hardware and software) that will remain with the Government of Tonga to provide capability to carry on supplementary survey work as needed to track change and monitor over time. Increasing capacity in analysis of the data will then bridge the current gap to enable these data to inform and guide climate risk driven modelling (coastal inundation, storm surge and hydrodynamic modelling), shoreline mapping, and vulnerability analysis of coastlines as part of the activities under Output 2.1, *indicative* survey and equipment purchases to support improved coastal adaptation planning and monitoring capacity are included. This equipment will be accompanied by a full package of training and capacity building for departmental staff to ensure that equipment and data can be fully utilised. Furthermore, recognizing that the equipment and data, assessments and analyses must be shared across multiple ministries, GCF financing will also be used to assist in developing a long-term Capacity Building Strategy and Plan for government use on coastal and climate risk monitoring and analysis to inform coastal adaptation planning (e.g. including understanding and use of climate and risk information and data such as satellite imagery, aerial photography, drone imagery, LIDAR topography and bathymetry) for cross-ministerial cooperation in producing and utilizing data for the purpose of coastal protection. The data collected through the project timeframe and beyond will also contribute to building the body of regional knowledge. Following a capacity needs assessment to inform the long-term Capacity Building Strategy and Plan for coastal adaptation planning including capacity building on understanding and use of climate and risk information and data such as satellite imagery, aerial photography, drone imagery, LIDAR topography and bathymetry, training will be provided to the relevant ministries so that operation and coordination can be fully understood and implemented.

[10] TCAP LIDAR survey 2019 https://tcap.tv/news/2021/10/27/lidar-imagery-data-in-tuvalu-an-empowering-tool-against-climate-change-chegj

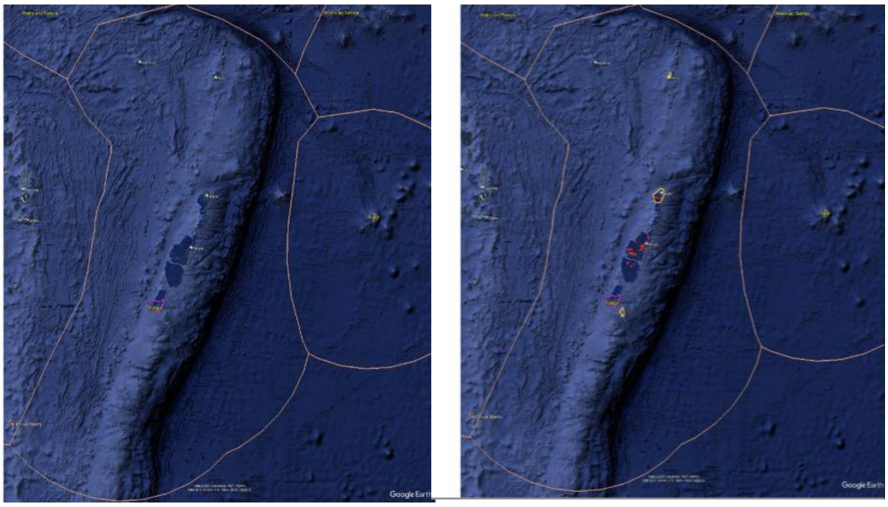
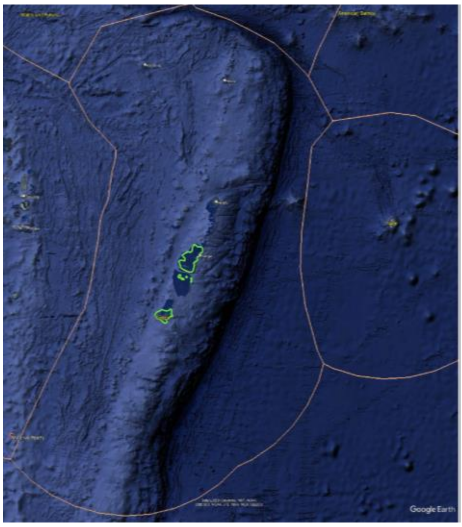


Figure 26 Current LiDAR coverage of Tonga

Left side–2011Topo/Bath coverage completed by DFAT/SOPAC of parts Tongatapu and Hahapai

Right side – 2023 recent coverage from SPC that includes 'Eua, Vava'u, Niuatoputapu and Tafahi

Figure 27 Project proposed LiDAR coverage for Tonga covering Tongatapu, and low-lying Islands in the Hahapi Group

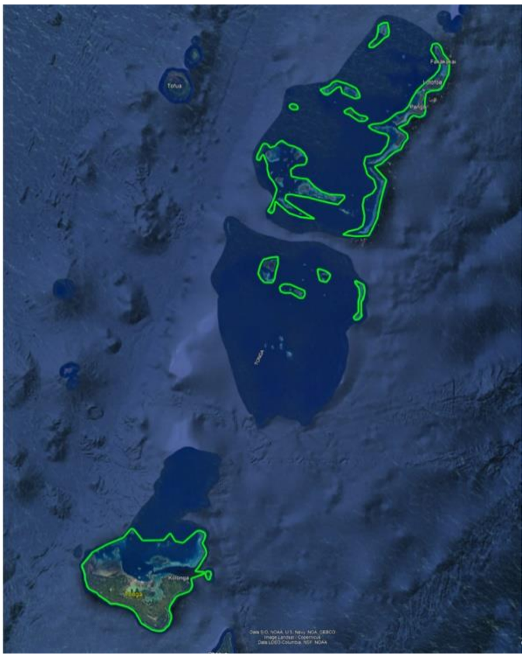


2023 proposed coverage
UNDP / GCF

Topo / Bath
Tongatapu
Low laying Is. Hahapai Group

Detailed coverage

Topography / Bathymetry	km2
Tongatapu and lagoon	751
Nomuka + lagoon	36.9
Mango Is + lagoon	19.6
Fomoifua Is & Tanoa Is + lagoon	11
Lalona Is & Telekitonga Is + reef	16.8
Pangai Is complex + reef	296
Ofolanga & Mo'Unga'One	21.8
Niviva Is and lagoon	31.3
Lofanga Is and lagoon	12.2
Fotuha'a Is	3.57
Tungua, Ha'afeva, Ua Is + lagoon	236
KM2 total	1436.17



<u>Activity 2.1 strengthens the mechanism for collecting and analysing data and information for better-informed climate risk monitoring and coastal adaptation planning</u>

Sub-Activity 2.1.1 Increase capacity of the Government to effectively collect, manage and analyse coastal monitoring data

Sub-Activity 2.1.2 Collecting, interpreting and using data on climate risks for coastal adaptation planning to produce scenario-based coastal risk maps and knowledge material for use under Output 1.

Sub-Activity 2.1.3 Improve multi-stakeholder coordination and collaboration on coastal adaptation and planning integrating climate change

GCF financing will also be used to assist in developing a long-term Capacity Building Strategy and Plan for government use on coastal and climate risk monitoring and analysis to inform coastal adaptation planning (e.g. including understanding and use of climate and risk information and data such as satellite imagery, aerial photography, drone imagery, LiDAR topography and bathymetry) for cross-ministerial cooperation in producing and utilising data for the purpose of coastal protection. The data collected through the project timeframe and beyond will also contribute to building the body of regional knowledge. Following a capacity needs assessment to inform the long-term Capacity Building Strategy and Plan for coastal adaptation planning including capacity building on understanding and use of climate and risk information and data such as satellite imagery, aerial photography, drone imagery, LiDAR topography and bathymetry, training will be provided to the relevant ministries so that operation and coordination can be fully understood and implemented. The key government institutions involved are the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC), the Ministry of Lands, Survey and Natural Resources (MoLSNR), and the Ministry of Internal Affairs (MoI).

Strengthening the monitoring system firstly involves providing support to build capacity in relevant GoT agencies in all aspects of managing and analysing coastal monitoring data. The approach will support the preparation of a capacity-building strategy for staff in government agencies to ensure that there is a cadre of personnel available to provide the technical base to inform coastal adaptation planning. Secondly, this activity aims to establish a monitoring system for collecting data. This comprises the collection of critical information such as detailed topographic, bathymetric, tidal, current, wave and sediment data. This will enable the preparation of inundation and storm surge modelling, hydrodynamic modelling, shoreline modelling, and coastal vulnerability analysis, which are all integral parts of effective, sustainable coastal adaptation monitoring and response. Once the data is available through the survey work discussed above, a further programme of activities is needed to bring the results down to the local / community scale. The elements of this include training for staff in local and national agencies. Specifically, training of 50 staff (50% women) in technical agencies in technical functions relating to coastal adaptation planning (modelling to inform coastal adaptation decisions including storm surge modelling, hydrodynamic modelling, coastal process modelling and vulnerability analysis), including the incorporation of sea-level and related climate simulations.

