Disaster and Climate Risk Assessment

18 December 2019

Kiribati: Outer Islands Transport Infrastructure Investment Project

Prepared by Ministry of Information, Communication, Transport and Tourism Development and the Ministry of Infrastructure and Sustainable Energy for the Asian Development Bank.

ABBREVIATIONS

ADB	–	Asian Development Bank
CMIP5	–	Coupled Model Intercomparison Project Phase 5
DCRA	–	disaster and climate risk assessment
ENSO	–	El Niño-Southern Oscillation
GOK	–	Government of Kiribati
IPCC	–	Intergovernmental Panel on Climate Change
IVA	–	integrated vulnerability and adaptation assessment
KOITIIP	–	Kiribati Outer Islands Transport Infrastructure Investment Project
SLR	–	sea level rise
UNFCCC	–	United Nations Framework Convention on Climate Change

GLOSSARY OF TERMS

Adaptation	Changes made in response to the likely threats and opportunities arising from climate variability and climate change.
Adaptation Assessment	The practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency, and feasibility.
Adaptation Measures	Adaptation measures are actions taken to help communities and ecosystems moderate, cope with, or take advantage of actual or expected
Adaptation Options	The range of actions and steps which can be taken to adapt to climate change. They include a wide range of actions that can be categorized as structural, institutional, or social.
Adaptive Capacity	The ability of a person, asset or system (human or natural) to adjust to a hazard or threats (including variability and extremes) to moderate potential damages, or to take advantage of opportunities, or to cope with the consequences.
Assets	Something that has potential or actual value to an organization.
Asset Design Life	How long the asset could be used before it would be work out or beyond economic repair, assuming routine maintenance but disregarding any potential for refurbishment or reconstruction.
Climate change	Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: ‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.’ The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.
Climate change impacts	The effects of climate change on natural and human systems. Depending on the state of adaptation, one can distinguish between potential impacts and residual impacts: Potential impacts: All impacts that may occur given a projected change in climate, without considering adaptation; and Residual impacts: The impacts of climate change that would occur after adaptation has taken place.
Climate Change Impact Assessment	The practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change on natural and human systems.
Climate proofing	A shorthand term for identifying risks to a development project, or any other specified natural or human asset, as a consequence of climate variability and change, and ensuring that those risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable, and socially acceptable changes implemented at one or more of the following stages in the project cycle: planning, design, construction, operation, and decommissioning (Asian Development Bank [ADB] 2005).
CMIP5	The Coupled Model Intercomparison Project Phase 5 (CMIP5) brings together 20 state-of-the-art GCM groups, which generated a large set of comparable climate-projections data. The project provides a framework for coordinated climate change simulations for assessment under the IPCC´s Fifth Assessment Report (AR5).

Consequence	A subsequent result (usually negative) that follows from damage to or loss from an asset. Quantifying potential consequences is a critical factor of determining risk. Consequences can be measured in terms of economic, social, environmental or other impacts.
Design Life	The length of service the structure is designed to provide in a functional state.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected.
Extreme weather event	Event that is rare at a particular place and time of year. Definitions of "rare" vary, but an extreme weather event would normally be as rare or rarer than the 10th or 90th percentile of the observed probability density function.
General Circulation Model	A General Circulation Model (GCM) is the most advanced type of climate model used for projecting changes in climate due to increasing greenhouse-gas concentrations, aerosols and external forcings like changes in solar activity and volcanic eruptions. These models contain numerical representations of physical processes in the atmosphere, ocean, cryosphere and land surface on a global three-dimensional grid, with the current generation of GCMs having a typical horizontal resolution of 100 to 300 km
Hazard	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.
Impacts	Effects on natural and human systems that result from hazards. It generally refers loss and damage due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Evaluating potential impacts is a crucial step in assessing vulnerability.
Infrastructure assets	Infrastructure assets are the physical assets that contribute to meeting the needs of the entities or the need for access to major economic and social facilities and services, e.g. roads, drainage, footpaths etc.
Inundation	The Total Water Level that occurs on normally dry ground as a result of the storm tide, and is expressed in terms of height of water, in meters, above ground level. Inundation provides the most clearly and commonly understood method for communicating storm surge-driven coastal flooding.
Level of risk	Magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood.
Life	Life is a measure of the anticipated life of an asset or component.
Life cycle	Time interval that commences with the identification of the need for an asset and terminates with the decommissioning of the asset or any associated liabilities.
Likelihood	Likelihood refers to the chance or probability that a hazard or threat will occur within a specified timeframe or planning horizon, and this can be a qualitative or quantitative measure.
Loss & Damage	Despite no official definition of 'Loss and Damage' by the UNFCCC, the term is widely agreed to refer to the 'residual impacts' of climate change. The term therefore refers to climate change impacts which cannot (or will not) be avoided by mitigation and adaptation. The key traits of such residual impacts, as identified within scientific literature, are that it is; "attributable to human-caused climate change, irreversible, unavoidable and intolerable".

Overtopping	Passing of water over the top of a structure as a result of wave run-up or surge action.
Probability	The likelihood of hazard events occurring. Probabilities have traditionally been determined from the historic frequency of events. With a changing climate and the introduction of non-climate stressors, the probability of hazard events also changes.
Projections	Potential future climate conditions calculated by computer-based models of the Earths systems (GCM's). Projections are based on sets of assumptions about the future (scenarios) that may or may not be realised. Current climate projections indicate that if human emissions of greenhouse gases continue increasing through to 2050 (a scenario, or possible future), most locations around the world will see substantial increases in average annual temperature and associated changes in weather and precipitation.
Resilience	Resilience is the ability of a system (human or natural) to prevent, withstand, respond to, or recover from the effects of hazards and threats in a timely and efficient manner.
Risk	The potential total costs if something of value is damaged or lost, considered together with the likelihood of that loss occurring. Risk is often represented as probability of the hazard occurring multiplied by the that would result if it did happen. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.
Risk analysis	Process to comprehend the nature of risk and to determine the level of risk.
Risk assessment	Overall process of risk identification, risk analysis and risk evaluation
Risk management	Coordinated activities to direct and control an organization with regard to risk.
Sensitivity	Sensitivity reflects the responsiveness of a system to climatic influences, and the degree to which changes in climate might affect that system in its current form. Sensitive systems are highly responsive to climate and can be significantly affected by small climate changes.
Significant wave height	Average height of the highest one third of the waves in a given sea state.
Storm surge	The temporary increase, at a particular locality, of the height of the sea due to extreme meteorological conditions. The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place.
Uncertainty	A state of incomplete knowledge. Uncertainty about future climate arises from the complexity of the global climate systems and the ability of the GCM's to represent it, as well as the inability to predict the decisions that a society will make.
Vulnerability	Vulnerability to the impacts of climate change are a function of exposure to climate conditions, sensitivity to those conditions, and the capacity to adapt to the changes. The IPCC defines vulnerability the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change and is site specific.
Vulnerability assessment	A vulnerability assessment attempts to identify the root causes for a system's vulnerability to climate changes.

Source: Intergovernmental Panel for Climate Change (IPCC), Fifth Assessment Report (AR5) of Working Group (WG): The WGII AR5 glossary defines many terms used across chapters of the report. Reflecting progress in science, some definitions differ in breadth and focus from the definitions used in the Fourth Assessment Report (AR4) and other IPCC reports.

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I. INTRODUCTION

A. Background

1. The Asian Development Bank (ADB) and the World Bank (WB) are supporting the Government of Kiribati (GOK) in the development of the Kiribati Outer Islands Transport Infrastructure Investment Project (KOITIIP), herein after referred to as the project. The project aims to improve transport connectivity for communities in selected outer islands of Kiribati through provision of sustainable, safe and resilient universal basic access transport infrastructure.

B. Context

2. Natural disasters are an ongoing concern in Asia and the Pacific, and impacts are projected to intensify in the decades to come due to climate change, further threatening the development and security of the region. Countries in Asia and the Pacific are among the most vulnerable globally to the adverse impacts of natural disasters and climate change, with poor and marginalized communities likely to suffer the most heavily.

3. ADB's Strategy 2020, along with Addressing Climate Change in Asia and the Pacific: Priorities for Action, Environment Operational Directions 2013–2020, and Sustainable Transport Initiative—Operational Plan are all aligned in committing ADB's technical and financial support to its developing member countries to address climate change, including mainstreaming climate risk management in transport sector investment projects.

4. ADB's adaptation program has grown in recent years to encompass a range of interventions to help developing member countries (DMC) reduce their vulnerability and address the impacts of disasters and climate change. Specifically, ADB is supporting the DMCs' efforts to integrate climate change risk management and disaster risk reduction into national development strategies, sector plans, and investment projects. In this context, ADB mandates that the investment projects it finances are assessed to identify risks at early stages of development and that projects at risk incorporate adaptation measures.

5. The long-term strategic framework of ADB, Strategy 2020, and its climate change strategy, Addressing Climate Change in Asia and the Pacific: Priorities for Action, confirm their commitment to help developing member countries in Asia and the Pacific address the increasing challenges posed by climate change and to build a climate-resilient region. In particular, ADB is seeking to assist its DMCs to enhance the disaster and climate resilience of vulnerable sectors, such as transport, agriculture, energy, water, and health, by 'climate-proofing' investments in these sectors to ensure their intended outcomes are not compromised by climate change.

6. In this light, ADB is supporting Kiribati's national goals by helping to develop key infrastructure assets, and by strengthening domestic capacity to manage and maintain them. A safe and efficient maritime transport system is essential in connecting Kiribati's population to economic opportunities and social services. ADB's assistance is aligned with Kiribati's national development priorities and is increasing equitable access to opportunities and essential services. Improving maritime connectivity between the main island of Tarawa—where 55% of the population lives—and the outer islands can increase access to essential resources and improve safety conditions for passengers and goods.

7. The Government of Kiribati has requested support from ADB and its development partners to provide safer transport to and from the outer islands. A key point of intervention will be to build

and refurbish maritime and land-based transport infrastructure on the outer islands of Abaiang, Nonouti, Beru and Tabiteuea South to better serve Kiribati's remote communities. Transport infrastructure is highly vulnerable to disasters and projected climate change. Rising sea levels, increase in temperature, changes in precipitation patterns, and extreme weather events can affect the operation and safety of roads, bridges, ports, and other transport infrastructure, and significantly disrupt the flow of goods, services, and people within and across countries of the region. This is of particular concern in Kiribati and its outer islands, which is already experiencing significant adverse impacts from a changing climate.

C. Purpose and Objectives of Disaster and Climate Risk Assessment

8. ADB has committed to assisting developing countries in climate proofing projects (including those financed by ADB) to ensure their outcomes are not compromised by climate change and variability or by natural hazards in general. As part of this commitment, the ADB requires consideration of the impact of natural hazards, and in particular climate change, on its infrastructure investments. Initial climate risk screening for this project undertaken during the project concept development phase by ADB, identified climate risk as being "medium", and hence a disaster and climate risk assessment (DCRA) is required to assess and mitigate anticipated climate change hazards, risks and impacts facing the KOITIIP project and it's sub-components, and to incorporate 'future climate change risk' considerations into the design, operations, and maintenance of the proposed electricity supply systems.

9. This DCRA study provides a review of the existing and future risks to the PSDIP project in accordance with the requirements of the ADB's Climate Risk Management Framework (ADB, 2014a) and the ADB Guidelines for Climate Proofing Investment in the Energy Sector.[1]

10. The objective of this study is to assess the vulnerability of KOITIIP to the impacts of current disasters and projected climate change and to identify adaptive measures to reduce vulnerability and minimize the risk of significant negative impacts to project assets and infrastructure. It should be noted that the level of detail of the assessment is generally dictated by the complexity of the project, available information on the project, and the available information on climate change projections for the project sites.

11. In this context, this DCRA assesses the disaster and climate change impacts associated with the design and construction of maritime and coastal road transport assets in the outer islands of Kiribati. It also identifies a range of adaptation options for managing and reducing disaster and climate risks to project assets, including project design, construction and operational activities. Finally, it outlines broader disaster and climate resilience measures, such as slope stabilization for protection of T/D infrastructure against landslides, which will be important for maintaining long term resilient outcomes of the project.

D. Disaster and Climate Risk Assessment Approach

12. Discussions during the Fact Finding Mission confirmed the need to adopt an 'integrated risk-based approach' for conducting the DCRA, based on a synthesis of the 'ADB Climate Proofing: A Risk-based Approach to Adaptation Guidelines 2005'; 'ADB Climate Risk Management Framework 2014'; ADB Guidelines for Climate Proofing Investment in the Energy Sector 2013; and the World Bank Group's three pillar approach which are closely related focusing

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[1] Asian Development Bank (ADB). 2014. *Climate Risk Management in ADB Projects*. Manila; ADB.2013. *Guidelines for Climate Proofing Investment in the Energy Sector*. Manila.

on: upstream analytical work on climate change; integration of climate risk management into the country dialogue; and the integration of climate risk management into projects.[2]

13. Hence, for the purpose of this DCRA, we have adopted a qualitative ‘risk-based’ approach for identifying the specific systematic disaster and climate risks to project infrastructure, assess how these hazards may affect project design or impact the project assets, and determine how to adapt the project engineering design specifications and standards necessary to disaster and climate proof transport infrastructure investment.

14. This approach uses ‘expert’ opinion to estimate likelihood (or frequency) and consequence (or impacts) to define disaster and climate risks in terms of for example high, medium, low, etc., and specifically focuses on quantify the risks to project infrastructure from hazards, and identifying practical adaptation options that can be integrated into the project design to improve and/or enhance the resilience of the proposed transport infrastructure to current and projected future climate impacts.

15. Following the planned hydrographic surveys, a more detailed DCRA will be developed in conjunction with the detailed design of maritime infrastructure to ensure that project-level disaster risks are fully assessed, DRR measures identified and costed, and best practices in building climate and disaster resilience are reflected in the final design.

II. DESCRIPTION OF THE PROJECT

16. The Asian Development Bank (ADB) and the World Bank are supporting the Government of Kiribati in the development of KOITIIP, herein after referred to as the project. The project aims to improve transport connectivity for communities in selected outer islands of Kiribati through provision of sustainable, safe and resilient universal basic access transport infrastructure. The intervention will also include capacity development in the stakeholder ministries.

17. **Project Development Objective (PDO)**. The proposed PDO is to improve the safe and resilient transport connectivity of selected outer islands in the Gilbert Islands Chain of Kiribati, and in the event of an eligible crisis or emergency, to provide an immediate response to the eligible crisis or emergency.

18. **Detailed Project Components and Activities.** The following project components and activities are being considered as part of the KOITIIP. They will be refined and decided during project preparation and will be subject to available financing.

- **Component 1: Safe Interisland Navigation.** This component will finance hydrographic surveying and maritime charting focusing on the target islands. Depending of available resources, the survey may cover other outer islands, which will be the key enabler for future infrastructure investments, will be implemented at the national level, and will provide maritime planning support.

