ADB

Pacific Studies Series

CLIMATE PROOFING

A Risk-based Approach to Adaptation




Asian Development Bank

ADB

Pacific Studies Series

Climate Proofing

A Risk-based Approach to Adaptation

Asian Development Bank

Printed in the Philippines.

Library of Congress Cataloging-in-Publication Data Available.
Publication Stock No. 030905

Asian Development Bank Developing countries in the Pacific can adapt their capacity for dealing with, and resilience to climate change and climate variability.

Table of Contents

List of Tables

List of Figures

List of Maps

List of Boxes

Abbreviations

ADB	Asian Development Bank
ARA	adaptation rapid assessment (process)
ARI	acute respiratory infection
CCAIRR	Climate Change Adaptation through Integrated Risk Reduction
CCC	Canadian Climate Centre
CEA	country environment assessment
CLIMAP	Climate Change Adaptation Program for the Pacific
COP	Conference of the Parties
CRP	climate risk profile
CSIRO	Commonwealth Scientific and Industrial Research Organization
CSP	Country Strategy and Program
CSPU	Country Strategy and Program Update
DEM	digital elevation model
EIA	environmental impact assessment
EIRR	economic internal rate of return
ENSO	El Niño Southern Oscillation (see Glossary)
EOCC	economic opportunity cost of capital
FSM	Federated States of Micronesia
GCM	global climate model
GEF	Global Environment Facility
GIS	geographical information system
GPS	Global Positioning Satellite
IDP	Infrastructure Development Plan (FSM)
IPCC	Intergovernmental Panel on Climate Change
JBIC	Japan Bank for International Cooperation
NAPA	national adaptation program of action
NGMACC	National Guidelines for Mainstreaming Adaptation to Climate Change
NDS	National Development Strategy (Cook Islands)
NGO	nongovernment organization
NIES	National Institute for Environmental Science (Japan)

NPV	net present value
O&M	operation and maintenance
PAA	project adaptation assessment
PAB	project adaptation brief
PDMC	Pacific developing member country (of ADB)
PPTA	project preparatory technical assistance
PV	present value
REACH	Renewable Energy, Energy Efficiency, and Climate Change
SDP	Sustainable Development Plan
SPCZ	South Pacific Convergence Zone
SPM	Strategic Planning Matrix (FSM)
UNFCCC	United Nations Framework Convention on Climate Change

Currency Equivalents

The local currency (NZ$) is used when reporting results for the Cook Islands case studies:

NZ$1.00 = US$ 0.6901

(as of 20 October 2004).

Otherwise, in this report '$' refers to U.S. dollars

Glossary

Adaptation (to climate variability and change) – Policies, actions, and other initiatives designed to limit the potential adverse impacts arising from climate variability and change (including extreme events), and exploit any positive consequences.

Adaptive capacity – The potential for adjustments, processes (both natural and human), practices, or structures to moderate or offset the potential for damage, or take advantage of opportunities, created by variations or changes in the climate.

Climate change – Trends or other systematic changes in either the average state of the climate, or its variability (including extreme events), with these changes persisting for an extended period, typically decades or longer (i.e., longer term). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations 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 extreme – A climatic event that is rare within its reference statistical distribution for a particular place. Typically "rare" is interpreted as an event that is below the 10th percentile or above the 90th percentile. An extreme climate event may be due to natural internal processes within the climate system, or to variations in natural or anthropogenic external forcing.

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.

Climate variability – Variations in climatic conditions (average, extreme events, etc.) on time and space scales beyond that of individual weather events, but not persisting for extended periods of, typically, decades or longer (i.e., shorter term). Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Consequence – The end result or effect caused by some event or action. A detrimental consequence is often referred to as an "impact."

El Niño Southern Oscillation - The El Niño Southern Oscillation (ENSO) is a result of ocean-atmosphere interactions internal to the tropical Pacific Ocean and the overlying atmosphere. Unusually warm temperatures in the eastern equatorial Pacific (termed an "El Niño event") reduce the normally large sea surface temperature difference between the eastern and western portions of the tropical Pacific. As a consequence, the northeast and southeast trade winds weaken and sea level falls in the west and rises in the east, as warmer waters move eastward along the equator. At the same time, the weakened trade winds reduce the upwelling of cold water in the eastern equatorial Pacific, thereby strengthening the warm temperature anomaly. A corresponding "La Niña event" occurs when temperatures in the eastern equatorial Pacific are unusually cool.

Enabling environment – The enabling environment for adaptation comprises the high-level and robust systems and capabilities that foster the adaptation process, including innovation, revitalization of traditional knowledge and practices, application of human knowledge and skills, policies, financing, legislation and regulations, information, markets, and decision support tools. It encourages and supports the climate proofing of development projects and related initiatives, as well as being supportive of the wider sustainable development process.