Providing support for inter-agency collaboration through the National Coastal Area Management Committee (or its equivalent) is also:

Output 2.2 Improve the knowledge base of multi-sectoral, multi-stakeholders on adaptation planning strategies for long-term resilient planning and transformative adaptation for Tonga based on climate risks and projections.

Activity 2.2.1 Support the use and interpretation of data collected in Output 2.1 by providing easily understood materials for multiple stakeholder types that consider strategic long-term coastal adaptation and inform the national multi-stakeholder adaptation planning engagement platform

This output enhances the mechanism for collecting and analysing data and information for better-informed climate risk monitoring and coastal adaptation planning, providing key capacity building, training and mentoring for coastal adaptation planning and monitoring and developing climate risk-informed coastal plans. At the same time, improving the knowledge base of multi-sectoral based, multi-stakeholders on adaptation planning strategies for long-term resilient planning and transformative adaptation for Tonga, which are based on risks and projects. This includes improving LiDAR coverage for Tonga's Islands, and capacities for interpreting key information, producing maps and knowledge material on scenario-based coastal risk maps, for decisions on long-term settlement patterns and climate risk for strategic long-term coastal planning while strengthening multistakeholder coordination and collaboration on coastal adaptation and planning integrating climate change. Four government agencies have responsibilities in the broad areas of monitoring coastal processes and maintaining/managing coastal protection: the Ministry of Lands, Survey and Natural Resources (MoLSNR); under MEIDECC the Department of Environment (for ecosystem monitoring) and Meteorological Department (for climate modelling); and the Ministry of Fisheries for coral reef monitoring as part of the general fisheries/marine ecosystems monitoring responsibilities. These agencies, and the Government of Tonga in general, do not currently have access to the data and expertise to collect, manage and analyze in-depth data on coastal climate change risks. This activity therefore aims to build capacity in relation to climate risk data/interpretation in order to allow for better-informed coastal adaptation planning. Baseline data on coastal topography bathymetry and tide/wave behaviour will be procured from external providers. LiDAR survey work will capture outer island groups and selected areas of Tongatapu where covergage is either missing or outdated. In addition to this survey, the project will also support the purchase of selected equipment (hardware and software) that will remain with the Government of Tonga to provide capability to carry on supplementary survey work as needed throughout the project, and subsequently. The budget allocated for procurement and deployment of LiDAR includes the costs of conducting the LiDAR survey as well as capacity building of the Government departments, especially the GIS Office. The project will collect this data in partnership with both the local Tongan authority (the GIS Office) and the SPC. Recognizing the limited geospatial capacities within Tonga, the SPC is a major link in terms of sustainability and how this data is archived and protected for continued use, access provision and ongoing availability. Housing data within the SPC builds sustainability given that the SPC is specifically tasked to carry out data archiving and analysis services for the Pacific Islands, and once this Project's data and products are incorporated into SPC systems they will provide access and support indefinitely. The SPC carries the regional mandate to supply, hold and undertake analysis of such data, a role that it already performs on behalf of Tonga. Therefore, data and analysis products produced via the project will be part of this ongoing (perpetual) agreement that predates and supersedes the short-term project timeframes. This model was successfully used for the LiDAR data collected in Tuvalu. Increasing capacity in analysis of the data will then bridge the current gap to enable these data to inform and guide climate risk driven modelling (coastal inundation, storm surge and hydrodynamic modelling), shoreline mapping, and vulnerability analysis of coastlines. Recognizing that the equipment and data, assessments and analyses must be shared across multiple ministries, GCF financing will also be used to assist in developing a long-term Capacity Building Strategy and Plan for government use on coastal and climate risk monitoring and analysis to inform coastal adaptation planning (e.g. including understanding and use of climate and risk information and data such as satellite imagery, aerial photography, drone imagery, LiDAR topography and bathymetry) for cross-ministerial cooperation in producing and utilizing data for the purpose of coastal protection.

Output 3 Reduced vulnerabilities of coastal communities in Hahake to climate hazards through coastal protection measures

Supplementing the work in Outputs 1 and 2, Output 3 will implement coastal protection measures in the Hahake region of north-eastern Tongatapu Island. This forms an important part of the project's integrated approach because the Government of Tonga has highlighted the urgent need to immediately mitigate the consequences of climate-induced erosion and wave-overtopping events threatening the lives and assets of the most vulnerable coastal communities in areas subject to inundation. The northeastern coastline of Tongatapu is considered among the most at risk of wave and erosion-driven land loss and damage to key coastal infrastructure in Tonga. The target area is experiencing wave-induced erosion and overtopping, putting houses and coastal infrastructure at risk. Such events undermine the road's structural integrity, and the absence of a drainage system in the road design causes sea waterlogging in the landward areas beyond the road. Waterlogging in the landward side damages coastal assets and causes erosional scarp undercutting of the road surface. With the projected sea level rise and episodes of intensive rainfall events in the future, coastal assets such as roads and houses are at risk from both the seaward and landward sides.

Figure 28 - Northeastern Tongatapu

Figure 29 - Northeastern Tongatapu, Nukuleka to Kolonga

Left, Area 1 Nukuleka to Talafo'o represents 2.4km of unstable shoreline which in part has been subject to piecemeal and failing remedial work. Earlier assessments (Webb 2016; Lewis 2016; 2017) indicate it is advisable to secure this shoreline using locally sourced limestone revetment as a medium-term measure to stabilise this shore whilst longer-term adaptation options are developed. Area 2 (west of Kolonga – 2.0km) has different geomorphology and requires a raised road and buried "last line of defence" armouring. This prevents overtopping and acts to protect the key infrastructure. Note: all areas are highly vulnerable to marine incursion and flooding (orange zone).

The selection of site-specific solutions has been based on the assessments of multiple factors, including pre-feasibility studies on a range of technical parameters relevant to the project. The primary studies for the Nukuleka revetment are those compiled between 2015 and 2017 during the implementation of the ADB-funded CRSP Project (see the reports from Webb 2016 *Coastal process in the locality* and Lewis 2016 *Wave modelling relating to the section of coastline,* Lewis (2017) *Engineering options).* Noting that Nukuleka has been previously subject to engineering (now failing), the footprint of which the project proposed to build over limits environmental impacts and stabilizes the shoreline, providing safer community access and reducing suspended sediment release during erosive events. The "Wave Modelling Report" (Lewis, 2016) identifies design wave heights for each of the Hahake coastal sections (refer map). The north-eastern coastline of

Tongatapu is considered among the most at risk of wave and erosion-driven land loss and damage to key coastal infrastructure in Tonga. The target area is experiencing wave-induced erosion and overtopping, putting houses and coastal infrastructure at risk. In north-eastern Tongatapu (presented in red rectangle in the map above), has been subject to erosion and wave overtopping hazard which has increased in severity. Erosion in area 1 and 2 has exposed the main island ring road and communities in area 1 to wave overtopping and marine flooding. This is especially evident during cyclones and storm events during high tides; at these times, waves routinely overwash the roadway, blocking traffic and damaging the pavement. Not only do such events undermine the road's structural integrity, but the absence of a drainage system in the road design causes sea waterlogging in the landward areas beyond the road. Waterlogging on the landward side damages coastal assets and causes erosional scarp undercutting of the road surface. With the projected sea level rise and episodes of intensive rainfall events in the future, coastal assets such as the road and houses are at risk from both the seaward and landward sides.

Figure 30 - Hahake coastal segments and corresponding data extraction points

Source: Wave Modelling Report, James Lewis, December 2016

As summarised in the table below, the design crest height varies along the coastline.