- **Component 2: Resilient Outer Island Access Infrastructure**. This component consists of the main civil works activities (including detailed design, supervision, and enabling works and equipment) to be undertaken on the prioritized outer islands.
    i. <u>Sub-Component 2.1: Improvement of Ships to Shore Transfer.</u> Investments include aids to navigation which will consist of both replacement of existing

[2] ADB. 2005. *Pacific Studies Series: Climate Proofing-A Risk-based Approach to Adaptation*. Manila. Footnote 1.

defective aids, and the installation of new aids (including illuminated navigation aids for safe night passage). Location of the new navigation aids will be guided by the hydrographic and charting outputs.

ii. Sub-Component 2.2: Rehabilitation of Island Access Infrastructure. Following completion of the hydrographic surveys (Component 1 – which is expected to take 2 years), this sub-component would finance (i) the construction of simple concrete boat ramps; (ii) construction of appropriately scaled port terminals (basic sheds) to provide protection of inward/outward goods and passengers at selected locations (maximum of 1 per island); and (iii) the design and construction/rehabilitation of a range of maritime infrastructure covering jetties, barges, small scale dredging, and related investments.

iii. Sub-Component 2.3: Rehabilitation of Island-Crossing Causeways. This sub-component will be focused on the provision of rehabilitation works for causeways, including enabling works and related investments, to ensure accessibility on prioritized outer islands. In addition to civil works, this sub-component would finance engineering studies prior to the commencement of detailed design, further geomorphological studies, detailed design, independent audits, and supervision.

- **Component 3: Institutional Strengthening.** This component would provide technical assistance to support the transport sector development and capacity building for the two implementing agencies Ministry of Information, Communication, Transport and Tourism Development and Ministry of Infrastructure and Sustainable Energy. Proposed technical assistance activities will include studies, training, and provision of small equipment. This sub-component could include technical studies and designs required for the preparation of potential future investments beyond Abaiang and the Southern Gilberts.

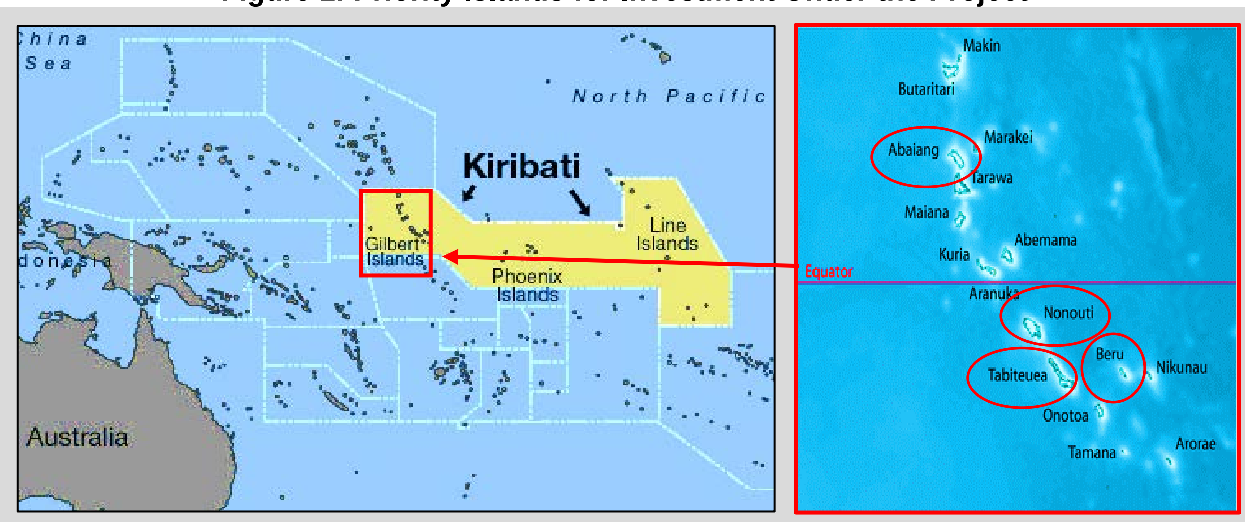
- **Component 4: Operational Support.** This sub-subcomponent will finance project management and operational costs - human resources or goods - associated with implementation of the proposed project. Activities to be financed will include (a) operating costs of the outer islands implementation unit (OIIU), including salary of key OIIU staff and consultants, as well as support to the implementing agencies for the overall technical supervision of the project; (b) relevant training for project staff; (c) acquisition of small equipment; (d) financial audits; (e) monitoring and evaluation; (e) compliance monitoring of environmental and social safeguards; and (f) project impact studies. Because of large project area needed to be covered during implementation, the project will consider a variety of digital technologies to facilitate the implementation of project activities as well as enhance monitoring and evaluation. Support for ensuring the beneficiaries' participation and feedback during project preparation and implementation will be included through the integration of sustainable citizen engagement processes.

- **Component 5: Contingency Emergency Response.** This component would support preparedness and rapid response to an eligible crisis or emergency, if needed. Following the declaration of a disaster or state of emergency, it allows for reallocation of credit and grant proceeds from other project components under streamlined procurement and disbursement procedures, or a mechanism to channel additional funds, should they become available, resulting from an emergency. These resources would be pooled with resources coming from other projects financed by the World Bank in the country. An Immediate Response Mechanism Coordinating Agency and expenditure management procedures will be defined in an Immediate Response Mechanism Operational Manual (IRM/OM), to be prepared separately and approved by the World Bank, in line with guidance provided under OP 10.00, paragraph 12.

19. **Proposed Project Implementation Timeline.** The project is proposed to be implemented over a 7-year timeline due to the interdependence of planned project activities. The rehabilitation of the maritime island access infrastructure under Sub-Component 2.2 would start only after the completion of the hydrographic surveys. Works for the construction/rehabilitation of a range of maritime infrastructure covering jetties, barges, small scale dredging, and related investments are expected to occur during years 4-7 of the project, following the one-year design and procurement phase.

20. **Priority Islands for Investments.** The GOK has identified four islands as priority investments locations for this project, these being Abaiang, Nonouti, Beru and Tabiteuea South as highlighted in Figure 1. Design studies will be completed for all these islands. Should funds permit further investment, then selection of additional islands will be undertaken in conjunction with GOK.

Figure 1: Priority Islands for Investment Under the Project



21. **Scope of Works**. Table 1 provides a summary of the key activities to be undertaken under Component 2: Resilient Outer Island Access Infrastructure, these being (i) Sub-Component 2.1: Improvement of Ship-to-Shore Transfer (maritime navigation aids); (ii) Sub-Component 2.2: Rehabilitation of Island Access Infrastructure (concrete boat ramps, small multipurpose maritime and maintenance facility/workshops, maritime infrastructure covering jetties, small scale dredging, and related investments); and (iii) Sub-Component 2.3: Rehabilitation of Island-Crossing Causeways. Table 1 provides a summary of the scope of works for the proposed infrastructure investment for each island.

Table 1: Technical Scope of Project Investments

Island	Project Sub-Component	Proposed Transport Infrastructure
Abaiang Island	**Sub-Component 2.2. Rehabilitation of Island Access Infrastructure**	**Boat ramp, pontoon, and shelter at Taburao**: The proposed concept maritime facility at Taburao is a reinforced concrete boat ramp recessed into the beach extending into the lagoon, featuring a short on-ramp pontoon and passenger terminal. The ramp would include a cradle and winch capable of retrieving small boats up to about 2.5 tons. The jetty would consist of a modular, articulated on-ramp

Island	Project Sub-Component	Proposed Transport Infrastructure
		pontoon and could be used during periods of higher tides only.
Beru Island	**Sub-Component 2.1. Improvement of Ship-to-Shore Transfer (maritime navigation aids)**	**Channel Dredging and shoreside improvements at Tebikeriki**: to allow the existing ramp to be used as a RORO facility and safer access from ship to shore. The proposed works would include: dredging the channel to a depth and width suitable for interisland ships (approximately 3m below mean low water springs); installation of new markers at entrance of access channel; new concrete facing and installation of sand/concrete back in front of existing seawall; concrete overlay on the existing ramp slab and roadway; construct new shelter/ waiting area/ storage facility.
	Sub-Component 2.3. Rehabilitation of Island-Crossing Causeways	**Rehabilitation of causeways and road transport infrastructure necessary for enhancing asset life, user safety for two causeways**: Northern Causeway (420m); and Southern Causeway (274m). Proposed works include: the installation of gabion groynes as a counter measure to erosion and the planting of mangroves and/or other salt tolerant species to compliment the gabion groynes, as a counter measure to erosion.
Nonouti Island	**Sub-Component 2.2 Rehabilitation of Island Access Infrastructure (Jetty, concrete boat ramp, small multipurpose maritime and maintenance facility/workshop, and small-scale dredging)**	**Construction of a new Multipurpose Maritime Facility at Matang**. This facility would allow fabrication and maintenance of much needed Aids to Navigation markers as well as providing a storage and maintenance facility for the soon to be gifted landing craft. The facility would consist of a concrete base slab, steel or timber framing, and corrugated iron roof sheeting. A cradle could be housed in the shed, capable of retrieving the landing craft to be gifted to the Council. The structure would be generally open/ not clad, however an enclosed area could be built into the rear of the building. This is a suitable area for ATON fabrication, and storage of valuables (such as tools, fuel, cement, etc.).
	Sub-Component 2.3. Rehabilitation of Island-Crossing Causeways	**Rehabilitation of causeways and road transport infrastructure necessary for enhancing asset life, user safety for five causeways**: Northern Causeway (275m); 2nd Causeway from the North (330m); 3rd Causeway from the North (144m); 4th Causeway from the North (144m) and Southern Causeway (167m). Proposed works variously include: road restoration, improved drainage systems, structural repairs of the causeway, installation of culverts, installation of gabion groynes as a counter measure to erosion and the planting of mangroves and/or other salt tolerant species to compliment the gabion groynes, as a counter measure to erosion at each location.
Tabiteuea South	**Sub-Component 2.2 Rehabilitation of Island Access Infrastructure (Jetty, concrete**	**Multipurpose Maritime Facility at Bairiki.** The facility would consist of a concrete base slab, steel or timber framing, and corrugated iron roof sheeting. A cradle could

Island	Project Sub-Component	Proposed Transport Infrastructure
	boat ramp, small multipurpose maritime and maintenance facility/workshop, and small-scale dredging)	be housed in the shed, capable of retrieving the landing craft soon to be gifted to the Tab South Council. The structure would be generally open/ not cladded, however an enclosed area would be built into the rear of the building. This is a suitable area for ATON fabrication, and storage of valuables (such as tools, fuel, cement, etc.).
	Sub-Component 2.3. Rehabilitation of Island-Crossing Causeways	**Rehabilitation of causeways and road transport infrastructure necessary for enhancing asset life, user safety for four causeways**: Northern Causeway (150m); 2nd Causeway from the North (102m); 3rd Causeway from the North (530m); and Southern Causeway (420m). Proposed works variously include road restoration, improved drainage systems, reconstruction and structural repairs of the causeway, sandbag road edging to counter wave lapping. installation of culverts, provide scour protection (precast concrete blocks) adjacent to the installed culverts, installation of gabion groynes as a counter measure to erosion and the planting of mangroves and/or other salt tolerant species to compliment the gabion groynes, as a counter measure to erosion at each location.

ATON = aid to navigation; m = meter; RORO = roll-on/roll-off.

Source: Asian Development Bank.

III. HAZARDSCAPE

A. Introduction

22. This section provides a review of natural hazard risks for Kiribati and was compiled from a number of sources (including Preventionweb, EM-Dat and ThinkHazard!). The Pacific region is known to be one of the most exposed to natural hazards and climate change in the world. Pacific Island Countries are exposed to a wide variety of natural hazards, including cyclones, droughts, earthquakes, electrical storms, extreme winds, floods, storm surges, tsunami and volcanic eruptions.

23. As discussed in Annex 1, some of these hazards will be exacerbated by changes in the climate, sea level rise and the intensity of climatic disasters like tropical cyclones, droughts and floods. Small Island Developing States, and especially the low-lying coral atoll nations such as Kiribati and Tuvalu are particularly vulnerable to these impacts due to their underlying limited natural endowments, economic constraints and limited adaptive capacity.

B. Natural Hazard Profile for Kiribati

24. **Surface air temperature and sea-surface temperature**. The ROK consists of 32 low-lying coral islands in three main groups that are scattered over 3.5 million kilometers in the central Pacific Ocean. These narrow islands, most less than two kilometers wide and not more than six meters above sea level, concentrate the entire population and most infrastructure along the coast, directly exposed to climatic threats. Droughts and geo-hazards, including earthquakes and tsunamis, also present risks.

25. The main risks for Kiribati as assessed by ThinkHazard!, are those arising from sea-level rise, coastal erosion and inundation, droughts, saline intrusion, and ecosystem degradation. However, Kiribati also faces a number of other non-climate induced natural hazard risks including earthquakes and Tsunami's as summarized in Table 2 below.

Table 2: Natural Hazard Profile for Kiribati (ThinkHazard!)

Natural Hazard	**Risk Level**
Coastal Flooding	*High*
Tsunami	*High*
Extreme Heat	*Medium*
Cyclone	*Low*
Flooding (river)	*Very Low*
Earthquake	*Very Low*

26. ThinkHazard! provides a general view of the hazards, for a given location, that should be considered in project design and implementation to promote disaster and climate resilience. The tool highlights the likelihood of different natural hazards affecting project areas (very low, low, medium and high), provides guidance on how to reduce the impact of these hazards, and where to find more information. The hazard levels provided are based on published hazard data, provided by a range of private, academic and public organizations.

27. Thinkhazard! identifies the following acute impact events threatening Kiribati that arise from natural sources. These are consistent with those identified under the National Disaster Risk Management Plan (NDRMP GOK 2012b), which identifies coastal inundation, Tsunamis and drought as the primary natural hazard risks facing Kiribati. These hazard risks are discussed in priority order below.

28. **Coastal flooding hazard risk (Hazard level: HIGH)**. In Kiribati, coastal flood hazard was assessed by ThinkHazard! as high according to the information that is currently available. This means that potentially-damaging waves are expected to flood the coast at least once in the next 10 years. Based on this information, the impact of coastal flood must be considered in different phases of the project for any activities located near the coast. Project planning decisions, project design, and construction methods should take into account the level of coastal flood hazard, and further detailed information should be obtained to adequately account for the level of hazard.

29. The National Disaster Risk Management Plan notes that "inundation is experienced in most islands of Kiribati when an active MJO within the Western Pacific region coincides with an El Niño event e.g. Tropical Cyclone Pam and Tropical Depression Bavi. Storm surges have also been experienced as well due to strong low-pressure systems that were nearing the Kiribati borders".