Global climate model – A numerical representation of the global climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. Global climate models are applied, as a research tool, to study and simulate the climate. They are also used for operational purposes, including monthly, seasonal, and interannual climate predictions.

Greenhouse gases – Those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiant heat energy at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. This property causes the greenhouse effect. Water vapor, carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (0_3) are the principal greenhouse gases in the Earth's atmosphere. Several entirely human-made greenhouse gases can also be found in the atmosphere, such as halocarbons and other chlorine- and bromine-containing compounds.

Incremental cost (of adaptation) – The additional costs arising from reducing climate risks through adaptation, when preparing for and implementing a policy, plan, or action.

Ka – A tropical tree (botanical name *Terminalia carolinensis*) the largest surviving stand of which can be found on the island of Kosrae, FSM.

La Niña event – See "El Niño Southern Oscillation".

Likelihood – The probability, or statistical chance, of a given event occurring within a specified period of time.

Mainstreaming (of adaptation) – The effective and equitable integration of adaptation activities into the preparation and implementation of policies, plans, and other instruments concerned with economic development, social progress, and/or environmental protection.

Mitigation (of climate change) – Policies, actions, and other initiatives that reduce the net emissions of greenhouse gases (q.v.), such as CO_2, CH_4, N_2O, that cause climate change through global warming.

Monte Carlo techniques – a method of generating a model of change in which the likelihood of an event is first determined and then a random number is used to determine whether the event actually occurs.

No regrets – Policies, plans, or actions that would generate net social benefits whether or not climate change occurs. No regrets opportunities for greenhouse gas emissions reduction are defined as those options whose benefits, such as reduced energy costs and reduced emissions of local/regional pollutants, equal or exceed their costs to society, excluding the benefits of avoided climate change. No regrets potential is defined as the gap between the market potential and the socioeconomic potential. The cost of an economic activity forgone by the choice of another activity.

Projection – Any description of the future, and the pathway that leads to it.

Rational Method – a simple mathematical technique used in water engineering for estimating peak flows of runoff from small catchments, in which Discharge (Q) = CiA, where C is the runoff coefficient, i is the rainfall intensity and A is the catchment area.

Return period – The average length of time between the occurrences of a specified event.

Risk – The combination of a hazardous event occurring, and the impact or consequence of that event.

Scenario – A plausible and often simplified course of anticipated events or a probable future condition, based on a coherent and internally consistent set of assumptions about key driving forces and relationships, constructed for explicit use in investigating the potential consequences of changes from current conditions.

Sea-level rise (fall) – An increase (decrease) in the mean level of the ocean, persisting for an extended period, typically decades or longer. Eustatic sea-level rise is a change in global average sea level brought about by an alteration to the volume of the world ocean. Relative sea-level rise occurs where there is a net increase in the level of the ocean relative to local land movements. Climate modelers largely concentrate on estimating eustatic sea-level change; risk assessors focus on relative sea-level change.

Sea-level change – Trends and other systematic changes in mean sea level, persisting for an extended period, typically decades or longer (i.e., longer term).

Sea-level variability – variations in mean sea-level conditions (including extreme events) that do not persist for extended periods of, typically, decades or longer (i.e., shorter term).

Vulnerability (to climate variability and change) – The extent to which a natural or human system is susceptible to sustaining damage resulting from climate variability and change, despite human actions to moderate or offset such damage. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Foreword

Since the early 1990s, the Asian Development Bank (ADB) has been at the forefront in assisting countries in the Asia and Pacific region to address climate change, through various technical assistance programs and lending operations.

ADB recently attracted the increasing interest of various aid providers (such as Denmark, Canada, and the Netherlands) for grant funding of its program on renewable energy, energy efficiency, and climate change, (REACH). Under the REACH program, ADB administers three grant funds: i) the Netherlands Cooperation Fund for Promotion of Renewable Energy, Energy Efficiency, and Greenhouse Gas Abatement ($4.5 million); ii) the Canadian Cooperation Fund for Climate Change ($3.2 million); and iii) the Danish Cooperation Fund for Renewable Energy and Energy Efficiency in Rural Areas ($3.5 million).

ADB's Climate Change Adaptation Program for the Pacific (CLIMAP) assists Pacific developing member countries to enhance their adaptive capacities and resilience to climate change and climate variability, including extreme events. It also assists these countries to prevent and address the adverse effects of global climate change, particularly sea-level rise and changing climate variability in coastal and marine areas. This is achieved through risk assessment, adaptation planning, and policy development, by climate proofing infrastructure, and through community and other development initiatives. This assistance involves preparation/design of adaptation measures at the project level as well as capacity building, including institutional strengthening and human resources development for adaptation.