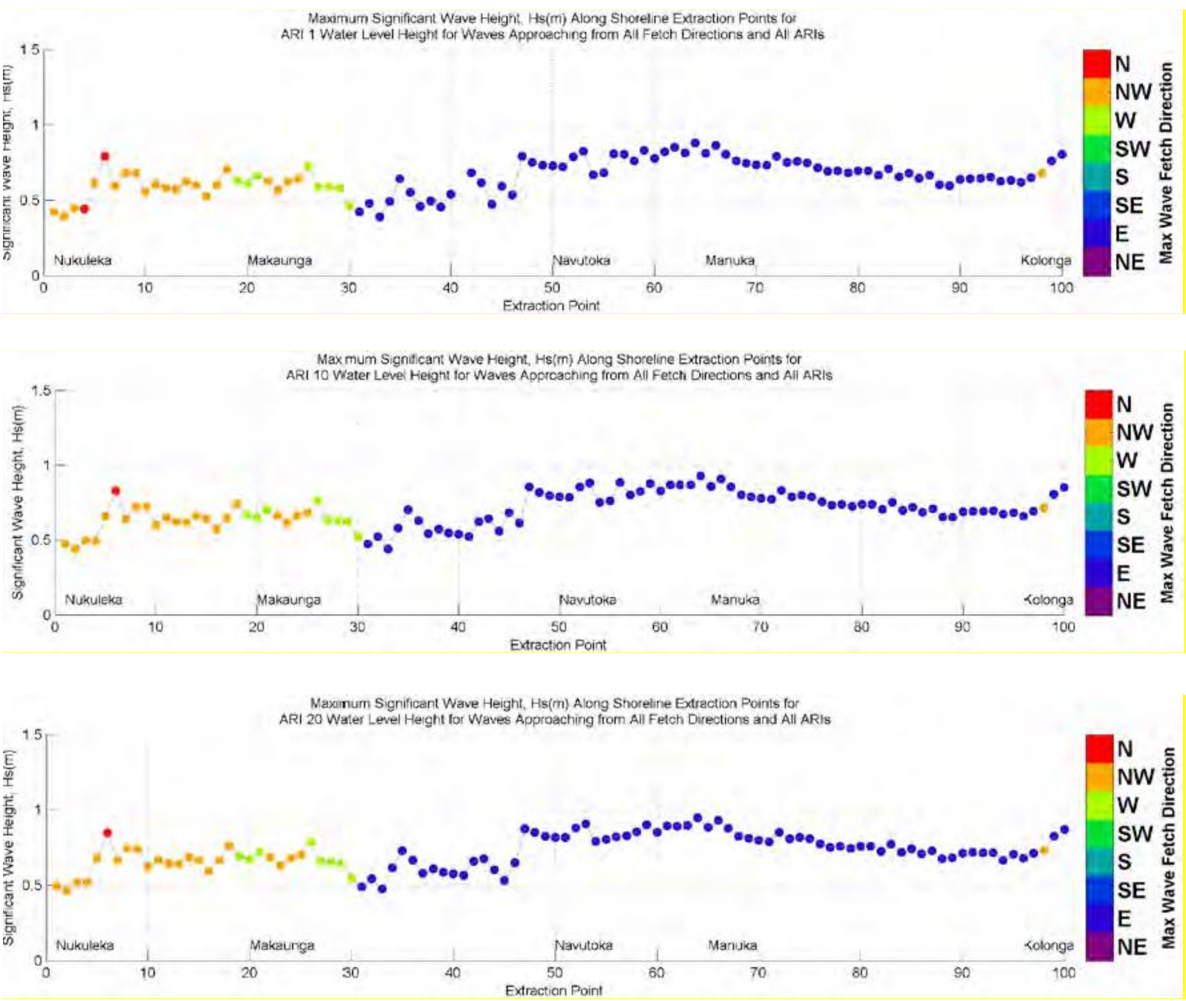
Table 6 The design crest height along the coastline

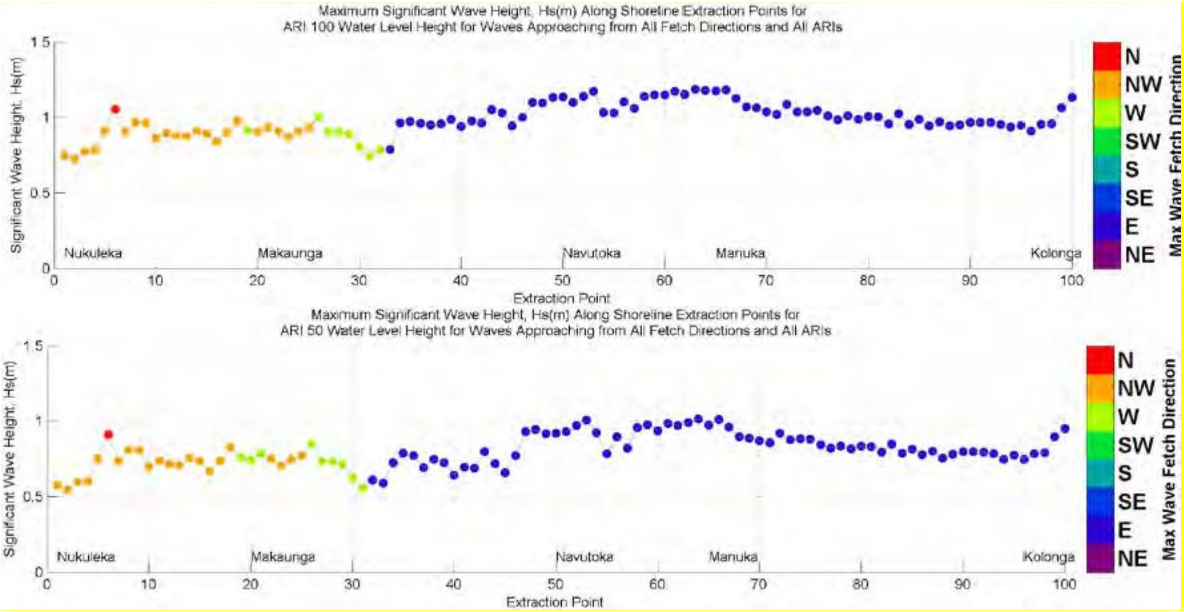
Coastal Compartment	cot α	γ_f	γ_β	R_c (m)	G_c (m)	C_r	q (l/s/m)	CREST HEIGHT (mMSL)
Nukuleka	5	0.55	0.76	**0.6**	1.2	**0.55**	**10.4**	**2.1**
Makaunga	5	0.55	0.82	**0.57**	1.2	**0.49**	**10.4**	**2.0**
Talafo'o	5	0.55	0.78	**0.56**	1.2	**0.51**	**10.6**	**2.0**
Navutoka West	5	0.55	0.91	**0.72**	1.2	**0.55**	**10.5**	**2.2**
Navutoka East	5	0.55	0.86	**0.85**	1.2	**0.67**	**10.6**	**2.3**
Manuka	5	0.55	0.91	**0.83**	1.2	**0.62**	**10.4**	**2.3**
Kolonga	5	0.55	0.88	**0.8**	1.2	**0.62**	**10.5**	**2.3**

Source: CRSP PIU 2017.

The modelling reported by Lewis (2016) shows that each section of the Hahake coastline is affected by waves generated from different fetches in different manners. As illustrated below, the maximum significant wave height (Hs) was extracted at all points overall modelled scenarios to understand which coastline sections are most affected by the differing fetch directions.

Figure 31 Maximum significant wave height (Hs) extracted at all points modelled along Hahake coastline





Maximum Significant Wave Height, Hs(m) along Hahake shoreline extraction points for ARI 1, 10, 20, 50, *100-year* water level for waves approaching from all fetch directions under all ARI conditions. The analysis shows that there is a clear link between wave height and water level (i.e. sea level). Increased water level over the model domain leads to increased wave height at the extraction points. This is due to less energy being dissipated offshore of the study site (at the reef platform edge) due to wave breaking. Some fetch lengths are also increased due to the increased water depth over shallow reef sections now being submerged.

Against the background of the physical information described above, two separate types of intervention are proposed. The first comprises the installation of 2.4 km of rock revetment along the coast between the villages of Talafo'o and Nukuleka (refer map below). The second involves deployment of selected adaptation measures along 2.0 km of coastline between Manuka and Kolonga as described in further detail below.