30. *Climate change impact*: According to the Intergovernmental Panel on Climate Change (IPCC), 2013, there is high confidence that extremes in sea level will increase with mean sea level rise yet there is low confidence in region-specific projections in storm surges. Projects in low-lying coastal areas such as Kiribati should be designed to be robust to projected increases in global sea level.

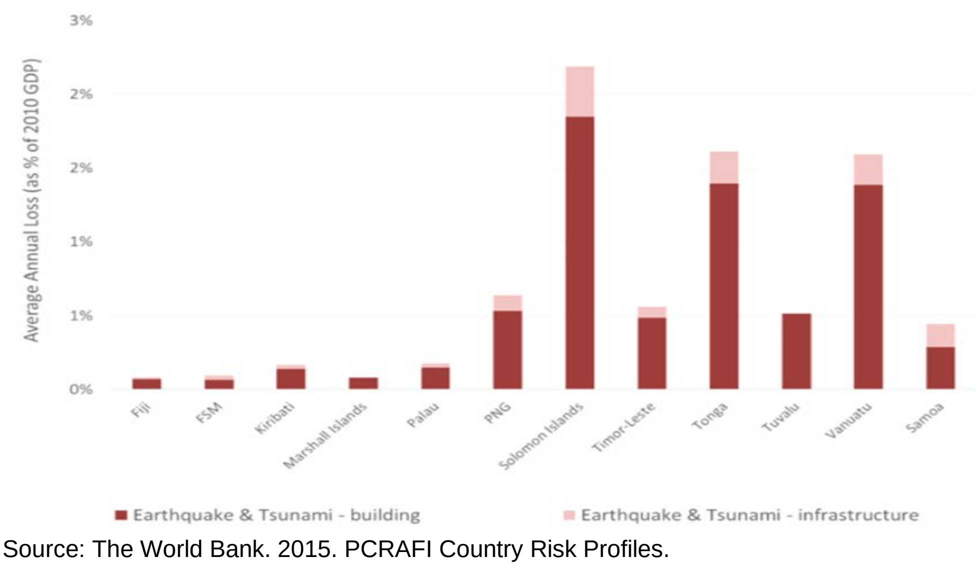
31. *Risk reduction measures*. Project planning, design, and construction practices should account for coastal flood and storm surge from cyclones and other weather events occurring in the project area. *Please note that these measures are generic and not project-specific.*

32. **Tsunami hazard risk (Hazard level: HIGH)**. In Kiribati, tsunami hazard is classified as high according to the information that is currently available. This means that there is more than a 20% chance of a potentially-damaging tsunami occurring in the next 50 years. Based on this information, the impact of tsunami should be considered in different phases of the project for any activities located near the coast. Project planning decisions, project design, and construction methods should take into account the level of tsunami hazard and further detailed information should be obtained to adequately account for the level of hazard.

33. The National Disaster Risk Management Plan notes that “Tsunami risk modelling and the limited historical records of tsunami events would suggest Kiribati has a lower tsunami risk relative to other Pacific Island countries and territories closer to subduction trenches, where earthquakes with the potential to generate tsunami can occur. Although the Kiribati population and government have had no direct experience with tsunami impacts, they are aware of the susceptibility of low-lying atolls to rising sea levels associated with climate change and of the potential for tsunami impact”.

34. Since 1994 there have been three small events detected at the Tarawa sea level gauge from the Kuril and Japan trench. These were 8.3 Mw events on 4 October 1994 and 15 November 2006 and a 9.0 Mw event on February 2012. Two events in 1994 and 2006 resulted in waves less than 10 cm in height, while the 2012 event resulted in a height of 20 cm recorded at the Tarawa tide gauge. Most recently, Kiribati has been placed under a tsunami warning by the Pacific Tsunami Warning Centre.

Figure 2: Expected Average Annual Losses due to Tsunami and Earthquake in Pacific Island Countries



Source: The World Bank. 2015. PCRAFI Country Risk Profiles.

35. *Climate change impact*: The areas at risk of tsunami will increase as global mean sea level rises. According to the IPCC (2013), global mean sea level rise depends on a variety of factors and estimates for 2100 range from ~20 centimeter (cm) to nearly 1 meter (m). However, regional

changes in sea level are difficult to predict. Projects in low-lying coastal areas such as in island states should be designed to be robust to projected increases in global sea level.

36. *Risk reduction measures.* Consider the effect that the destruction or serious damage to buildings and infrastructure associated with the project could have on the local population and environment, and the impact of tsunami inundation on the availability and function of transport, communications etc. for continued operation of the project. If the project is involves the development of critical infrastructure (e.g., a hospital, fire station, or power transmission line), investigate the cascading effect of vulnerable network dependencies of the project (e.g. power supply and computer and communication networks) that may impact the project, even if the project itself is not inundated. Early warning may be required if this could reduce consequential and compounding damage. Consider the requirements for successful evacuation of the project location in case of a warning (e.g., adequate transportation, evacuation routes, and safe refuges etc.). *Please note that these measures are generic and not project-specific.*

37. **Extreme heat hazard risk (Hazard level: Medium)**. In Kiribati, extreme heat hazard is classified as medium based on modeled heat information currently available. This means that there is more than a 25% chance that at least one period of prolonged exposure to extreme heat, resulting in heat stress, will occur in the next five years. Project planning decisions, project design, and construction methods should take into account the level of extreme hazard.

38. *Climate change impact*: According to the most recent assessment report of the Intergovernmental panel on Climate Change (IPCC, 2013), continued emissions of greenhouse gases will cause further warming, and it is virtually certain that there will be more frequent hot temperature extremes over most land areas during the next fifty years. Warming will not be regionally uniform. In the area you have selected, the temperature increase in the next fifty years will be much lower than the worldwide average, but still significant. It would be prudent to design projects in this area to be robust to global warming in the long-term.

39. *Risk reduction measures.* Consultation with engineering and climate impact assessment professionals will provide a more detailed understanding of the risk posed to your asset by extreme heat. Consideration should be given to the vulnerability of other assets within the project's dependency network, including heat management measures appropriate to your sector of operation, for example, technological adaptation, building design, or changing working practices *Please note that these measures are generic and not project-specific.*

40. **Cyclone hazard risk (Hazard level: Low)**. In Kiribati, cyclone hazard is classified as low according to the information that is currently available. This means that there is a 1% chance of potentially-damaging wind speeds in your project area in the next 10 years. Based on this information, the impact of cyclones should be considered in the project, in particular during design and construction. Project planning decisions, project design, and construction methods should take into account the level of cyclone hazards. Note that damages can not only occur due to wind but also cyclone induced heavy rainfall, storm surge and subsequent flooding as well as inundation of coastal areas. Further detailed information should be obtained to adequately account for the level of hazard.

41. Due to its specific geographic location spanning the equatorial belt, Kiribati generally escapes the major climate-related threat of cyclones. However, the relatively small size of its islands means it is highly vulnerable to most climate-related hazards. The limited information base does not allow a definitive assessment of any geologic hazards to which Kiribati may be prone. However, Kiribati experiences tropical storms and depressions, but they usually do not cause

wind speeds string enough to categorize as tropical cyclone. However, in 1978 tropical cyclone Alice spawned as a tropical depression in Kiribati and crossed the island of Tarawa causing minor damage before developing into a full blown tropical cyclone and hitting the Marshall Islands. More recently, in March 2015 Tropical Cyclone Pam, whilst not directly hitting Kiribati still caused significant storm tides, coastal flooding, erosion and loss of houses and infrastructure.

42. More recently, in February 2019, infrastructure and properties were severely damaged in Tamana and Arorae by a storm surge that was caused by an active low pressure tropical depression) system that developed near the southern islands in Kiribati and which later moved southward to the Fiji Islands, where it fully developed into Tropical Cyclone Mona.

43. *Climate change impact*: Global average tropical cyclone wind speed and rainfall is likely to increase in the future, and the global average frequency of tropical cyclones is likely to decrease or remain unchanged. It is possible that the frequency of the most intense tropical cyclones will increase substantially in some ocean regions (IPCC, 2013). The present hazard level in areas currently affected by tropical cyclones may increase in the long-term. Projects located in such areas should be robust to future increases in cyclone hazard.

44. The major climate hazards to which the Kiribati is exposed regularly include rising sea levels, storm events, heavy rainfall, drought, storm surges, extreme tidal and significant wave events. Of these, the most serious are considered to be the combination of extreme high tides, extreme wave events, heavy rainfall and windstorms, and this is primarily due to their high frequency and potential for causing significant damage through flooding, erosion and other impacts. The combined effect of storm surges and tides, or storm tides, can be especially destructive. However, it should also be noted that there is considerable variation in hazard patterns across the archipelago and even between islands in the same atoll, due to local variation in bathymetric, geo-physical, environmental and climatic factors, and these aspects also need to considered. For example, the northern atolls face a greater risk of cyclonic winds and storm surges than the southern atolls, where the risk is much lower because of proximity to the equator.

45. In addition to this, with sea level rise and the deterioration of the ecological services provided by fringing coral reefs and mangrove ecosystems protecting vulnerable coastlines, this risk from cyclone, storm surge and significant wave events is becoming greater and specially to coastal infrastructure and urban populations. There is wide agreement that the combination of sea level rise and deterioration in coral reef and mangrove ecosystems will make coastal areas considerably more vulnerable to storms. Coral reefs and mangrove forests serve as wave barriers and prevent the full force of storm surges from hitting coastal regions. Recent study shows that coral reefs decrease 97 percent of the storm-wave power and reduce wave height by 84%.

46. **Risk reduction measures.** Consultation with engineering and climate impact assessment professionals will provide a more detailed understanding of the risk posed to assets by extreme storm events and cyclones. Project planning, design, and construction practices should account for strong wind from potential cyclones in the project area, and the consideration and incorporation of the government’s emergency response policy and protocols to cyclones (including coastal and inland flooding and wind hazard) as necessary. *Please note that these measures are generic and not project-specific.*

47. **Flooding hazard risk (Hazard level: Very Low)**. In Kiribati, localized urban and river flood hazard is classified as very low based on modeled flood information currently available. This means that there is a chance of less than 10% that potentially damaging and life-threatening river floods occur in the coming 10 years. Therefore, based on this information, flood hazard does not

need to be explicitly considered for your project. Surface flood hazard in urban and rural areas is not included in this hazard classification and may also be possible in this location.

48. South Tarawa and other islands in the Gilbert Group experienced flooding throughout December 2018 and January 2019, with a rainfall accumulation of 292.6 millimeter (mm). It was reported that this is the highest ever recorded for South Tarawa and other islands in the Gilbert Group. Extensive seawater flooding in low lying areas was also experienced and reported from Tamana, Arorae and later from Onotoa, Beru, Nikunau, Tabiteuea North and South. This event cost approximately Australian dollar (AU$) 700,000 in immediate remedial and recovery actions. However, additional costs for further processes and activities for this issue have not yet been reported.

49. Although the hazard is considered to be very low or non-existent in the project location based on the information available in ThinkHazard!, additional information may show some level of hazard. If local or additional information sources suggest that there is flood hazard, follow the recommendations below and seek expert guidance on additional recommended actions. It is recommended that local flood regulations and conditions possibly leading to highly localized water nuisance problems are considered. In particular, it is recommended to check the condition of and possible flaws in local water management systems, e.g. poorly dimensioned or maintained stormwater drainage channels.

50. *Climate change impacts*: Model projections are inconsistent in their estimates of changes in rainfall for Kiribati. However, it is highly likely that the present hazard level may increase in the future due to climate change and the increasing incidence of extreme rainfall events. It would be prudent to design projects in this area to be robust to localized flooding and stormwater flood hazard in the long-term.

51. *Risk reduction measures*. Consideration should be given to the vulnerability of urban and transport assets within the project's dependency network. If your project is interdependent with other projects, it is important to assess the vulnerability of the entire network if the service provided is critical. Your project or development should consider localized flood management measures, such as restoration of natural wetlands, removal of impermeable surfaces, or implementation of flood defenses at the project site and surrounding catchment. Built infrastructure may alter flood hazard, and consideration should be given to how built infrastructure may alter the landscape and potentially influence how an area responds during a flood. Any alteration of the landscape should be undertaken with consideration as to how this will influence the local hydrology. *Please note that these measures are generic and not project-specific.*

52. **Earthquake hazard risk**. Kiribati is located within the more stable center of the Pacific tectonic plate, which in theory reduces the likelihood of damaging geological hazards such as earthquakes. Hence earthquake hazard for Kiribati is classified as very low according to the information that is currently available. This means that there is less than a 2% chance of potentially-damaging earthquake shaking in your project area in the next 50 years. Based on this information, the impact of earthquake need not be considered in different phases of the project, in particular during design and construction. Although the hazard is considered to be very low or non-existent in the project location based on the information available, additional information may show some level of hazard. If local or additional information sources suggest that there is earthquake hazard, follow the recommendations below and seek expert guidance on additional recommended actions.

53. **Risk reduction measures.** Find out if the local building regulations include minimum standards for earthquake protection, even in very low hazard areas. To do this, engage the local engineering community, especially those serving with the local government, in discussions; or consult external experts. Comply with the minimum standards. *Please note that these measures are generic and not project-specific.*

IV. VULNERABILITY ASSESSMENT

A. Introduction

54. The analysis of vulnerability for this study is based on the presence (or absence) of climate hazards, and the emphasis is fundamentally oriented to, and focused on the 'exposure' and 'sensitivity' of the maritime and road transport infrastructure assets proposed for each subproject location and their facilities and services. The aim of the vulnerability assessment is to describe the 'climate induced vulnerability context' for the infrastructure under consideration. It focuses on three key aspects, these being:

i. the 'exposure of the asset or infrastructure' to climate to threats and hazards;
ii. the relative 'sensitivity of the asset or infrastructure' to the impact of the hazard; and
iii. the ability or capacity to adapt to climate change impacts.

55. Climate change vulnerability of a new infrastructure project or existing infrastructure asset is defined for this rating scheme as a function of the asset's exposure, sensitivity and capacity to adapt to projected changes in temperature, rainfall, sea level and other climatic variables. The combination of exposure and sensitivity determines the potential impact of climate change on the asset. The combination of potential impact and adaptive capacity determines the asset's vulnerability. Clearly, the transport infrastructure proposed under this project must be designed for a more complex, and potentially harsher climatic condition in order to cope with the future challenges facing Kiribati and their outer islands.

B. Vulnerability Context

56. **Kiribati**. Kiribati is recognized as being one of the most vulnerable countries in the world to the impacts of climate change and sea level rise. The small, low-lying atoll islands of Kiribati are some of the lowest islands in the world, are highly vulnerable to inundation from storm surge, sea level rise, changes in sediment transport and increasing coastal erosion and recession.

57. These narrow islands, with most of the islands being less than two kilometers wide and 3 meters above mean sea level most, concentrate the entire population and most infrastructure along the coast, directly exposed to climatic threats. The More than 44% of settlements, including 42% of the population, and more than 70% of all critical infrastructure are located below 3m above sea level and/or within 100m of shoreline.

58. The country's low atolls are already subject to sea level rise and increasing storm surge are damaging buildings and infrastructure and causing saltwater intrusion into the groundwater supply. By 2050, most of the land on the major islands is likely to become inundated. Intensive rainfall, storm surges and swell waves are expected to be aggravated through sea level rise and climate change effects on weather patterns, including extreme high tides and wind and wave action associated with cyclones. This will compound underlying trends of increasing coastal erosion and pressure on scarce land resources, and increase physical vulnerability of island populations, infrastructure and livelihood assets.

59. The major climate hazards to which the Kiribati is exposed however, relate to the combined impacts from rising sea levels, coastal erosion and inundation, increasing wave heights and extreme tides. Of these, the most serious are considered to be extreme tides, increasing significant wave heights and ocean swell, and storm surge associated with extreme storm events and cyclones, primarily because of their high frequency and great potential for causing damage through flooding, erosion and other impacts.

60. Over the past 80 years, five major tropical cyclones and four extreme tide events also caused severe damage to all regions of the country. Table 3 provides a summary of the occurrence this type of natural disasters in Kiribati since 1938.

Table 3: Climate Induced Natural Disasters in Kiribati since 1978

Event	Date	Description
Tropical cyclone Gordon	1978/1979	Tropical cyclone struck the southern islands severely
Tropical cyclone Anne	1987/1988	Tropical cyclone struck the southern islands severely
Swell	9 December 2008	Damage incurred to coastal infrastructure and buildings as a result of strong winds and destructive waves (1 fatality)
Ferry accident on high seas	13 July 2009	En route between Tarawa and the outlying island of Maiana, a ferry capsized in high seas, killing 33 people.
Extreme tide	29 January to 1 February 2010	Coastal inundation of near shore infrastructure.
Extreme tide and swell	28 February to 2 March 2014	Widespread damage was incurred across western Kiribati (Makin, Marakei and Onotoa). Households were damaged, and coastal residents were forced to move inland. Inundation and major damage to causeways and houses also experienced in Tarawa.
Extreme tide	10–13 August 2014	Considerable damage was inflicted on sea walls and causeways in South Tarawa.
Extreme tide	20–23 January 2015	Inundation and major damage to coastal infrastructure and buildings as a result of destructive waves (2 fatalities).
Tropical cyclone Pam and Tropical storm Bavi	March 2015	Coastal inundation and erosion causing damage to homes and infrastructure on many islands around western Kiribati. In Tarawa, the Nippon causeway was damaged and had to be closed. In the southern islands, residents were forced to evacuate their homes due to storm surge.
Tropical cyclone Pali and low-pressure system	9 January 2016	Major coastal inundation (4 fatalities).
Ferry accident in strong waves	18 January 2018	After leaving Nonouti, a ferry ran aground twice, causing structural damage. It later sank in open seas, killing 95 people.

Source. Government of Kiribati.

61. **Coastal vulnerability**. Coastal vulnerability stemming from sea level rise (SLR), changing weather patterns, storm surges and coastal erosion is challenging traditional systems for use and development of Kiribati's coastal lands. The cumulative impact of these factors into the future represents a significant challenge for Kiribati, and arguably necessitates different approaches and tools such as 'climate proofing' to respond effectively. The IPCC has highlighted the potential global risks from climate change for coastal communities living on low lying small islands (IPCC 2007).

62. **The Gilbert Islands**. The Gilbert Islands lie between 3º23'North (Makin) and 2º41'S (Arorae) in the Central Pacific, and this puts the islands between the normally accepted limits for the development of tropical depressions, cyclones and typhoons in both hemispheres. In early 2015 the islands were damaged by strong winds, storm surge, wave set up and high waves generated by distant cyclones, four of which started within 1,100 kilometer (km) of the islands.

63. In March 2015, tropic cyclone PAM started some 1,200 km south and sending heavy waves to the Gilbert Islands. The causeway linking the Port of Betio with Bairiki and the rest of South Tarawa was over topped and sustained severe damage as shown in Figure 3 below.

Figure 3: Damaged Causeway, Lagoon-side of Betio Causeway

Source: C. Brown. 2016. The Coastal Challenges of Adaptation for Sea Level Rise in Kiribati.

64. **Island vulnerability**. From a coastal perspective, potential impacts arising from rising sea levels and changing weather patterns leading to an increase in storm surge and erosion probably represent the greatest risk to the small outer islands of Abaiang, Beru, Nonouti and Tabiteuea South. SLR will also drive the greatest changes to island shoreline morphology. Windward islands are projected to become thinner as seaward and lagoonal shorelines erode, accreting toward more leeward shorelines and shorelines with comparably wider reef flats.

65. Likewise, leeward islands are anticipated to become thinner and longer, accreting towards their longitudinal ends. The shorelines of these islands will likely change dramatically over the next century as SLR and altered wave climates drive new erosional regimes. It is vital to the sustainability of island communities that the relative magnitudes of these effects are addressed when planning for projected future climates.

66. An Integrated Vulnerability and Adaptation Assessment (IVA) was undertaken for Abaiang atoll by the Secretariat of the Pacific Regional Environment Programme (SPREP), Secretariat of the Pacific Community (SPC), and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in 2015, to assess the capacity of Abaiang to adapt to environmental change and reduce community vulnerability to climate change and disaster risks.

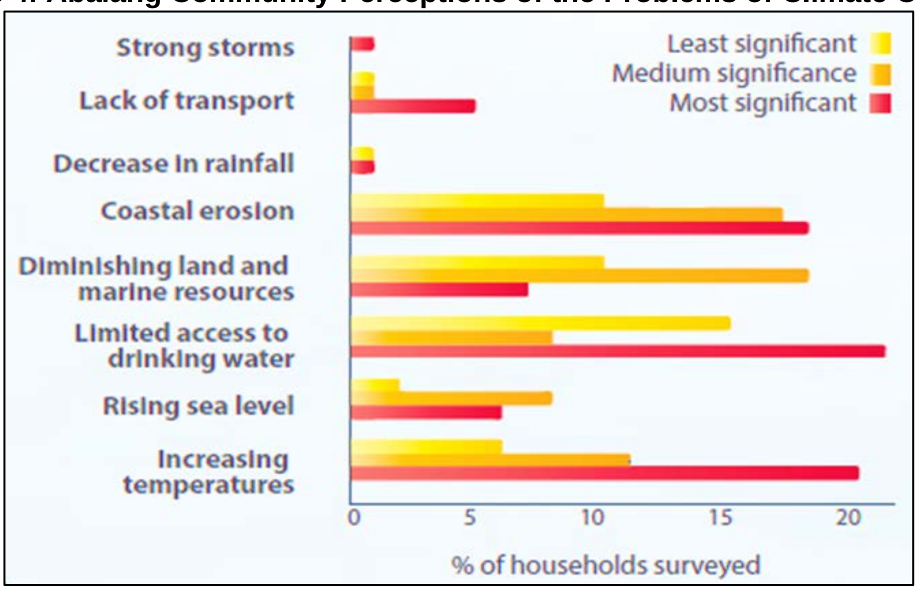
67. The Government of Kiribati selected Abaiang from a group of atolls considered 'most vulnerable' for this study, due to factors such as the inland shift or coastal recession of 80 metres of the coastline threatening Tebunginako village, and the comparatively large population of vulnerable people potentially exposed to the adverse impacts of flooding and inundation on this island.

68. The IVA for Abaiang adopted a 'whole of Island' community-based approach to the assessment of vulnerability on the island, focusing on communities, governance, economics, education, employment, food, health, income, infrastructure, housing, knowledge, population, sanitation and water, to plan adaptation activities to assist across multiple sectors. Importantly, Abaiang's exposure to the effects of climate change and disaster risks was assessed from a technical as well as local community perspective, and a range of key community identified as highlighted in Figure 4. These included accessing drinking water, coastal erosion, increasing temperature and diminishing land and marine resources.

69. Accordingly, a range of climate change adaptation options were identified and prioritized to assist in addressing with key vulnerabilities and community concerns, and these included: access to drinking water, coastal erosion, increasing temperature, diminishing land and marine resources and a range of other economic development issues.

70. **Island resilience**. Whilst the outer island atoll systems of Kiribati are inherently vulnerable to climate and other natural hazards due to their geo-geographical characteristics (including their small size, low elevation, narrow width and unconsolidated nature of the atolls), they are also highly resilient in their own right. Historically, these islands have exhibited considerable natural resilience to fluctuating sea levels, varying climatic conditions, wave action, extreme weather events and other major hazard events. The coral reefs, in particular, play an important role in protecting the islands from the impacts of extreme weather events, along with coastal accretion and formation of sand ridges and other natural features.

Figure 4: Abaiang Community Perceptions of the Problems of Climate Change



Source: SPREP, SPC, GIZ 2015.

71. Atoll islands are dynamic features that respond to seasonal alterations in wave conditions and sea level. With sea level and wave climates projected to change over the next century, it is unclear how shoreline wave runup and erosion patterns along these low elevation islands will respond, making it difficult for communities to prepare for the future.

72. However, the IVA analysis of community perceptions on climate change found that the community on Abaiang had a very low awareness of ecosystem benefits that come from mangroves and other coastal plantings, and that there were limited opportunities for mangrove

restoration and regrowth, and the community held a preference for seawalls for protection from coastal erosion.

73. **Coastal management**. The Government of Kiribati has identified climate resilience as one of the key policy priorities in the national development agenda and has developed a coastal protection program that addresses the country's vulnerability to natural disasters and the impacts of climate change on the coastal zone. This program recognizes the importance of the natural protective functions of mangrove and reef systems as the country's first line of defense against a range of natural hazards including climate risks. This concept gaining momentum, especially since the effects of Cyclone Pam in 2015, and the community perception that the impacts would have been far greater without the buffering role and protection provided by fringing reefs and mangroves.

C. Exposure of Project Infrastructure to Climate Risks and Impacts

74. **Vulnerable transport infrastructure.** The analysis of vulnerability for this study is based on the presence (or absence) of climate hazards, and the emphasis is fundamentally oriented to, and focused on the '**exposur**e' and '**sensitivit**y' of the Subprojects and associated transport infrastructure and their interdependencies. The changes in climate variables expected for Kiribati and the outer island Subproject locations considered relevant to this DCRA include:

i. **Changes in temperature and heat waves**. Both through the gradual increase in temperature and an increase in extreme temperatures (which are likely to impact road pavements);
ii. **Changes in rainfall**. Leading to changes in flooding, drought and saline intrusion that will reduce the structural strength of pavements and may impact road and causeway foundations;
iii. **Extreme rainfall events**. Such as stronger and/or more frequent storms, will affect the capacity of drainage and overflow systems to deal with stronger or faster velocity of water flows;
iv. **Sea level rise, extreme tides, cyclones and storm surge**. Morphological and bathymetric changes to reefs and lagoons, increases in wave runup and significant wave heights, and flooding increasing lagoon depths, to incident wave heights, greater coastal flooding and inundation;
v. **Changes in wind and wave climate**. Wind direction and strength, nearshore wave conditions and significant wave heights;
vi. **Changes in coastal processes**. Currents, wave-driven shoreline erosion, longshore sediment transportation and loss, shoreline accretion and retreat; and
vii. **Changes in oceanic conditions**. Rising ocean temperatures, coral bleaching, ocean acidification and coastal processes.

75. **Exposure**. The exposure of project infrastructure was assessed on the basis of a range of 'exposure factors' ranging from ranging from negligible impact through to very high. Table 4 provides a summary of exposure ratings for infrastructure proposed under the KOITIIP project. The exposure ratings indicate the degree to which it is expected that a change in climate hazard will affect a particular infrastructure asset, and it considers the level of exposure, the magnitude of the impact and whether or not the climate hazard will affect the useful life of the asset. Exposure in this context refers to the presence of infrastructure assets in places that could be adversely affected by specific climate induced hazards and is assessed as 'Negligible' if the risk falls within the probability of natural variation. Exposure ratings above this from low through to very high present 'increasing risk levels' which are considered to be outside the probability of natural variation.

76. Direct impacts include damage to structural integrity; indirect impacts may include changes in average and peak demands, which may result in revisions to the operations and capacity of the proposed infrastructure. Table 4 provides a summary of the assessed level of 'exposure' of maritime and road transport infrastructure proposed under the project.

77. Based on this assessment, it is clear that whilst the transport infrastructure proposed under the project are directly exposed to a range of impacts from a change in climate variables, the expected changes in the frequency and intensity of extreme weather events, and increased sea level represent the greatest threat to both maritime and land based infrastructure. The level of exposure is based only on the assessment of the primary impacts of climate change as a result of physical loss or damage to infrastructure assets, and does not take account of secondary impacts such as increased maintenance costs, disruptions to the transport system, increased safety risks or higher reconstruction costs.

Table 4: Exposure of Project Infrastructure to Climate Risks and Impacts

		Exposure to Climate Change Hazards						
		Changes in temperature & heatwaves	**Changes in rainfall, seasonality & drought**	**Extreme precipitation (flooding & inundation)**	**SLR, extreme tides, cyclones & storm surge:**	**Changes in wind and wave climate**	**Changes in coastal processes (erosion & sedimentation)**	**Changes in oceanic conditions**
Infrastructure Type	**Navigation aids**	Negligible	Negligible	Low	High	Moderate	Moderate	Negligible
	Boat ramps and jetties	Negligible	Negligible	Moderate	High	Moderate	High	Negligible
	Causeways and roads	Low	Low	Moderate	Very High	Moderate	Very High	Low
	Buildings and structures	Low	Low	Low	High	Negligible	Low	Negligible

Source: Adapted from ADB. 2011. Guidelines for Climate Proofing Investments in the Transport Sector. Manila.

D. Sensitivity of Project Infrastructure at Risk from Climate Hazards

78. **Sensitivity of infrastructure assets**. The impacts of climate change on the range of infrastructure and assets proposed under the project will depend on the location of the asset and it's relative exposure to climate change hazards, as well as any adaptation measures that may have been put in place to avoid or minimize the magnitude of impacts and the inherent 'resilience' of the asset.

79. Changes in the climate are likely to impact on the 'useful life' of project transport infrastructure in two ways, these being: impacts from 'physical damage' associated with climate hazards (such as flooding, erosion etc.); and/or 'chemical deterioration' of the construction materials from which the proposed transport infrastructure assets will be built (including chemical corrosion and deterioration of concrete and bitumen).