Figure 32 Project sites in Hahake

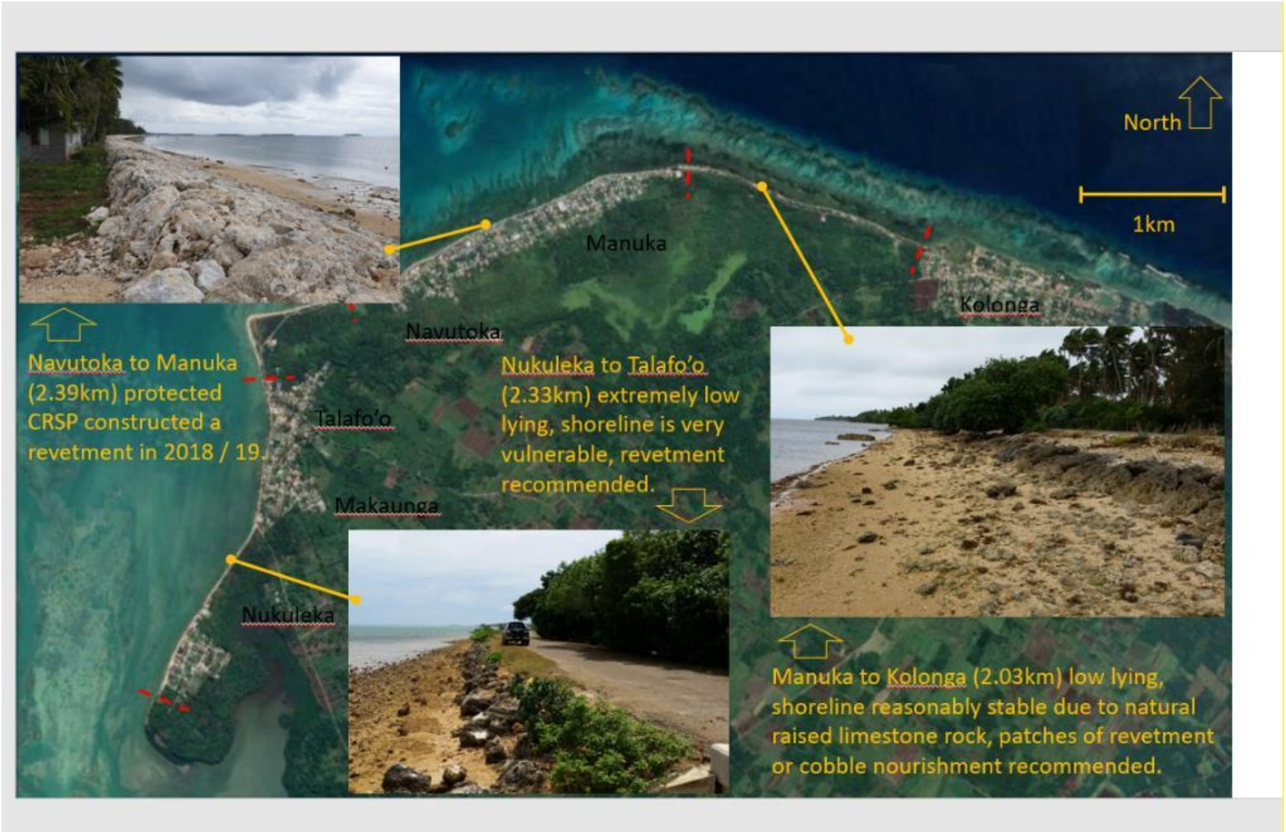


Figure 33 Location of Sub-activity 3.1.2. Construction of 2.3kms of reventment Nukuleka - Talafo'ou (left side, red line) and Sub-activity 3.1.2. Construction of 2kms of coastal protection measures developed for the Manuku to Kolonga shoreline (Right side, orange line)

The green line shows the areas covered by earlier work, while the orange line on the right shows the coastal protection measures and raised road area, and the red line shows the site for the construction of the revetment. The pink line in the middle section refers to the (ad hoc) revetment installed over the years by the Government of Tonga that attempts to secure some of this coastline but which is in disrepair. At the northeastern end of the Hahake Peninsula (shown above in Figure 38, 2kms of coastal protection measures developed - Manuku to Kolonga on the Right side, orange line), will put in place a raised road and buried "last line of defense" armoring. This prevents overtopping and acts to protect the key infrastructure.

Figure 34 Current shoreline between Nukuleka and Talafo'ou

The selection of site-specific solutions has been based on the assessments of multiple factors, including a) the existence of pre-feasibility studies on a range of technical parameters relevant to the project: *Coastal process in the locality* (Webb, 2016); *Wave modelling relating to the section of coastline* (Lewis 2016), and *Engineering options* (Lewis, 2017). The report "Coastal Processes, Monitoring & Engineering Options" (Webb, 2016) describes in detail the coastal zone in the locality of the proposed coastal protection work.

The report explains that the coastline comprises a 'tropical reef mediated system', meaning the shore is protected by living reefs built from once living reef material. Such shores are dependent on physical processes (wind, waves, and currents) to naturally maintain the coastal form. They are also prone to becoming unstable if part of the system (biological, chemical or physical) is subject to change. In light of the above, the activities under this output will enhance coastal protection in Hahake, where climate change-induced coastal erosion and wave overtopping are already causing land loss and damage to coastal infrastructure. At the end of the GCF project, it is envisaged that an additional 4 km of vulnerable coastlines will have been strengthened with a range of coastal adaptation measures (including rock revetments) preventing erosion, wave overtopping and/or subsequent coastal flooding which are expected to be worsened under projected climate change scenarios. The selection also shares synergies with previous project work, notably CRSP, alongside engagement within the local community, particularly for the section in Nukuleka to Talafo'ou, and the EU GCCA measures adjacent to the approach being applied between Manuu to Kolonga, as well as strong GoT commitment. For example, some areas of the wider Hahake coast have benefitted from existing adaptation measures, including coastal groynes and sea walls of differing design and effectiveness. The most recent of these have been rock revetments supported through the ADB-funded CRSP project. Notably, the areas with the revetment constructed under the CRSP avoided inundation during the recent tsunami event, whereas those areas still unprotected suffered marine incursion, flooding and physical damage to infrastructure. There are overlaps between the project locations and the beneficiaries that they include under Output 3, and the beneficiaries covered by previously implemented projects. The Tonga Climate Resilience Sector Project (CRSP), Asian Development Bank, 2013-2019: contributed 2kms of revetment for coastal protection measures in the Hahake area. The current proposed Tonga Coastal Resilience project will complement this earlier work, adopting the lessons regarding revetment design and community consultation. The village of Navutoka (the largest in Hahake) is protected by the ABD revetment completed in 2019. However, Navutoka's inhabitants are also included as direct inhabitants of the proposed Tongal Coastal Resilience project, because unless the entire shoreline of Hahake is protected (as is the aim of Output 3's Activity 3.1), flooding can occur from marine water entering currently unprotected neighbouring shores and moving around to flood landward side of Navutoka. The proposed Tonga Coastal Resilience project closes off the gaps in seaward defences to stop the flooding of the entire, low-lying Hahake area, and thus, all villages will have significant protection benefits. The ADB revetment protected from direct wave impacts, but did not protect from potential flooding that can occur if neighboring unprotected shores are significantly over topped. To provide comprehensive flood risk prevention the entire low laying Hahake foreshore requires improved protection. The UNDP Coastal Resilience Project is therefore designed to do this, as it will close gaps in the existing flood prevention infrastructure and intends to bring the entire foreshore to a more uniform flood protection design specification.

The current project is designed to supplement this earlier work by using compatible design specifications based on a 40-year design life for the proposed rock revetments. The coastal protection measures constructed for sub-activity 3.1.2. build upon the small-scale coastal protection and ecosystem-based measures in northwest Tongatapu (Sopu to Ha'atafu) under GCCA+. The green line shows the areas covered by this earlier work, while the orange line on the right shows the coastal protection measures area under the Coastal Resilience proposed project, and the red line shows the site for the construction of the revetment. At the southernmost end of the Hahake Peninsula, 2.3 km of rock revetment will be installed along the coast between the villages of Makaunga and Nukuleka to protect the low-lying and highly vulnerable shoreline. On the western side, coastal protection measures for the Manuka to Kolonga shoreline will be installed.

At the southernmost end of the Hahake Peninsula, 2.3 km of rock revetment will be installed along the coast between the villages of Makaunga and Nukuleka to protect the low-lying and highly vulnerable shoreline. On the western side, coastal protection measures for the Manuka to Kolonga shoreline will consist of over topping protection but not a foreshore revetment. A foreshore revetment is not considered appropriate at this location (Kolonga) because unlike Makaunga to Nukuleka this eastern section has not been subject to previous extensive foreshore revetment works. This section of coast remains as an important recreational shoreline that has some important strand vegetation and geological features, all of which mean whist this shore is stressed and in places erosive, this shore has a greater measure of ecosystem-integrity based resilience than the Nukuleka foreshore which has seen various and often ad hoc structures constructed over decades. Nukuleka by comparison has been subject to continuous ad hoc, poorly designed (and failing) engineering for decades and has no residual soft shoreline left due to its erosive nature.

The Kolonga section will consist of raising the roadway easement (approximately 1m but to be determined via modelling). The shoreward flank of the raised road would also be armoured (with local limestone) as a mostly buried last line of defence given it is possible this shore will become progressively more erosive. This work will be implemented on the existing road easement and is specifically conceived to provide much needed overtopping protection but not disturb the existing foreshore system or associated stand vegetation. The main objective of this approach is to protect the low-lying agriculturally important areas on the landward side of the road, nearby assets and the roadway itself from marine over wash as it is currently very exposed, while also ensuring that the existing ecological integrity of this area of coast is undisturbed and can continue to provide critical services of ecosystem-based resilience. The landward freshwater swamp areas are extensive, used for swamp taro and tree crop cultivation as well as fresh groundwater supply. If a major breach occurred on this shore and allowed large volumes of marine waters to enter this could have far reaching damage and implications to many of the villages in the Hahake peninsular. The raised roadway would also prevent routine cutting of this road during wave events as sand, rocks and other debris are frequently thrown over the road. The approach would retain this important accessway and emergency evacuation route (e.g. tsunami warnings) and also protect the mains electricity lines which run parallel to the road.

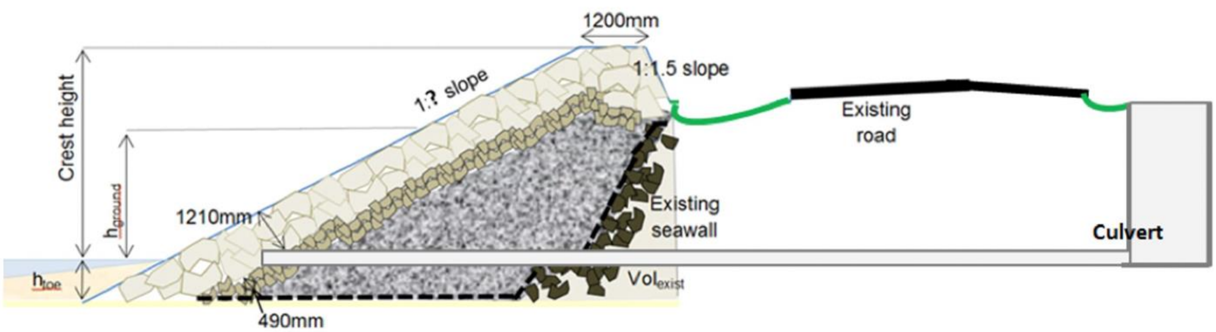
<u>Activity 3.1. Build coastal protection measures along 4km of coastline in Hahake</u>

Sub-Activity 3.1.1 Detailed design and site-specific assessments of coastal protection measures finalized for Hahake

Sub-Activity 3.1.2 Construct coastal protection measures in Hahake

The revetment will be based on an existing proven design illustrated below (as already constructed in the adjacent coastal area under ADB), and remaining intact and robust post-tsunami:

Figure 35 Proposed rock revetment construction of 2.3kms of revetment Nukuleka - Talafo'ou



Legend	Rock Class	Type	D_{15} (mm)	D_{50} (mm)	D_{85} (mm)
	Class I	Armour Stone	528	605	677
	Class II	Secondary Armour	104	180	250
	Class III	Filter Layer	20	24	28
	-	Backfill	-	-	-
	-	Geotextile Layer	-	-	-

Proposed Rock Revetment Concept – Source: Lewis, 2017.

Lewis (2017) prepared a comparative analysis of cost, design and effectiveness of a revetment with different face slopes (1:5, 1:3 and 1:1.5). Lewis noted that the lower gradient involves greater structural volume and footprint, noting that “the difference between the 1:1.5 and the 1:5 offshore slope results in an approximate 300% increase in total structure volume and footprint”, with flow-on increase in costs for materials and construction. Noting that costs have significantly risen since 2017, however, interesting to see is the comparison in gradient and price impact shown in the table below.

Table 7 Costs, design and effectiveness of revetment at different slope ratios

Table x: Cost / design (slope) estimates			
Offshore toe slope	1:5	1:3	1:1.5
Estimated cost in USD/km (2017 estimate)	$1,079,486	$595,565	$334,966
[adapted from Lewis 2017]			

On the basis of these estimates, and design/effectiveness considerations, a face slope of 1:3 for design[11]. This was mainly due to the significant cost savings for the 1:3-sloped structure with little coastal amenity benefit being gained when moving to the 1:5-sloped structure. A 1:5 sloped structure also results in an average offshore extension of almost 13m, meaning that there would be significant disruption to the coastline's natural amenity and the beach's reclamation.

Tongatapu is a raised limestone island and has significant resources of limestone rock, particularly in its South-East corner where the topography reaches almost 60 m MSL. Lewis (2017) identified approximately six quarries servicing the island on a range of construction projects, and these numbers remain in 2023 (August). The predominant use of the local quarried rock is for aggregate used for roads and the construction of buildings on the island. However, local quarries have the capacity to supply larger rocks that are required for the revetment construction. During 2023, a site visit at Tonga’s main quarry guided by the owner / operator confirmed the availability of likely volumes and rock quality requirements and capability and that the quarry had opened new resource areas that had high-quality remineralised limestone rock. This was being processed as very large 2m x 2m boulders through to fine 5mm crushed sand products. On inspection of the new quarry face high-quality limestone similar to that used across approximately 10km the Nuku’alofa foreshore was available.

Lewis (2017) also provided Outline drawings of the concept design for the revetment. These are based on the proposed section concept shown above, and LiDAR mapping of the coastline of the Hahake Peninsula. Key stages of the implementation of this output are:

- Detailed site topographic survey
- Detailed design to prepare tender and construction drawings
- Tendering and construction.

Providing climate resilient drainage to reducing sea flooding and road damage: Revetments and other raised surface features act to intercept normal drainage paths. Consequent flooding and uncontrolled runoff paths can exacerbate erosion along the coastal edge, and cause inundation damage to land and buildings. Moreover, if flash-flooding coincides with (extremely) high tides, drainage channels can overflow due to being inundated by encroaching seawater. Revetments therefore need to be designed to include drainage culverts so that areas behind the revetment can drain. In most cases this should include flap gates or other one-way controls so that high sea levels do not quickly inundate areas behind the revetment, notwithstanding that rubble revetments are permeable and will slowly pass high sea levels. On the Hahake

[11] CRSP PIU. February 2017. Coastal Process, Monitoring & Engineering Options Assessment: Engineering Design - DRAFT

peninsula the road is immediately behind the foreshore coastal protection. Drainage culverts here therefore need to incorporate drainage of the road and the adjacent ground on the inland side of the road. Throughout 2017 - 2018 CRSP gained development consent to proceed with a limestone revetment which was completed over 2.4km of the north Hahake shoreline. This has been widely viewed by local communities and the GoT as a highly successful undertaking, preventing erosion and wave overtopping hazard, and withstanding and providing a breaker successfully for the tsunami wave in 2022.

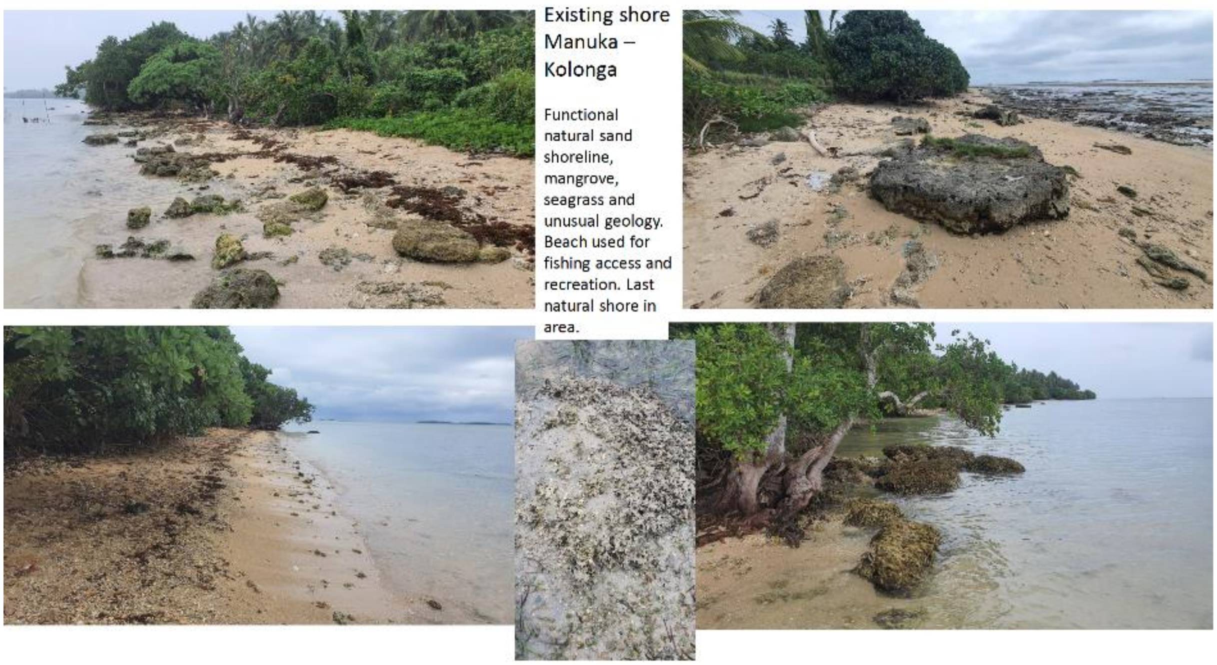
It is likely that the coastline was previously (several hundred years ago) 1.0-1.5 km further inland, and today's shoreline is the seaward edge of a narrow deposit of reef debris surrounding a former intertidal zone. If unprotected, this shore line is liable to rapid change and wave over wash and is highly sensitive to sea level rise (Webb, 2016). Given the setting the greater majority of the communities and infrastructure on this coast are located in conditions of extreme exposure to marine hazards. The shoreline position has been unexpectedly stable across this area over the last 50 years, largely due to piecemeal revetment works. In many locations, however, the revetment is in poor repair and requires urgent maintenance, and that continued failures in the revetment due to wave attack that will lead to increasing issues of erosion and damage to infrastructure and property (Webb, 2016). Revetment establishment, repair and improvement is recommended as the primary approach to coastal protection on the Hahake shoreline. Local quarried limestone blocks are available for this structure, and there is significant local experience with these forms of protective structures. If a redesigned revetment lies over the footprint of the existing structure there would be negligible environmental impacts (Webb, 2016).