80. Table 5 provides an overview of potential 'sensitivity' of maritime and road transport infrastructure proposed under the project that are exposed to the key climate-related hazards, and these include (i) increased average temperature and incidence of extreme heat (heatwaves);

(ii) changes in season rainfall distribution and increased incidence of drought; (iii) increasing intensity and frequency of extreme events (SLR, storm events, flooding, strong winds and cyclones); (iv) changes in wind and wave climate; (v) changes in coastal processes (currents, beach erosion and sedimentation); and (vi) changes in oceanic conditions (sea temperatures, coral bleaching and oceanic acidification).

Table 5. Sensitivity of Project Infrastructure to Climate Risks and Impacts

	Climate Hazards	**Infrastructure Type**			
		Navigation aids	Boat ramps and jetties	Causeways and roads	Buildings and structures
Key Sensitivity Factors for Transport Infrastructure Assets	Changes in temperature and heatwaves	Negligible	Negligible	Low	Negligible
	Changes in rainfall, seasonality and drought	Negligible	Negligible	Low	Negligible
	Extreme precipitation (localized flooding and inundation)	Negligible	Negligible	Low	Low
	SLR, extreme tides, storm surge & cyclones (flooding and overtopping)	Moderate	Moderate	Very High	Moderate
	Changes in wind and wave climate (wave climate and significant heights)	Moderate	Moderate	Moderate	Low
	Changes in coastal processes (erosion and sedimentation)	Moderate	Moderate	Very High	Moderate
	Changes in oceanic conditions (temperature and acidification)	Negligible	Negligible	Negligible	Negligible

Source: Adapted from ADB. 2011. Guidelines for Climate Proofing Investments in the Transport Sector. Manila.

81. Based on the analysis undertaken in Table 5, it is clear that the sensitivity of transport infrastructure proposed under the project are most sensitive to climate events associated with sea level rise, extreme tides and storms. Causeways and road infrastructure, and to a lesser extent transport buildings and structures were assessed as being most sensitive to climate impacts, followed by boat ramps, jetties and navigation aid assets.

E. Adaptive Capacity

82. The Government of Kiribati fully recognizes that in order to effectively manage climate change risks, it is necessary to integrate climate risk planning and climate change adaptation into the country's development policy and planning frameworks across all sectors and levels of government (i.e. from the national to the island level). Integrating climate risk considerations into island land use planning, coastal protection and coastal development is especially critical given the high degree of physical exposure of island populations and critical infrastructure assets to climate-change induced loss and damage. The Asian Development Bank and the World Bank have also stressed the need to consider climate change impacts and to strengthen the adaptive capacity of development initiatives (ADB 2005).

83. **Adaptive capacity**. Adaptive capacity is the capacity of an infrastructure system or organization to adapt to climate change. This can be determined by factors such as knowledge, location, design standards and management arrangements and procedures.

84. In order to facilitate more effective, climate resilient planning decisions, project design, and construction methods must take into account the level of climate hazard – and practical adaptation options and measures developed to climate proof infrastructure in order to reduce the effects of climate change in the future. These may include information on sea level rise, heat impacts, coastal flooding and erosion etc. Some options for climate proofing infrastructure may be quite fundamental, and such as the application of existing design standards and best practices for flood mitigation. In other cases, the climate proofing measures may necessitate changing the way things are done or shifting priorities.

85. Both maritime and road transport infrastructure already have a high level of adaptive capacity and resilience to the impacts of weather induced natural hazards, especially the coastal infrastructure assets such as causeways, boat ramps and roads. As the knowledge and information supporting the climate change adaptation is continually improved, significant opportunities are available to climate proof infrastructure and augments asset life expectancy. For the purposes of this assessment however, the primary concern is the ability to climate proof the transport infrastructure proposed under the project, and this to a large extent relate to the expected asset design life, design standards and planning controls that may be employed.

86. A first step to climate proofing transport infrastructure is to build in adaptive capacity in infrastructure design, through the consideration the potential impacts of a changing climate generating exacerbated flood, storm surge, inundation, heat, extreme storm and weather events etc., and the incorporation of recent policy and/or best industry guidelines that relate to climate resilient design. This includes the application of appropriate Australian and other international standards and design codes pertaining to maritime transport infrastructure or coastal transport infrastructure such as: Australian Standard™ Guidelines for the design of maritime structures (2005) which covers jetties, floating pontoons, seawalls, and breakwater structures; BS6349-1: Maritime Structures. Code of practice for general criteria; together with other general aspects relevant to this project such as the Australian/New Zealand Standards (AS/NZS) 7000 design standards which typically covers the design and construction of roads and buildings etc.

V. RISK ASSESSMENT

A. Methodology

87. **Hazard risk assessment**. As previously mentioned, we have taken a risk-based approach for this DCRA. Risk is defined as the combination of the likelihood that (or frequency with which) an extreme flooding event will occur and the consequences that result. Both contributing factors are important. For example, an increase in the frequency of flooding events will obviously increase the risk of damage, but as more infrastructure is built in vulnerable locations and its value increases, the consequences of a flooding event of the same magnitude that occurred previously will become more costly, thus also raising the risk.

88. The analysis of risk under this methodology is based on the International Standard for Risk Management, ISO 3100 'risk assessment matrix' methodology. Figure 5 illustrates a typical risk framework that links the likelihood (or frequency) of the hazard with the scale of the consequence, and the resulting level of risk.

Figure 5: Risk Assessment Framework

Likelihood Level	Consequence Level				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic

5 Almost Certain	L (5)	M (10)	H (15)	E (20)	E (25)
4 Likely	L (4)	M (8)	H (12)	H (16)	E (20)
3 Possible	L (3)	M (6)	M (9)	H (12)	H (15)
2 Unlikely	L (2)	L (4)	M (6)	M (8)	M (10)
1 Rare	L (1)	L (2)	L (3)	L (4)	M (5)

Source: International Standard for Risk Management, ISO 3100 'risk assessment matrix' methodology.

E = > 20	Extreme Risk: potentially threatening the overall viability of the project and requiring priority action.
H = > 12	High Risk: are the most severe risks that can be accepted as part of the design and routine operation of the T/D infrastructure and facilities.
M = > 5	Medium Risk: risk that can be expected to influence the design and routine operation of the T/D infrastructure and facilities and where control measures can be applied and will be sufficient.
L = < 5	Low Risk: where existing control measures will be sufficient to mitigate any potential impacts and /or where no action will be required to treat them unless they become more severe.

89. The risk matrix defines the level of risk for a particular combination of consequence and likelihood. It allows us to qualitatively asses the likelihood and scale of hazard consequences for the energy infrastructure and assets associated with the project (including an analysis of control and/or mitigation measures) and level of risk. The risk ratings are a combination of the probability (or likelihood) of a climate hazard (derived from the climate modelling) and the consequence in terms of impacts on infrastructure (derived in a large part from the analysis of the sensitivity of the asset or infrastructure to climate hazards).

90. **Likelihood**. For this DCRA, likelihoods have been assigned based on consideration of both the historical occurrence, and the level of confidence associated with the climate change projections, for the key hazards. Table 6 provides the qualitative measures used to assess the likelihood of a climate hazard occurring now, using six categories, ranging from 'rare' (1) to 'almost certain' (6) and is based on past experience and the climate modeling available for the region.

Table 6: Qualitative Measures of Likelihood

Level	Descriptor	Likelihood	Annual Exceedance Probability
5	**Almost Certain**	There is a high possibility the event will occur as there is a history of frequent occurrence. The event is expected to occur in most circumstances	Will probably occur more than once a year
4	**Likely**	It is likely that the event will occur as there is a history of casual occurrence. The event has occurred several times or more in the past.	Will probably occur once in 1-10 years
3	**Possible**	The event has occurred at least in the past and may occur again	May occur once in 10-100 years
2	**Unlikely**	There is a low possibility that the event will occur, however, there is a history of infrequent and/or isolated occurrence.	May occur once in 100 years
1	**Rare**	It is highly unlikely that the event will occur except in extreme/exceptional circumstances, which have not been recorded historically.	Unlikely during the next 100 years

Source: Adapted from International Standard for Risk Management, ISO 3100 'risk assessment matrix' methodology.

91. **Consequence**. Consequence is defined as the outcome or impact from an event occurring. For this study five categories have been used to assess the consequence or consequences of particular climate hazards. These range from 'catastrophic' (5) to 'insignificant'

(1) as illustrated in Table 7, and have been used to describe the type and severity of a consequence of an impact on the project infrastructure resulting from a specific climate hazard event or combination of impacts. As multiple consequences may apply for a single hazard or aspect, the approach used was to take the worst credible risk (in terms of consequence versus likelihood).

Table 7: Qualitative Measures of Consequence

Level	Descriptor	Infrastructure Services
1	**Insignificance**	No infrastructure damage. Numerous risk reduction and control measures exist.
2	**Minor**	Localized infrastructure services disruption. No permanent damage. Some minor restoration work required. Early renewal of infrastructure by 5%–10%. Suitable risk reduction and control measures exist.
3	**Moderate**	Widespread infrastructure damage and loss of service. Damage recoverable by maintenance and minor repair. Early renewal of infrastructure by 10%–20%. Some suitable risk reduction and control measures exist.
4	**Major**	Extensive infrastructure damage requiring extensive repair. Permanent loss of regional infrastructure services e.g. roadways washed away by coastal flooding. Early renewal of Infrastructure by 20%–50%. Loss or retreat of coastal land. Few suitable risk reduction and control measures exist.
5	**Catastrophic**	Permanent damage and/or loss of infrastructure services. Loss or retreat of infrastructure of transport infrastructure, facilities and services. No suitable risk reduction and control measures exist.

Source: Adapted from International Standard for Risk Management, ISO 3100 ‘risk assessment matrix’ methodology.

92. This methodology allows us to identify, analyze and determine the level of climate hazard and relative climate induced risk for each category of infrastructure and assets proposed under the project based on expert opinion, and to visualize the effects and consequences of risk reduction options and measures necessary to mitigate the potential future impacts by climate proofing the transport infrastructure and assets.

B. Infrastructure Hazard Risk Assessment

93. Table 8 over page presents the results from the hazard risk assessment undertaken for this project and highlights the hazard risk ratings for the maritime and road transport infrastructure associated infrastructure proposed under each Subproject for both Current and Future (2070) time frames.

94. This is based on the design life of the proposed infrastructure of 50 years. In this context we have adopted the NSWs Government: Transport for NSW asset design life estimates outlined in the Australian Standard™ Guidelines for the design of maritime structures (2005) which covers the design of near-shore coastal structures and assets.

95. The hazard risk ratings are derived on the basis of the climate change analysis undertaken in Section III), together with the analysis of climate (exposure and sensitivity and adaptive capacity undertaken in Sections VI B) and C) respectively, and modulated based on the contextual understanding of subproject locations and conditions, and a review of the adaptive capacity and climate resilience outlined in Section VI D). The results indicate where risks may exist and where further work may be required to reduce or manage these climate and geophysical risks. The actual

ratings themselves, while instructive, inform the identification of potential adaptation options and measures for the future climate proofing of the project and its assets.

Table 8: DCRA Matrix for Key Project Infrastructure (Current and Future 2070)

Hazard Category	Current Risk to Project Infrastructure	Likelihood of Future Hazard (2070)		Consequence of Future Hazard			2070 Hazard Risk Rating
Changes in temperature and heatwaves	Increasing temperatures and increasing magnitude and frequency of extreme heat events.	Surface air temperature are projected to continue to increase by 2070. *Very high confidence*	**4 Likely**	Higher temperatures and extremes may lead to limited infrastructure damage to roads and pavements. *Suitable risk reduction and control measures exist.*	**2 Minor 1**		**M (8) MEDIUM RISK**
Changes in rainfall, seasonality and drought	Annual and seasonal rainfall in Kiribati is projected to increase, rainfall extremes are projected to increase, and the frequency of drought is projected to decrease relative to the current climate.	It is likely that there will be changes in rainfall patterns, seasonality and drought through to 2070. *High confidence*	**4 Likely**	Increasing drought hazard which may lead to minor infrastructure damage. *Suitable risk reduction and control measures exist.*	**2 Minor**		**M (8) MEDIUM RISK**
Extreme precipitation (flooding and inundation)	Increasing intensity and frequency of extreme rainfall events (storm events, flooding, and Inundation) which pose risks to the project infrastructure assets at all locations.	It is likely that there will be an increase in extreme events – as they have occurred several times or more in the past. *High confidence*	**4 Likely**	Flooding/inundation may incur damage to localized infrastructure damage and disruptions to transport systems. *Suitable risk reduction and control measures exist.*	**2 Minor**		**M (8) MEDIUM RISK**
Increasing intensity and frequency of extreme events (SLR, extreme tides, cyclones and storm surge)	Increase in SLR and the number of extreme events associated with higher sea levels, and more extreme storm events, high tides, storm surge and high waves.	Increasing SLR and frequency of king tides, extreme storm events and overtopping. Decreasing frequency but increasing intensity of tropical cyclones - history of infrequent and/or isolated occurrence occurance in adjacent provinces. *May occur once in 100 years*	**4 Likely**	An increase in the frequency and intensity of high tides, extreme storms, overtopping and storm surge cause widespread infrastructure damage and loss. *Damage recoverable by maintenance and minor repair. Risk reduction and control measures exist.*	**4 Major**		**H (16) HIGH RISK**

Hazard Category	Current Risk to Project Infrastructure	Likelihood of Future Hazard (2070)		Consequence of Future Hazard			Future 2070 Hazard Risk Rating
Changes in coastal processes (erosion & sedimentation)	Sea-level rise combined with natural year-to-year changes will accentuate the impact of storm surges and coastal flooding, coastal erosion and sedimentation.	Changes in SLR and extreme storm events are expected to drive changes in wind, wave and currents. *Very high confidence*	**5 Almost Certain**	An increase in the frequency and intensity of coastal erosion and sedimentation may cause widespread infrastructure damage and loss. *Damage recoverable by maintenance and minor repair. Risk reduction and control measures exist.*	**3 Moderate**		**H (15) HIGH RISK**
Changes in oceanic conditions (ocean temperatures and acidification)	Increasing sea surface temperatures and ocean acidity poses minimal risk to project infrastructure, however they will threaten coral reef ecosystems	There is high confidence that sea surface temperature ocean acidification will increase by 2070. *High confidence*	**4 Likely**	Higher ocean temperatures and acidity may lead to minor damage to infrastructure and materials. Secondary impacts expected as a result of coral bleaching and reef degradation *Suitable non engineering risk reduction and control measures need to be applied.*	**1 Insignificant**		**M (4) LOW RISK**

Source: Adapted from International Standard for Risk Management, ISO 3100 'risk assessment matrix' methodology.