Notably, there has been some community dissatisfaction with pilot trials in 2015 (involving installation of groynes and segmented breakwaters at different locations in Hahake) in that they are perceived to not provide 'adequate protection of their road, homes and other property or infrastructure from wave overwash and flooding (Webb, 2016). In part this represents a misunderstanding and incorrect expectations of what the structures could do. Also, it must be made clear to communities that any revetment work in Hahake is a short to medium term strategy (maximum 50 years) to hold the line and protect homes and property whilst longer term strategies are implemented. Both the segmented breakwaters at Manuka and the groynes at Nukuleka are designed to reduce energy and accumulate sediments (Webb, 2016). These have not greatly improved the principal marine hazard of wave over-wash and incursion at the shoreline (Webb, 2016). Even a mild storm or wave event will again result in wave over wash, if these methods were used over larger areas there is a risk of detrimental effects on the shore through changes to the manner in which sediments move (Webb, 2016). It is likely that a rebuilt revetment running parallel to the road will still be necessary to prevent wave over-wash at the shoreline, and a well‐designed revetment in the first place would have accomplished the desired outcome. A well‐designed revetment will most effectively address the issue of wave overtopping and protect shoreline position.

Figure 36 - Manuka to Kolonga shoreline

The coastal area Manuka - Kolonga to the west of Kolonga village remains a natural system and has never been protected by revetment. Unlike areas further west it has numerous raised outcrops of limestone bedrock that essentially "fix" beach position along this zone. The raised limestone outcrops provide greater resistance to change in this shoreline over time than other localities, but field assessment in October 2016 indicated this shore is eroding landwards localised areas. This is particularly evident at the easternmost end. There are locations where erosion is very close to the road and continued monitoring will be important to prioritise remedial action. The figure below shows the coastline in this locality, including the low-lying nature of the adjacent land/plantation, close proximity of the eroded beach to the road, and intermittent patches of vegetation. The target area is approximately 2 km in length.

Figure 37 Existing shoreline for Manuka to Kolonga

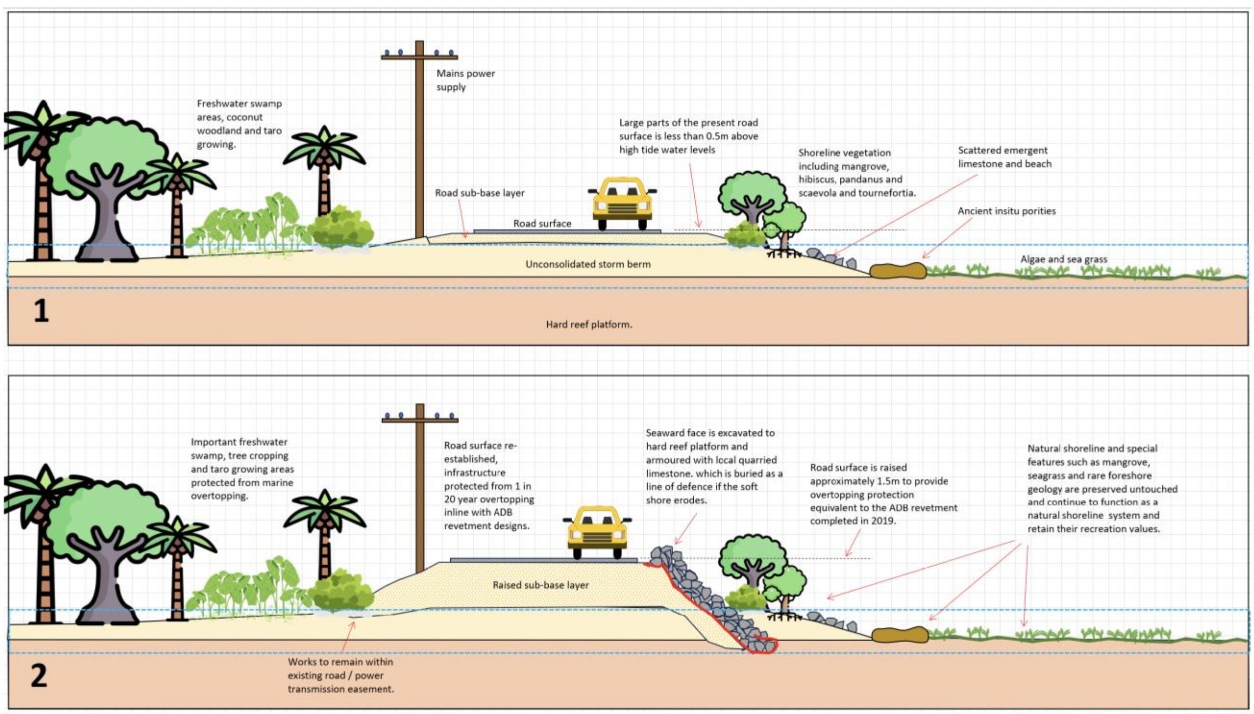


Vegetation is important for improving slope stability, consolidating sediments, and providing some shoreline protection. Numerous studies[12] for example, have highlighted how coastal vegetation provides a measure

[12] See, for example, Mendez, F.J. I.J. & Losada. 2004. An empirical model to estimate the propagation of random breaking and nonbreaking waves over vegetation fields. *Coastal Engineering,* 51: 103–118.; Lee, T.M. 2005. Monitoring the dynamics of coastal vegetation in Southwestern Taiwan. *Environmental Monitoring and Assessment,* 111: 307–323.; Lee, T.M. 2005. Monitoring the dynamics of coastal vegetation in Southwestern Taiwan. *Environmental Monitoring and Assessment,* 111: 307–323.; Daidu, F., Guo, Y., Wang, P. & J.Z. Shi. 2006. Cross-shore variations in morphodynamic processes of an open-coast mudflat in the Changjiang Delta, China: with an emphasis on storm impacts. *Continental Shelf Research,* 26: 517–538.; Moller, I. 2006. Quantifying saltmarsh vegetation and its effect on wave height dissipation; results from a UK east coast saltmarsh. *Estuarine, Coastal and Shelf Science,* XX: 1–15.; Turker, U., Yagci, O. & M.S. Kabdasl. 2006. Analysis of coastal damage of beach profile under the protection of emergent vegetation. *Ocean Engineering,* 33: 810–828.

of shoreline protection have been conducted showing that mangrove forest and other coastal vegetation of certain density can reduce wave height considerably and protect the coast from erosion, as well as effectively prevent coastal sand movement during strong winds (Prasetya, 2007). Healthy coastal forests such as mangroves and saltmarshes can serve as a coastal defence system where they grow in equilibrium with erosion and accretion processes generated by waves, winds and other natural actions. Given the character of this area of coastline in Area 2, the proposed design therefore combines a nature-based solutions (NBS) approach with minimal infrastructure investments to secure critical assets and prevent inundation intrusion into the adjacent growing area and residential water-supply from groundwater reservoirs. The design seeks to ensure that the character and traits of the existing shoreline remain intact, and undisturbed given the role that they currently play for recreational uses and fishing access. The back beach berm is very low along this beach and wave over-topping remains a high risk, even if shoreline position has been reasonably stable without engineering. There are several locations where the beach has eroded to within a metre or so of the road and will need protection in order to reduce overwash and threat to the road. At the same time, there is vegetation, including some large mangrove trees and geologically significant assets along this area of shoreline.

Figure 38 Schematic of approach to shoreline protection for Sub-activity 3.1.2.2 Construction of 2kms of coastal protection measures developed for the Manuku to Kolonga shoreline



Unlike the Nukuleka to Talafo'ou section of shoreline, which has long had various piecemeal revetments in place, the Manuka to Kolonga shoreline has not. This also means that the road is very unprotected in sections, and likely to be subjected to overtopping frequently. Given these considerations, the protection proposed for this section of shoreline seeks to armour the road and raise its height, in order to provide protection for the road (which is also the evacuation access road) and also prevent inward inundation. The raising of the road will ensure that critical evacuation infrastructure is protected (the road, which forms the evacuation route for cyclone or tsunami and flood incidence), as well as the vegetated area behind the road which is at risk of saline intrusion with overtopping or coastal inundation. Raising the road but retaining the natural coastline features which include sections of mangroves, ground vegetation (retaining sand), beach shrubs and trees ensure that natural protection will be retained in this area. These features provide the local community with wind breaks and some protection from storms. The sandy beaches in this area also serve recreation purposes and for fishers.

Ecosystem-based adaptation approaches: In some areas gaps in coastal vegetation contribute to beach scouring due to wave action. In these situations, revegetation will be supported through planting of location-appropriate biota. Ecosystem approaches to coastal protection, as they relate to coastal planting, can be considered in two categories:[13]

a) establishment of offshore vegetation, such as mangroves, to dissipate wave energy before it reaches the shoreline and to trap fine sediment while maintaining habitats for juvenile fish and marine species;
b) establishment of backshore vegetation to reduce wave runup extent and damage potential, trap windblown sand and improve ecological connectivity between the land and sea;

Category b) is considered the more appropriate option for the target site due to its siting/habitat (open to offshore wave action) and for conformity with surrounding areas. Appropriate vegetation will be identified through consultation with relevant government agencies, local communities, and NGOs.

Some relevant considerations are:

- Suitability for growing at the site (salt/wind tolerance etc
- Able to assist in reducing overtopping flows and wind-blown transport (PRIF 2017)
- Local origin and availability.

On the latter of these issues, Whistler (2011)[14] reported that '[t]he flora of Tonga is very similar to that of the adjacent islands and archipelagos, particularly Samoa. It is estimated to comprise 340 native angiosperm species, only 3% (15 species) of which are thought to be endemic to the archipelago. No genera are endemic to Tonga.' Of the species endemic to the archipelago, only four were reported as occurring in Tongatapu: *Pittosporum yunckeri, Polyalthia amicorum, Robiquetia tongensis, Xylosma smithiana*[15]. An additional consideration is to avoid the introduction or proliferation of invasive or potentially invasive plant species. In this regard the Pacific Island Ecosystems at Risk project (PIER) has developed a list of 'PIER plant species present in the Tongatapu Group listed by scientific name' [16]. To support and maintain the above adaptation measures, signage and local communication programmes will be deployed to encourage communities to both support the measures and refrain from activities that could undermine the project objectives. Examples of the latter are keeping vehicles away from the tidal / shore areas, and ceasing 'beach mining' of gravels /aggregates.

The road surface would be raised approximately 1.5m to provide overtopping protection equivalent to the ADB revetment completed in 2019. The seaward face would be excavated to hard reef platform and armoured with local quarried limestone, which is buried as a last line of defence if the soft shore erodes. Road surface would be re-established, so that infrastructure is protected from a 1 in 20 year overtopping in line with the ADB revetment designs. Finally, the important freshwater swamp, tree cropping and taro growing areas would be protected from marine overtopping. This design would not cause any physical

[13] PRIF. 2017. Affordable Coastal Protection in the Pacific Islands. Desktop Review. Sydney: Pacific Region Infrastructure Facility. PRIF 2017a. Guidance for coastal protection works in Pacific island countries: Pacific Region Infrastructure Facility.
[14] Whistler, A. et al (2011): The rare plants of Tonga. Report prepared for Tonga Trust Ltd
[15] Suitability or otherwise for coastal protection of this species has not been established in the current study.
[16] Available at: http://www.hear.org/pier/locations/pacific/tonga/tongatapu_group/specieslist.htm

disturbance to the existing shoreline, which as Webb (2016) notes, is functional and charismatic with mangroves, sea grasses and interesting geology. The road raising approach leaves the shoreline undisturbed but still provides the crucial wave over topping protection required by the community and if the shoreline does erode faster than expected at this time the buried armoured revetment will act as a last line of defence preventing loss of the roadway – a key asset for this rural community and will also prevent marine water incursion into the freshwater swamps and plantations inland. Consideration has been given to the use of gabion baskets (wire cages filled with rock) for patch protection on this shore, but these are not recommended as they are subject to rapid corrosion and collapse. Also, in a rocky shore environment plastic coated wire (as commonly used on gabion cages) is subject to abrasive forces that quickly crack and puncture the plastic coating; subsequent rust is rapid in these saline environments and the baskets quickly fail. This conclusion is in line with the work of PRIF (2017a), which also provides examples of construction experience in the Pacific islands region (good and bad) and recommended building techniques / materials.

<u>Licenses and permits</u>: No licenses and permits have been applied for to date (as outlined in Annex 9). The development area is government-held and confirmation from MLSLR for a Development Consent permit is still required as per the Act. The application will also require EIA and stakeholder consultation reports. Licenses and permits, such as the EIA approval required for coastal works will be applied for in the early implementation phase. These permits will be applied for at the implementation stage as the Detailed Project Proposal, including technical specifications and design drawings, must accompany the Application as required under sections 32 and 36 of the National Spatial Planning and Management Act 2012, with the application to be made to the Ministry of Lands Survey and Natural Resources. The application is made to the Ministry of Lands Survey and Natural Resources. As a Government of Tonga project these processes will be facilitated by relevant Ministries. As MEIDECC is the leading Government agency for the Project with the CEO and Minister aware of the Project, there is clear indication of consent and assurances from Government for the Project.

The Development Consent for Coastal Protection Development issued by the MLSNR requires the following documentations:

- Detailed Project Proposal including technical specifications and design drawings
- Environmental Impact Assessment
- Land ownership
- Consultations with relevant authorities and stakeholders

All infrastructure lays within the footprint of existing Government infrastructure easements. As to the specific construction licencing of the eventual Project designs this must go via established formal development application processes. It is illegal to seek such permissions/licencing without adherence to local government processes.

The Government has provided reassurances that all land rights as required will be provided during implementation. Government has endorsed this Project and is aware that all Project capital works are located over the footprint of existing government infrastructure easements. Nonetheless a formal process of Development Consent via formal application in Tonga (i.e. formal permission to construct new infrastructure) will need to be undertaken. The DA process (Development Application) will occur only once more detailed analysis of the 2 works sites has been completed by Project technical staff and provisional designs adequate for the DA process can be submitted. It is expected this will also trigger the local ESIA process which will also be implemented by the Project. Project Technical Staff are expected to be secured in Q3 – 4 of year 1 and provisional designs are expected to be underway by Q1 - 2 year 2, this would coincide with submission of the relevant documents to the Government of Tonga to trigger the development application, associated ESIA process and ultimately result in development consent (licencing). It is not possible to pre-empt this internal Tongan Government DA process prior to the existence of a Project Office and staff and it would be inappropriate to attempt to do so.

The primary permit is the Development Consent for Coastal Protection Development issued by the Ministry ofLands Survey and Natural Resources. It should be noted also that part of the area targeted for the project (Western side of the Kolonga village) is listed as a Special Management Area under the Fisheries (Coastal Communities) Regulations, which may require consultation with Ministry of Fisheries and the Kolonga Coastal Community Management Committee forendorsement.

Labour and materials: Preliminary assessments have been undertaken in terms of availability and quality of labour/construction work evaluated from the lessons learned during the ADB CRSP project – which suggest that utilizing local companies to be involved in construction work would mitigate the issue of any potential risk of labour shortage. Similarly, staggering construction times between the two project sites for construction work is intended to mitigate this risk further as it will limit the demand on workforce requirements if compared with undertaking construction at the two sites in parallel. Furthermore, initial assessments were undertaken to assess the availability and quality of construction material (rocks) in the main quarry in Tonga, and close monitoring of the availability will continue during project approval and implementation phases.

Activity 3.2 Sharing of lessons learned and best practices in climate resilient coastal protection measures for scale-up at the national and regional level

The following are covered under Output 3.2 in the following activities:

Sub-Activity 3.2.1 Technical evaluations of the design and effectiveness of the coastal protection measures conducted

Sub-Activity 3.2.2. Production of and publication of a report on lessons learned

Sub-Activity 3.2.3 Organize an international /regional conference for sharing lessons learned in climate-resilient coastal protection and management

In Tonga, and in the Pacific region in general, effective coastal protection measures are limited in number and diversity. The limitation is even more severe when one considers design standards that incorporate future climate risks. The coastal protection measures proposed in this project incorporates future climate risks reflected in the analysis of significant wave heights. But more importantly, this project is considered transformational in its approach of combining a short-term and long-term measures (in developing a climate resilient land use plan) to adapt to climate risks, and this is truly innovative in the context of the Pacific region. Overall lessons of not only the technical effectiveness of the coastal protection measures implemented in Activity 3.1, but also the process of and results from Output 1 and 2 will be disseminated regionally and internationally. As many countries in the Pacific will be facing difficult decisions relating to climate change impacts on exposed coastal populations in the future, the experience from Tonga will make significant contributions to the regional body of knowledge and insights.

7.1.1 Effects of adaptation measures on the marine environment

As noted above, the environmental effects of building the revetment works are considered to be ‘negligible’, given that the construction will take place in the footprint of previous coastal works, while also providing benefits through improved protection and drainage management. Similarly, the approach along the northern coast is considered to both avoid causing any potential damages, as well as also enhance environmental benefits through activities focussing on revegetation and behaviour change. The installation of patch revetments on a very localised scale is considered to involve minimal adverse effects. There may be some transient issues arising through the construction phase, mainly through mobilisation of beach material (coral sand), from rock placement activities. These are considered below in the context of management and protection of the local marine environment.