E = > 20	**Extreme Risk**: potentially threatening the overall viability of the project and requiring priority action.	**M = > 5**	**Medium Risk**: risk that can be expected to influence the design and routine operation of the T/D infrastructure and facilities and where control measures can be applied and will be sufficient.
H = > 12	**High Risk**: are the most severe risks that can be accepted as part of the design and routine operation of the T/D infrastructure and facilities.	**L = < 5**	**Low Risk**: where existing control measures will be sufficient to mitigate any potential impacts and /or where no action will be required to treat them unless they become more severe.

C. Priority Climate Hazard Risks

96. The last step in the DCRA methodology involves identifying and prioritizing the most appropriate adaptation measures to incorporate into the project. This includes the identification of strategies to minimize damages caused by the changing climate and to take advantage of the opportunities for climate proofing project infrastructure. As evident from the DCRA Matrix for Key Project Infrastructure in the previous section, none of the climate change hazard risks assessed under this study were categorized as Extreme (i.e. potentially threatening the overall viability of the project and requiring priority action). However, the priority climate hazard risks identified as being most relevant to this project and its individual subprojects in priority order were assessed as follows:

High Risks:	1)	Increasing intensity and frequency of extreme events (SLR, extreme tides, cyclones and storm surge)	H (16)
	2)	Changes in coastal processes (erosion and sedimentation)	H (15)
Medium Risks:	3)	Changes in temperature and heatwaves	M (8)
	4)	Extreme precipitation (flooding and inundation)	M (8)
	5)	Changes in season rainfall distribution and increased incidence of drought	M (8)
Low Risk:	6)	Changes in oceanic conditions (ocean temperatures and acidification)	M (4)

VI. ADAPTATION ASESSMENT

A. Adapting to Climate Change

97. The goal of the adaptation assessment is to identify and prioritize the most appropriate adaptation measures to incorporate into the project. This includes the identification of adaptation options and measures to minimize damages caused by the changing climate and to take advantage of the opportunities that a changing climate may present.

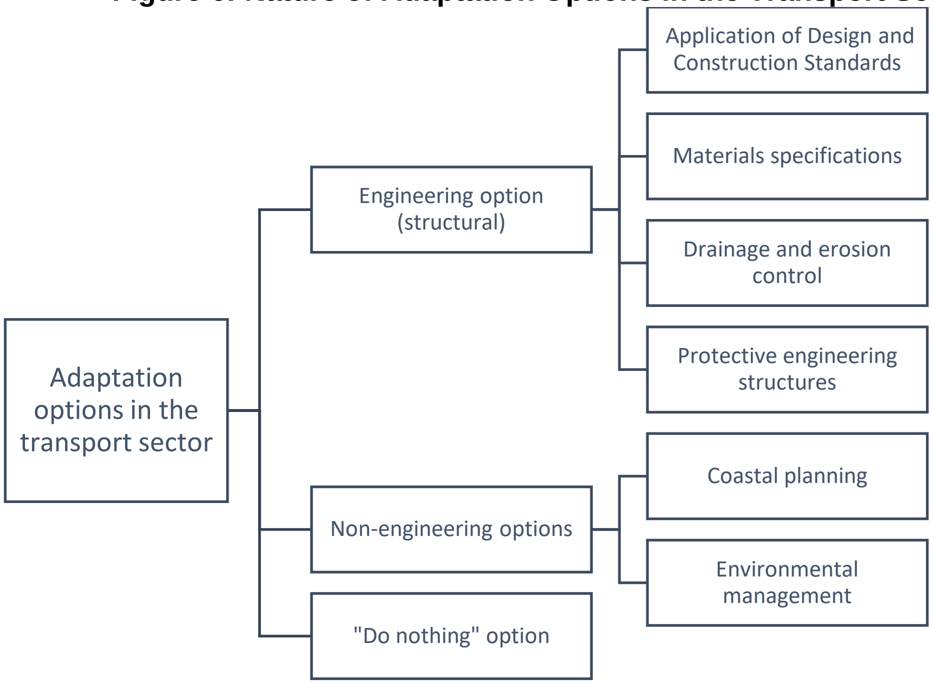
B. Adaptation Options for the Transport Sector

98. **Adaptation options**. Adaptation options are the range of actions and steps which can be taken to adapt to climate change. They include a wide range of actions that can be categorized as structural, institutional, or social. However, adaptation options in the transport sector may generally be grouped into engineering (structural) options and non-engineering options, as shown in Figure 6 below.

99. **Adaptation**. Adaptation for the purposes of this project relates to actions in response to actual or projected climate change and impacts that lead to a reduction in risk to the transport infrastructure proposed under the project. All of the transport infrastructure assets proposed under this project are to be constructed in marine and coastal waters and on or near the shoreline, and are highly susceptible to the impacts of sea level rise and coastal inundation. In this context, it is important that the design and construction of structures associated with the project take into account such changes to the coastline within the life span of the structure, employing the best construction methods and materials for the situation and intended life span of the asset, and ensuring that maintenance over the structure's life span is feasible and affordable. This includes the application of appropriate international standards and design codes pertaining to maritime transport infrastructure or coastal transport infrastructure such as: BS6349-1: Maritime Structures.

Code of practice for general criteria; BS6349-7: Guide to the design and construction of seawalls etc. highlighted in the assessment of adaptive capacity in Section IV D).

Figure 6: Nature of Adaptation Options in the Transport Sector



Source: ADB. 2011. *Guidelines for Climate Proofing Investment in the Transport Sector: Road Infrastructure Projects*. Manila.

100. **Engineering options**. Engineering options include includes ensuring the stability of any of the transport infrastructure assets proposed under the project, including a consideration of subsurface conditions and specification of construction materials to preserve the expected lifetime of the transport structure, or other materials that may need to be used. In the case of coastal transport infrastructure such as boat ramps, causeways and roads, protective engineering structures can be used to fend off rising sea levels and storm surges. These may include seawalls, rocky aprons, breakwater systems, and other structures.

101. **Non-Engineering options**. In addition to engineering options, a range of non-engineering options exist that may be applied to reduce the impact of climate change impacts on coastal transport infrastructure such as coastal mangrove plantings and sustainable reef management for the provision of coastal protection benefits.

102. **Do nothing options**. Lastly, it is important to recognize that in some cases, the best adaptation option(s) may be a decision not to act, or to maintain a business as usual approach ("do nothing" option). Under these circumstances, findings from the DCRA, and the assessment of adaptation options may indicate that doing nothing is the best course of action. In many cases, sufficient risk allowance has been built into the project to account for climate change (for example where appropriate Design Standards have been adopted), or that the nature of the changes are too uncertain or minimal, or that the consequences of climate change are too severe to justify in situ adaptation.

103. In the latter circumstance, a best course of action may to be to allow the infrastructure to deteriorate and be decommissioned. In other cases, the up-front capital investment associated

with any technically feasible adaptation option may be so large as to outweigh any possible benefits associated with the climate proofing of the infrastructure over its design life. Not investing in adaptation under these circumstances may be the best course of action (from both a technical and economic perspective).

C. Potential Adaptation Options & Measures

104. Adaptation measures usually fall into one of the following strategies (i) accommodate; (ii) protect or defend; and (iii) retreat. Unfortunately, the options for ‘retreat’ for the majority of situations on small island atolls such as covered under this project are extremely limited.

105. **Accommodate**. To accommodate the effects of climate change is to adapt in a harmonious way – without resisting or retreating. Climate change accommodation involves modifying existing infrastructure in-situ and without additional external protection measures.

106. **Protect and defend**. To protect or defend against climate change involves placing a barrier of some kind between the asset and the climate to reduce exposure. There are a broad range of options from the simple like painting steel structures through to costly structures such as sea walls on an eroding coast.

107. **Planned retreat**. Where building structures, infrastructure and other associated transport facilities in areas adjacent to receding shorelines are sited further inland and/ or relocated to another more suitable location.

108. During the detailed design phase, at least one of these strategies should be adopted to mitigate climate change risks. With this in mind a number of potential climate proofing measures were examined involving both hard engineering measures as well as soft measures that may be suitable for application under this project, in addition to the application of international design and constructions for maritime and coastal transport infrastructure assets.

109. **Climate proofing**. Climate proofing is a shorthand term for identifying risks to a development project, or any other specified natural or human asset, as a consequence of climate variability and change, and ensuring that those risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable, and socially acceptable changes implemented at one or more of the following stages in the project cycle: planning, design, construction, operation, and decommissioning (ADB 2005).

110. There are a limited range of potential hazard risk mitigation and adaptation response measures that may be adopted or deployed for climate proofing transport assets and infrastructure proposed under this project in view of both the geophysical challenges faced by Kiribati in terms of the size and elevation of the subject island – and predicted climate change and sea level rise. These measures include both existing measures already covered under the current feasibility studies, as well as a number of additional activities that may be implemented specifically for climate change adaptation, and include the following

- **Infrastructure design and construction standards**: Accommodate the effects of changing flood levels and behavior due to climate change in the design process (i.e. during feasibility, concept design and detailed design) through the application of appropriate international standards and guidelines. Where necessary incorporate more resilient/robust design specifications and construction standards areas potentially susceptible to extreme coastal hazard risks that may result from the impact of climate change-exacerbated hazards during a minimum design life of 50 years.

- **Placement, design and realignment of infrastructure assets**. Planned retreat or relocation of transport infrastructure from highly vulnerable coastal locations to low risk areas. Update design, siting and operational planning for extreme events (coastal flooding, inundation and erosion), and including the identification of alternative road alignments to avoid flood prone areas or coastal hazard zones. Placement of transport and ancillary infrastructure in locations to minimize transport system vulnerabilities in response to possible climate impacts and threats.
- **Materials selection**. Identify and select suitable materials for construction of infrastructure assets and structures to minimize damage and/or deterioration of transport infrastructure as a result of SLR, coastal inundation and saline intrusion and other climate change impacts.
- **Coastal defense**. Coastal defense mechanisms such as groynes, sea walls, levies and coastal drainage systems to provide protection for coastal flooding and erosion risk management due to storm tides and sea level rise.
- **Protection of coastal habitats**. Employ non-structural risk reduction and adaptation measures, such as mangrove plantings for protection against SLR, coastal flooding and storm surge.
- **Risk communication on climate change.** Communication of climate change risks to decision-makers and wider community (flooding, storm surge, heatwave and sea level rise) could be improved through the adoption of a program such as Coastcare – which builds the capacity of local community groups through improved knowledge and skills about climate change.

D. Estimated Climate Change and Disaster Risk Reduction Finance

111. Component 1–Safe Inter-Island Navigation can be considered a “Type 2” adaptation activity, meaning that it is predicated on the need to address climate change risks. Thus, the adaptation finance for Component 1 equals the total ADB financing provided for that component ($3.5 million).

112. As earlier mentioned, detailed designs will be undertaken after completion of the hydrographic surveys. Therefore, it is difficult at this time to estimate the extent and nature of climate proofing (“Type 1” adaptation activities) that will need to be incorporated into project designs for Component 2–Resilient Outer Island Access Infrastructure. For the three sub-components, it is assumed that 10% of the project infrastructure costs (or $607,000) will be counted as climate change finance which is consistent with past maritime projects in the Pacific. For institutional strengthening (Component 3), another $243,000 is counted. Additionally, the cost of disaster risk reduction (DRR) measures to enhance the disaster resilience of maritime infrastructure is estimated at $2.429 million.

Table 9: Estimated Disaster Risk Reduction and Climate Change Adaptation Finance

DRR/CCA Activity	Target Disaster Risk	Target Climate Change Risk	Estimated DRR Costs	Estimated CCA Costs	Justification
COMPONENT 1: Safe Inter-Island Navigation – $3.5 million for hydrographic surveying and updating of all outdated nautical charts in Kiribati.					
Various survey tools will assess the effects of the current and future climate and better	Extreme waves and tides	Sea level rise, and changes in	$0m	$3.50m	Type 2 adaptation activity – predicated on the need to address climate

predict natural phenomena, including natural disasters.		wind and wave climate			risks, including climate change and variability.
COMPONENT 2: Resilient Outer Island Access Infrastructure					
Sub-component 2.1: Improvement of Ships-to-Shore Transfer – $930,000 for investments in aids to navigation in four selected islands.					
Investments will be made in aids to navigation in four selected islands. Marker heights will account for current and future wave climate and water levels and strengthened beacons will account for lagoon currents during high tides.	Extreme waves and tides	Sea level rise and changes in wind and wave climate	$186,000	$93,000	Incremental costs, calculated at 20% of the total estimated cost for DRR and 10% for CCA
Sub-component 2.2: Rehabilitation of Island Access Infrastructure – $4.67 million for constructing boat ramps, port terminals, and a range of maritime infrastructure (e.g. jetties, barges, dredging).					
Around concrete ramps, additional erosion protection will account for high risk of coastal erosion. Passenger terminals and multipurpose maritime facilities will be designed to withstand increased wind loads.	Extreme waves and tides, coastal erosion	Sea level rise, changes in wind and wave climate, and changes in coastal processes	$934,000	$467,000	Incremental costs, calculated at 20% of the total estimated cost for DRR and 10% for CCA
Sub-component 2.3: Rehabilitation of Island-Crossing Causeways – $470,000 for rehabilitating works for causeways on prioritized outer islands.					
Improvements to 11 causeways (on 3 islands) will address past damage due to wave lapping, overtopping, and submergence, and also better protect against future damage. Investments will include: structural repairs to revetments, installation of culverts, improvements to road surface and drainage, installation of coastal structures (e.g. groyne fields, breakwaters), provision of scour protection, and planting of mangroves.	Extreme waves and tides, coastal erosion	and changes in coastal processes	$94,000	$47,000	Incremental costs, calculated at 20% of the total estimated cost for DRR and 10% for CCA

COMPONENT 3: Strengthening the Enabling Environment - $2.43 million for building greater institutional capacity to design, implement and maintain transport sector investments.					
Capacity building will include contingency planning, extreme weather maritime management, and resilient operational and maintenance practices.	Extreme waves	Sea level rise, changes in wind and wave climate	$1.215 million	$243,000	Incremental costs, calculated at 50% of the total estimated cost for DRR and 10% for CCA
		TOTAL	**$2.429 million**	**$4.35 million**	

Source: Asian Development Bank.

ANNEX 1: PROJECTED CLIMATE CHANGE IN KIRIBATI

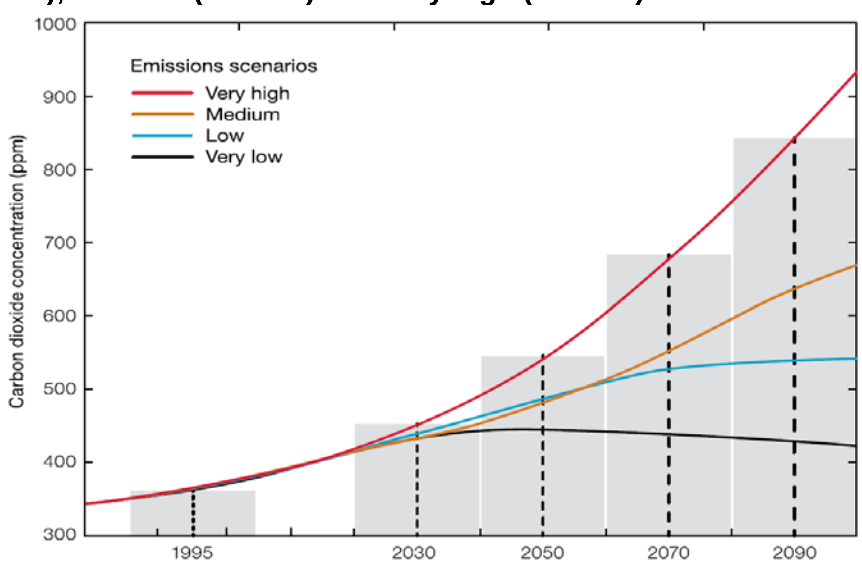
A. Assessing Kiribati's Changing Climate

113. This section provides a brief review of the future changes to climate in the North-West Pacific Region (using Coupled Model Intercomparison Project Phase 5 [CMIP5] simulations), and the specific changes to temperature, rainfall, oceans and extreme events for Kiribati and the outer islands considered under this project using SimCLIM (CLIMsystems Ltd.). Climate projections can be presented via or through multi-model ensembles such as CMIP5, or individual models such as SimCLIM. We support this analysis of climate impacts with observations from the Australian Bureau of Meteorology and CSIRO, 2011.

114. SimCLIM is a flexible software package that links data and models in order to simulate the impacts of climatic variations and change, including extreme climatic events, on different sectors. For the purpose of this DCRA, SimCLIM was used to i) describe baseline climates; ii) examine current climate variability and extremes; iii) generate climate and sea level change scenarios; and iv) assess the likely impacts of climate change on infrastructure assets proposed under the project.

115. The projection years of 2050 and 2080 were chosen for this analysis in consultation with the ADB, as these timeframes are consistent with the expected design life of the project deliverables (infrastructure), and Representative Concentration Pathway (RCP) 8.5 mid scenario and 5th and 95th percent variance were selected based on the high-level climate risks that need to be considered for the transport infrastructure proposed under the project. Figure 7 illustrates the range of Carbon dioxide concentrations (in parts per million) associated with the very low (RCP2.6), low (RCP4.5), medium (RCP6.0) and very high (RCP8.5) emissions scenarios for 20-year time periods (shaded) centred on 1995 (the reference period), 2030, 2050, 2070 and 2090 (Australian Bureau of Meteorology and CSIRO, 2014).

Figure 7: The climate projections for Kiribati for IPCC RCPs: very low (RCP2.6), low (RCP4.5), medium (RCP6.0) and very high (RCP8.5) emissions scenarios



Source: Australian Bureau of Meteorology and CSIRO, 2014.

116. These scenarios cover a broad range of possibilities. For example, the lowest scenario shows the likely outcome if global emissions are significantly reduced, while the highest scenario shows the impact of a pathway with no policy of reducing emissions. Since individual models give different results, the projections are presented as a range of values. When interpreting projected changes in the mean climate in the Pacific, it is important to keep in mind that natural climate variability, such as the state of the El Niño-Southern Oscillation, strongly affects the climate from one year to the next.

B. Rising Temperatures

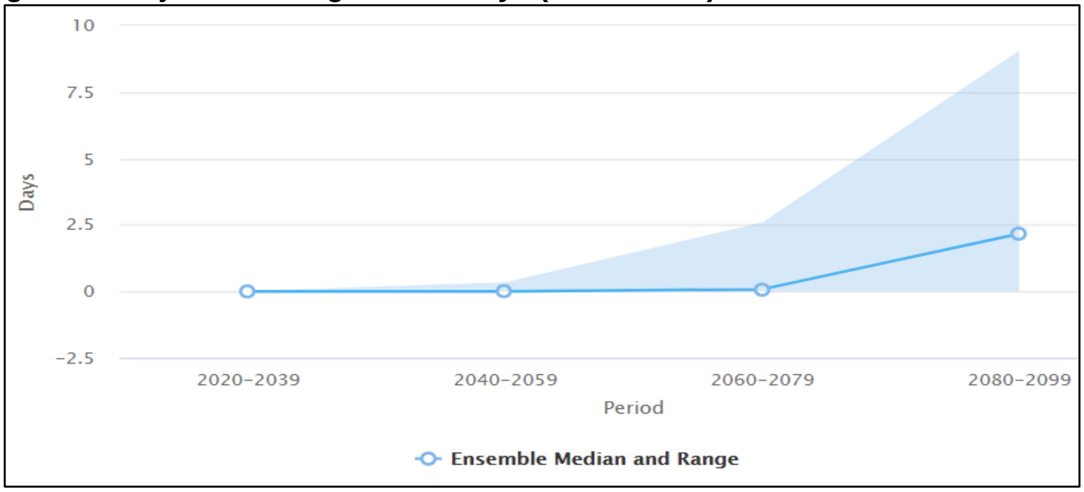
117. **Surface air temperature and sea-surface temperature**. According to the Pacific Climate Change Science Program (PCCSP) scientists, based projections for the Gilbert, Phoenix and Line Islands over the course of the 21st century, annual mean temperatures and extremely high daily temperatures will continue to rise (very high confidence) and warming will be large compared to natural variability (Australian Bureau of Meteorology and CSIRO, 2011).

118. Temperatures in Kiribati have warmed and will continue to warm with more very hot days in the future. CMIP5 projections for all emissions scenarios indicate that the annual average air temperature and sea-surface temperature will increase in the future in Kiribati. By 2030, under a very high emissions scenario, this increase in temperature is projected to be in the range of 0.5–1.2°C. Later in the century the range of projected temperature increase under the different scenarios broadens. The model ensemble's estimate of warming under the most extreme climate scenario (RCP8.5) is an average temperature increase of approximately 1.6°C by 2050 and approximately 3.0°C by 2090.

119. CLIMsystems modelling provide the median and 5, 95 percentiles projections of seasonal and annual precipitation change for 2050 and 2080 for Kiribati, and an increasing trend was shown in all the four atolls. By 2030, the annual average temperature for Kiribati is projected to increase by 0.6 – 1.3ºC above current levels for most RCPs. By 2080, temperatures are expected to increase by 0.6 to 1.7ºC for RCP2.6 and 2.8 to 5.1ºC for RCP 8.5. The annual mean temperature in Abaiang could increase from 28.12 to 30.44ºC by 2080. Similar mean temperature increases are expected for the other three atolls (CLIMsystems 2019).

120. Extreme maximum temperatures are also projected to increase, resulting in a rise in the number of hot days and warm nights and a decline in cooler weather. Figure 8 shows the CMIP5 projected change in hot days (above 35ºC) for Kiribati from 2020 through to 2099.

Figure 8: Projected Change in Hot Days (Tmax>35ºC) for Kiribati for 2020 to 2099



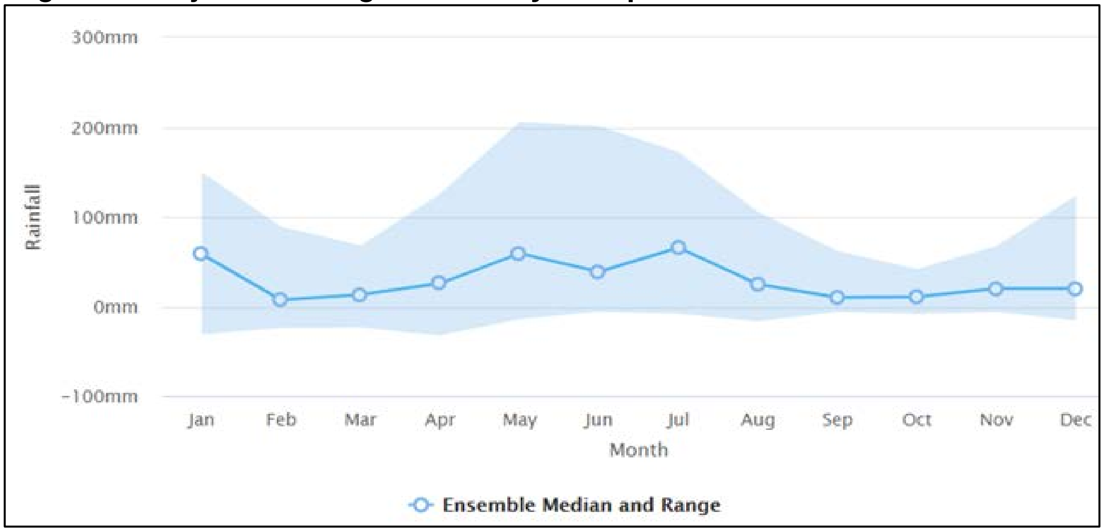
Source: World Bank Climate Change Knowledge Portal 2019.

C. Changes in Rainfall, Seasonality and Drought

121. **Annual and seasonal mean rainfall**. Almost all the global climate models project an increase in average annual and seasonal rainfall over the course of the 21st century. Annual and seasonal rainfall in Kiribati is projected to increase, rainfall extremes are projected to increase, and the frequency of drought is projected to decrease relative to the current climate. According to weather records and observations, the impact of droughts, usually associated with La Niña years, can be severe in Kiribati. But in the future, it is predicted that average rainfall will increase during both the wet and dry seasons, and there is moderate confidence that the number of droughts will decrease.

122. The CMIP5 model ensemble's forecast also suggests an increase in average monthly precipitation for Kiribati in 2080 and 2099 in the most extreme scenario (RCP8.5) as highlighted in Figure 9 below. Projections show extreme rainfall days are likely to occur more often and be more intense. However, none of these increases are significantly different from zero (no change in precipitation), suggesting uncertainty over whether any change in average precipitation levels will occur.

Figure 9: Projected Change in Monthly Precipitation for Kiribati for 2080–2099



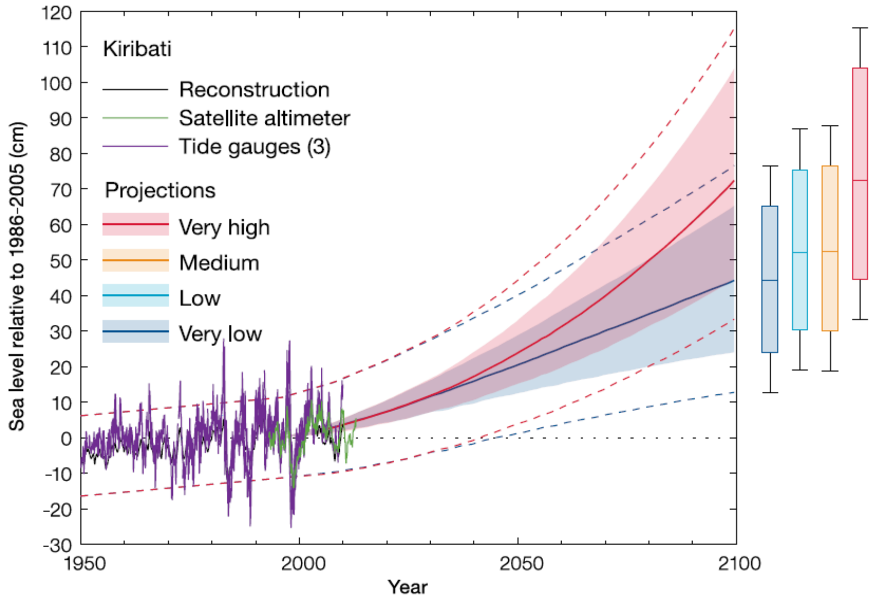
Source: World Bank Climate Change Knowledge Portal 2019.

123. According to the Pacific Climate Change Science Program (PCCSP) scientists, based projections for the Gilbert, Phoenix and Line Islands over the course of the 21st century, annual and seasonal mean rainfall is projected to increase (high confidence), and the intensity and frequency of days of extreme rainfall are projected to increase (high confidence). This increase is projected to be greater in the Gilbert Islands and lower in the Line Islands (Climate Change in the Pacific: Scientific Assessment and New Research | Volume 2: Country Reports (####)). CLIMsystems modelling likewise suggests that annual and seasonal mean precipitations are projected to increase in all the project atoll locations under mean ensemble climate change for 2050 and 2080, and project that extreme precipitation will increase significantly across the four target islands.

D. Rising Sea Levels and Storm Tides

124. **Mean sea-level rise**. Sea level near Kiribati has risen and will continue to rise throughout this century. According to the Pacific Climate Change Science Program (PCCSP) scientists, based projections for the Gilbert, Phoenix and Line Islands over the course of the 21st century, mean sea-level rise is projected to continue (very high confidence) (Australian Bureau of Meteorology and CSIRO, 2011). By 2030, under a very high emissions scenario, this rise in sea level is projected to be in the range of 7–17 cm. By the end of the century sea levels around the Pacific are projected to rise by at least 26-55 cm for RCP2.6 and 45-82 cm for RCP8.5 as illustrated in Figure 10 below.

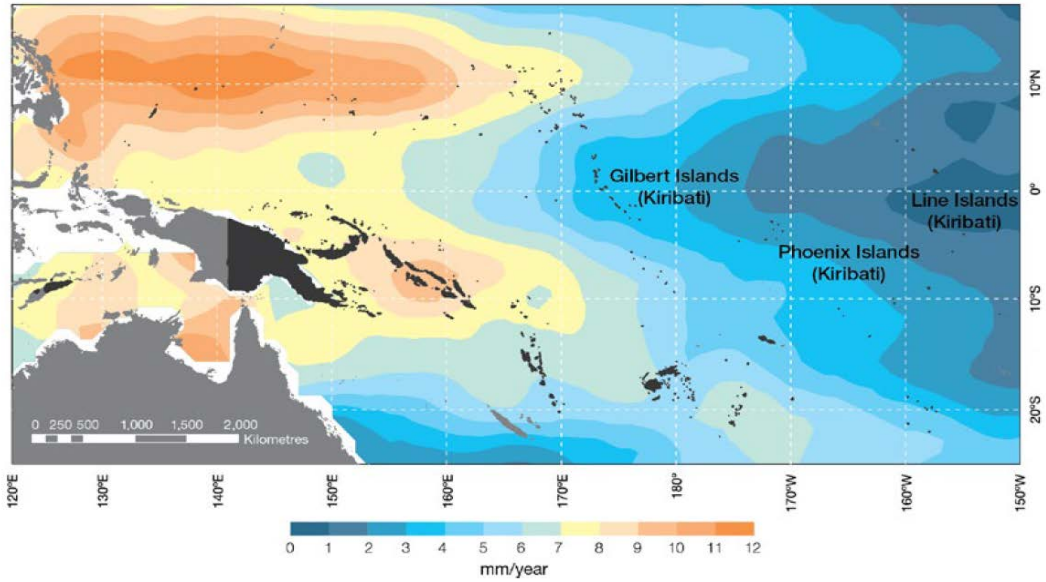
Figure 10: Observed and Projected SLR for Kiribati to 2100 (compared to 1986-2005 levels) for all RCPs.