There is one significant marine protected area in the general vicinity of the adaptation works, involving the Fanga'uta lagoon and its surrounds. The Fanga'uta Lagoon was declared as a marine reserve in 1974, Subsequently, to address the declining health of the lagoon, the Ridge to Reef project developed a revised approach, resulting in management of the lagoon under the Fanga'uta Stewardship Plan (FSP)[17]. The FSP encompasses the lagoon and its watershed catchment as shown below[18].

The revetment works between Nukuleka and Talafo'o are situated within the catchment area on the most seaward coast of the lagoon, therefore the proposed investment/works 'must be endorsed by the FSP Steering Committee'[19]. The project will therefore work closely with the Steering Committee and relevant stakeholders to ensure compatibility with the FSP.

Tonga also has a network of Special Managed Areas (SMA) which, in some cases, include Fish Habitat Reserves (FHR)[20], covering areas between the two sites for adaptation works[21]. This highlights the need for consultation with the local community, including Coastal Community Management Committees.

7.1.2 Innovativeness and Effectiveness of the proposed interventions

Taken together, the activities under this project are considered transformational in combining short-term and long-term measures (in developing a climate-resilient land use plan) to adapt to climate change risks. Many Pacific countries will face difficult challenges as coastal populations face heightened risks due to climate change, especially sea level rise, in the future. Most countries are currently not prepared institutionally, socially, and legally to address these risks, so the Tonga experience will significantly contribute to the regional body of knowledge and insights. To scale-up the learning from this approach, a programme of activities will focus on identifying lessons learned and disseminating the information through various media and workshop formats. The major elements of this will be:

- Processes to document the experience of communities/stakeholders as they work through the process changes in land use management/planning and community decision-making.
- Documenting the outcome of these information-based and community-led processes and identifying lessons learned, including the 'lessons learned' event.
- A formal assessment of the technical design and effectiveness of the coastal protection measures implemented.
- Disseminating the lessons learned through the above through a variety of events and processes, including:
    - A regional workshop on key lessons and outcomes
    - Publication of reviews/assessments on coastal protection measures adopted under the project
    - Video and social media enable access to a wide range of audiences.

[17] GEF Ridge to Reef: https://www.thegef.org/news/heart-south-pacific-integrated-stewardship-fanga%E2%80%99uta-lagoon-tonga
[18] Fanga'uta Stewardship Plan: *A healthy lagoon reflects a healthy land and people. Government of Tonga*
[19] FSP Action Plan 2017 – 2021. Government of Tonga p2.
[20] SMA brochure, Ministry of Fisheries: https://www.tongafish.gov.to/images/documents/Publications/Brochures/SMA%20brochure-tonga-En.pdf
[21] Smallhorn-West P. et al (2020) Kingdom of Tonga Special Management Area report 2020. 86 p.

Interventions 1 and 2 of the project lay the foundation for a significant change in the way coastal adaption is managed in the face of sea level rise and related climate hazards and involve developing national scale awareness of the threats posed by sea level rise in terms of its direct impacts on coastal land and communities. This is partnered with a comprehensive data collection, management, and interpretation process to inform adaptation decisions from the national to the community / local level. This is the first time such a comprehensive approach to coastal climate risks/adaptation has been carried out at the scale of an entire nation in the Pacific Islands region.

Further, it involves a fundamental change in approach for coastal adaptation in Tonga, from opportunistic local actions, based on short-term concerns and, in some cases, maladaptive responses, towards comprehensive, evidence-based understanding of risks, with responses built on community commitment and sound assessment of adaptation options.

The proposed project's design incorporates lessons and best practices from several other projects to bring about transformative impact. These lessons include a) the use of locally appropriate technologies and solutions based on information available that is expected to be cost-effective; b) the effectiveness of a comprehensive barrier removal strategy; c) an innovative approach for capacity development in the Tonga context; and d) the critical importance of leveraging available local resources for promoting longer-term autonomous adaptation. These lessons have been derived from experiences on previous aid projects in Tonga, and community-based adaptation initiatives in other SIDS in the region. The Project will serve as an enabling environment for communities to govern, manage and implement their own climate change adaptation projects. The government alone cannot change how people act; initiatives need to be developed that spur people to take action, building their capacity to intervene, be innovative and cope in the face of coastal erosion and climate change.

The design of the interventions is in alignment with present international best practices in implementing coastal protection strategies that work with the natural processes rather than challenging the forces of the ocean head-on. Additionally, the design incorporates hard engineering interventions together with softer solutions such as coral restoration, mangrove plantation, and coastal vegetation. This project is innovative in that it offers a range of mixes of options that not only increase the longevity of the investments but also allow the Government and communities to learn about those options.

The successful project outcomes are intended to help reduce climate change vulnerability and enhance adaptive capacity in three Island Groups by introducing a blend of hard and soft engineering measures. It shall also enhance education and awareness of coastal management in the context of climate change by initiating local community awareness to stress that there are alternatives to hard engineering solutions. There will be effective monitoring of the coastal protection measures in collaboration with key stakeholders and from this community partnerships shall be strengthened.

7.2 Sustainability of the proposed interventions

Output 1 is designed to establish a soundly-based approach to adaptation decision-making that will be employed over the medium term and well beyond the project's conclusion. It aims to establish a national-level approach to land use and adaption in the coastal area and empower communities to become directly involved in decisions in their localities. This will be informed by solid baseline of technical information on a range of risk factors (coastal topography, wave modelling, rates of sea level rise etc) and the capacity in government agencies and civil society to interpret this information in decision making (Output 2).

For Output 3, the project design is based on the premise that the responsibility for monitoring, maintenance and upkeep of hard engineering structures should be with MEIDECC (as expressed in the letter of co-financing), with technical assistance from MoI and substantial contributions from local communities. Any interventions relating to the protection and management of the coastal zone would also need to be fit for purpose and that the interventions are congruent with community expectations. This community involvement and participation in the project concept development, design and implementation (including maintenance and monitoring of mangrove areas) will ensure that climate change adaptation interventions in the coastal zone are operated and maintained sustainably.

The overall design of this project, which has attempted to move from a piecemeal approach to a more comprehensive framework by looking at an entire geomorphological section of coastline and understanding the processes and coastal dynamics, provides a good sustainable approach for the MEIDECC and the Ministry of Infrastructure to use in the future. This should lead the way to replace the short-term reactive approach with a longer-term, planned, proactive and sustainable approach.

Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change and includes adjustments in both behaviour and resources and technologies. The presence of adaptive capacity is a necessary condition for the design and implementation of coastal protection measures to reduce the likelihood and the magnitude of negative impacts resulting from climate change. Adaptive capacity also enables taking advantage of opportunities or benefits from climate change. Adaptive capacity also entails the availability of financial resources, human resources, and adaptation options. This project has been designed to increase adaptive capacity during and after the implementation of the project. Coastal adaptation measures such as replanting and re-establishment will have (and will) increase the capacity of the communities/villages to cope with adverse impacts of climate change and availability, thereby increasing their adaptive capacity.

7.3 Knowledge management and learning

The project has strong elements of learning and knowledge management. First, the capacity of the MEIDECC, and the MoLSNR will be strengthened to collect data on coastal, marine and meteorological processes related to coastal vulnerability. This will contribute to the national body of knowledge on, for example, how increasing sea levels and intensifying cyclones have site-specific impacts on risks from storm surges and coastal inundation; and how healthy ecosystem functions positively interact with hard engineering solutions and build long-term coastal resilience.

Overall lessons of the technical effectiveness of the coastal protection measures implemented in Activity 3.1, in conjunction with the process of and results from Outputs 1 and 2, will be disseminated regionally and internationally through national/regional/international conference proceedings and other media. This will share the lessons learned and best practices in climate resilient coastal protection measures for scale-up at the national and regional level in the publication of lessons learned from the technical evaluations of the design and effectiveness of the coastal protection measures conducted. These will be shared also through the organisation of an international and/or regional conference to bring together practitioners as well as policy and planning for sharing lessons learned in climate resilient coastal protection and management. As many countries in the Pacific will be facing a difficult decision to consider relocating some of the most exposed coastal populations in the future, and most countries today are not prepared institutionally, socially, and legally to do so, the experience from Tonga will make significant contributions to the regional body of knowledge and insights in the Pacific, for neighbouring Pacific SIDS governments and policy decision-makers.The project also has a significant output of learning at the community level. This ranges from promoting a basic understanding of the linkages between climate change and coastal vulnerability and between ecosystem health and coastal resilience to specific knowledge about and skills for effective coral plantation, wetland restoration and water quality sampling. Enhanced community-level knowledge in these areas ultimately contributes to the strengthened understanding of the intricate interactions of ecosystems at the coastal landscape level (i.e. the concept of “ridge to reef”).

How community members will participate in project activities and strengthen their learning about climate change and coastal resilience has been informed by past successful projects and community consultations undertaken during the design of this project. Effective community engagement in project activities and knowledge building as an output of this process positively feed back into the sustainability of the overall project results.

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