Source: Australian Bureau of Meteorology and CSIRO, 2014.

125. In Figure 11 above, tide gauge records of relative sea level (since 1950) are indicated in purple, and the satellite record (since 1993) in the green. The reconstructed sea level data for Kiribati (since 1950 is shown in black. Mean SLR projections from 1995 to s100 are given for the very high (red solid line) and very low emissions scenarios (blue solid line), with the 5-95% uncertainty range shown by the red and blue shaded regions. The bars to the right show the four RCP for 2100. Figure 11 illustrates the regional distribution of the rate of sea-level rise measured by satellite altimeters from January 1993 to December 2010, with the location of Kiribati indicated. The sea-level rise near Kiribati measured by satellite altimeters since 1993 ranges from 1–4 mm per year, compared with the global average of 3.2 ± 0.4 mm per year (Australian Bureau of Meteorology and CSIRO, 2011). The change is partly linked to a pattern related to climate variability from year to year and decade to decade.

Figure 11. Regional Distribution of the Rate of Sea-Level Rise



Source: Australian Bureau of Meteorology and CSIRO, 2011.

126. SLR combined with natural year-to-year changes will accentuate the impact of storm surges and coastal flooding, especially for the low-lying atolls of Kiribati, which are on average only 2 meters above sea level. Table 9 Provides a summary of sea-level rise projections for the Gilbert Islands. For four RCP scenarios, and this is illustrative of the levels of sea-level rise that the target islands will have to contend with through to 2090.

Table 10: Sea Level Rise Projections for the Gilbert Islands, Kiribati

	2030 (cm)	2050 (cm)	2070 (cm)	2090 (cm)
Gilbert Islands				
Very low emissions scenario	7–17	13–29	18–44	23–59
Low emissions scenario	7–16	13–30	20–47	27–66
Medium emissions scenario	7–16	13–29	19–46	28–67
Very high emissions scenario	7–17	16–33	26–56	38–87

Source: Australian Bureau of Meteorology and CSIRO, 2014.

127. Even a moderate in SLR can result in extreme sea level events associated with high tides and storm surges that will occur more frequently then they currently do so. Over much of the last ten years or so the perception is that king tides have become more frequent. This is indeed likely and is due to a combination of an increased frequency of La Niña events (compared to the period prior to 2000) which has pushed sea levels up and is further exacerbated by sea-level rise. For example, the average number of hours that sea levels exceeded a level of 2.8 m above SEAFRAME datum in the 1970s was just over 5 hours per year. These exceedances have increased over the subsequent decades, occurring over 28 hours on average each year between 2000 and 2008.

128. Long-term sea-level rise will continue to push sea levels higher resulting in high tide levels increasingly exceeding what may be presently considered a king-tide level. A rough "rule of thumb" is that the frequency of flooding events trebles for every 0.1 m of sea-level rise (Hunter

2012). This means that for transport infrastructure designed for a 1-in-100-year flooding event (a common design criteria), could experience the same flood every few months after the sea level had risen 0.5 m.

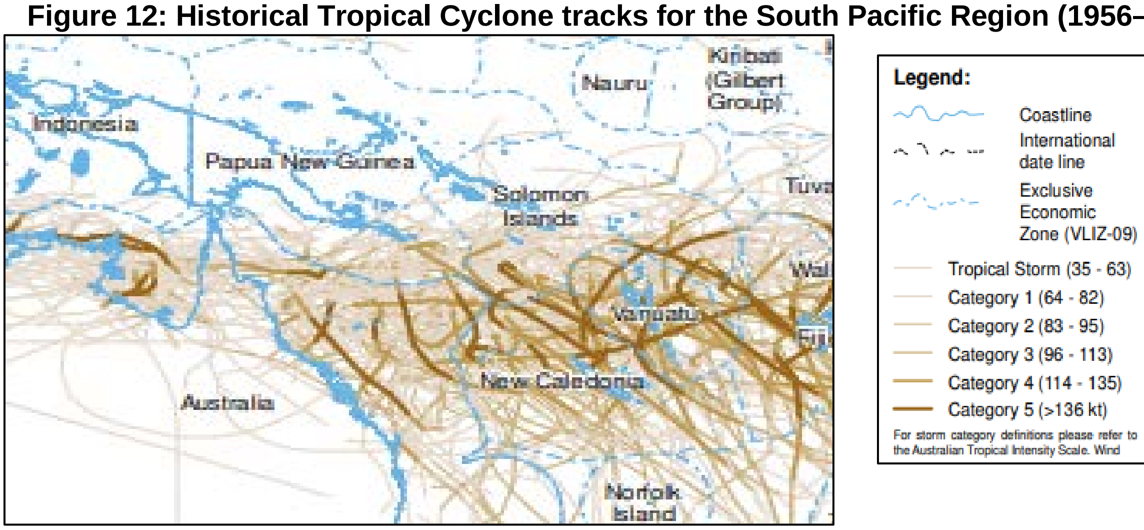
E. Extreme Storms, Storm Surges and Cyclones

129. Kiribati lies just outside the main tropical cyclone belt within the Southwest Pacific region. Tropical cyclones hit the country at the rate of about one cyclone per year, and rarely pass within 400 km of the Kiribati Islands. Between 1969/70 and 2009/10 three cyclones passed within 400 km of Arorae Island in western Kiribati and three cyclones within 400 km of Caroline Island in eastern Kiribati (CSIRO).

130. Globally, there is general agreement between models that there will be an increase in the mean maximum wind speed of cyclones by between 2% and 11%, and an increase in rainfall rates of the order of 20% within 100 km of the cyclone center (Knutson et al., 2010). Although the trends in frequency of tropical cyclones across the Pacific during the cyclone season between 1956 and 2009 indicate that there is a reduction in the general number of cyclones, their intensity has been increasing in recent decades (CSIRO, 2015), and this pattern is evident for the Central Pacific Ocean and Kiribati in general.

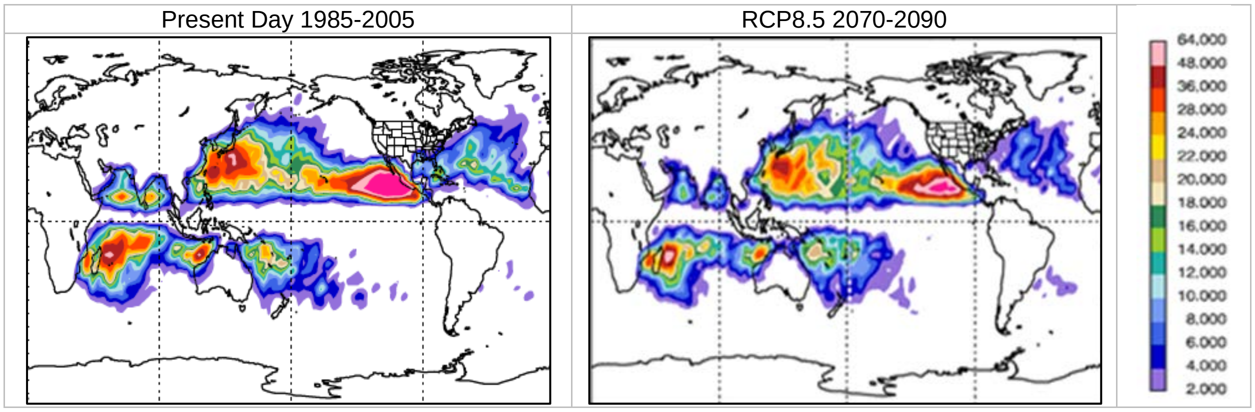
131. Figure 12 shows the historical storm tracks from 1956 to 2009 for the southern hemisphere cyclone season (November to April). These changes are also associated with a poleward movement of cyclone tracks in the Southern Hemisphere and equatorward movement of tracks in the Northern Hemisphere. Figure 13 below shows the projected changes in 20-year mean track densities for extreme storms (Cat 4 and 5) and tropical cyclones in the Pacific under current and future warming scenarios (RCP8.5) based on a high-resolution climate model BRACE, and suggests a pronounced increases in extreme storm activity in the North West South Pacific east of Australia. Extreme storm activity in the North West Pacific in the future is projected to more than double, and dramatic increases occur in the South Pacific as well (Bacmeister et al 2005).

Figure 12: Historical Tropical Cyclone tracks for the South Pacific Region (1956–2009)



Source: OHCA, 2012.

Figure 13: Projected Changes in Track Densities for Extreme Storms and Cyclones in the Pacific



Source: Bacmeister *et al* 2005: Projected changes in tropical cyclone activity under future warming scenarios using a high-resolution climate model.

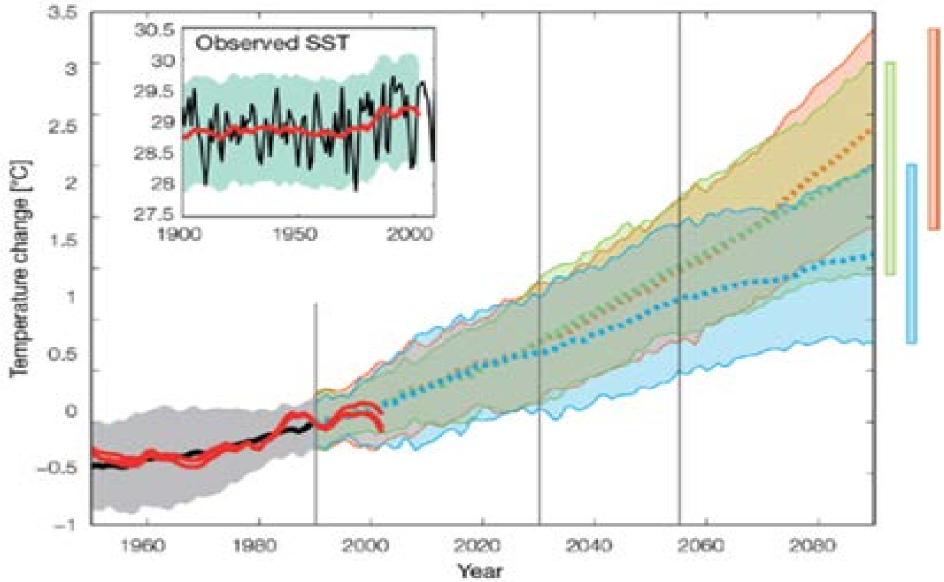
132. However, it should also be noted though that there is considerable variation in cyclone and storm hazard patterns across the archipelago and even between islands in the same atoll, due to local variation in geophysical and climatic factors. Coastal inundation is a constant concern on low-lying islands in Kiribati. Because Kiribati is close to the equator (latitude 1°N), it is not threatened by cyclone-generated inundation. Rather, inundation is expected to be triggered by high storm tide levels or swells, or the co-occurrence of extreme storm and tropical cyclone activity. For example, the northern atolls face a greater risk of cyclonic winds and storm surges than the southern atolls, where the risk is much lower because of proximity to the equator.

133. Whilst all of the target islands are located outside the major cyclone path and are considered to be of low to moderate cyclone risk, the Gilbert Islands are considered to be vulnerable to other important extremes including extreme sea levels and storm surges associated with an increase in the incidence of cyclones and extreme storm events. There is a greater increase in losses projected for more extreme (higher return period) events.

F. Changes in Oceanic Conditions

134. **Increasing Sea Surface Temperatures**. Sea surface temperatures have risen gradually since the 1970s in the waters around the Gilbert Islands by approximately 0.15°C per decade with the rise in air surface temperatures. There is high confidence that sea surface temperature will increase by 0.6–0.8°C by 2035. Increases between 1.2°C and 2.7°C by 2100 are considered possible. By 2030, increases of 0.4-1.0ºC by 2030 and by 2090, increases of 2-4ºC (RCP8.5) compared to current are expected (Australian Bureau of Meteorology and CSIRO, 2011). Figure 14 shows the observed and projected mean sea-surface temperatures for the Gilbert Islands for A2 High (red), A1B1 Medium (green) and B1 Low (blue) emission scenarios through to 2100.

Figure 14: Gilbert Islands Historical and Simulated Mean Sea Surface Temperature

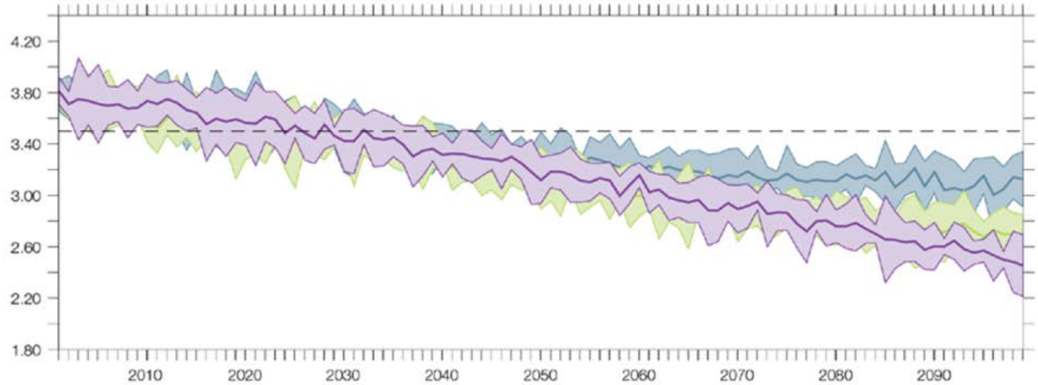


Source: Australian Bureau of Meteorology and CSIRO, 2011.

135. **Ocean acidification**. Ocean acidification has been slowly increasing in Kiribati's waters since the 18th Century. According to the Pacific Climate Change Science Program (PCCSP) scientists, based projections for the Gilbert, Phoenix and Line Islands over the course of the 21st century, ocean acidification will continue to increase and threaten coral reef ecosystems as carbon dioxide dissolves in sea water to produce carbonic acid, there is very high confidence that the rate of ocean acidification will be proportional to carbon dioxide emissions.

136. Under all four emissions scenarios the acidity level of sea waters in the Kiribati region will continue to increase over the 21st century, with the greatest change under the very high emissions scenario. In the Gilbert Islands, the aragonite saturation state has declined from about 4.5 in the late 18th century to an observed value of about 3.9 ± 0.1 by 2000 as illustrated in Figure 15 over page (Australian Bureau of Meteorology and CSIRO, 2011).

Figure 15: Maximum Annual Aragonite Saturation State – Gilbert Islands



Source: Australian Bureau of Meteorology and CSIRO, 2011.

The impact of increased acidification on the health of reef ecosystems is likely to be compounded by other stressors including coral bleaching associated with sea temperature rise.

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