CLIMAP builds on ongoing and recently completed adaptation programs through a consultation and analysis process. It follows an integrated approach covering economic, financial, technical, and legal aspects as well as social, environmental, and networking dimensions. This requires the active and sustained engagement of various experts and stakeholders from the scientific community, decision makers, and public and private sector operators, as well as nongovernment organizations and representatives of civil society.

ADB foresaw the need to prepare a series of case studies that demonstrate a risk-based approach to adaptation to climate change, including the mainstreaming of adaptation. These would link to, and support, initiatives being taken to prepare for mainstreaming adaptation in ADB's own policies and procedures.

Climate Proofing—A Risk-based Approach to Adaptation is the result of a regional technical assistance (RETA) funded under REACH by the Canadian Cooperation Fund for Climate Change—Greenhouse Gas Abatement, Carbon Sequestration and Adaptation. The technical assistance was administered by ADB.

The case studies were prepared by Maunsell (NZ) Ltd., working in association with the International Global Change Institute of the University of Waikato, New Zealand. The team was directed by Edy Brotoisworo, Senior Environment Specialist, Pacific

Department; who succeeded Daniele Ponzi, then Senior Economist (Environment), Pacific Department. Design, coordination, and implementation of the RETA benefited from the overall guidance of Peter N. King, former Director, Area B, Pacific Department, Robert Y. Siy Jr., Director, Area A, Pacific Department and Indu Bhushan, Director, Area B, Pacific Department, ADB.

The leader of the team of consultants who prepared the case studies was John E. Hay of the International Global Change Institute (IGCI), University of Waikato, Hamilton, New Zealand. The team included Richard Warrick, also of IGCI, Chris Cheatham, Consultant, Suva, Fiji Islands; Teresa Manarangi-Trott, Pacific Communications, Rarotonga, Cook Islands; Joseph Konno, Consultant, Chuuk, Federated States of Micronesia; Peter Hartley, Maunsell (NZ) Ltd., Auckland, New Zealand.

ADB also acknowledges, with thanks, the assistance and cooperation of the Governments of the Federated States of Micronesia and the Cook Islands.

Philip Erquiaga
Director General
Pacific Department
Asian Development Bank

Acknowledgments

Case study preparations were a team effort, hence many are deserving of acknowledgement and thanks.

Project Team

John Hay	Team Leader, International Global Change Institute (IGCI), University of Waikato
Richard Warrick	Team Member, IGCI, University of Waikato
Wei Ye	SimClim Development, University of Waikato
Peter Kouwenhoven	SimClim Development, University of Waikato
Liza Koshy	Data Management and GIS, IGSI, University of Waikato
Claire Gibson	Information, IGCI, University of Waikato
Yengpeng Yi	Data Processing, IGCI, University of Waikato
Joseph Kono	Team Member (FSM)
Teresa Manarangi-Trott	Team Member (Cook Islands)
Mr. Kevin Oldham	Project Director, Maunsell (NZ) Ltd.
Peter Hartley	Project Manager, Maunsell (NZ) Ltd.
Nadine Wakim	Flood Modelling, Maunsell (NZ) Ltd.

Federated States of Micronesia

Department of Finance and Administration

Nick Andon	Secretary
Senny Philip	International Finance Coordinator

Department of Transportation, Communication and Infrastructure

Akilino H. Susaia	Secretary
Phillip Joseph	Water Engineer (CLIMAP Project Officer)
Tajmilur Rahman	Civil Engineer

Department of Economic Affairs

Ishmael L. Lebehn	Acting Secretary
John Mooteb	Deputy Secretary
Okean Ehmes	Biodiversity Project Manager
Cindy Ehmes	Sustainable Development Planner

Eneriko Suldan	Division of Statistics
Val A. Martin	Marine Resources Conservation Management Officer

Department of Justice

Marstella E. Jack	Assistant Attorney General

Department of Foreign Affairs

Vince Sivas	Foreign Service Officer

Department of Health, Education & Social Affairs

Moses Pretrick	Environmental Health Coordinator
Jane Gallen	GEF POPs Project Coordinator

Weather Services

Ceasar Hadley	Meteorologist-In-Charge
Wilfred Nanpei	Meteorologist

Pohnpei State

Elden Hellan	Director, Environmental Protection Agency
Henry Susaia	Environmental Protection Agency (CLIMAP Project Officer)
Kondios Gornelius	Chief, Division of Survey and Mapping, Dept. of Land & Natural Resources
Benley Lucios	Division of Survey and Mapping, Dept. of Land and Natural Resources
Joyce Nanpei	Field Supervisor, Division of Survey and Mapping, Dept. of Land and Natural Resources
Waliet E. Elisa	Surveyor, Dept. of Land and Natural Resources
Anderson Andon	Surveyor, Dept. of Land and Natural Resources
Peterson Anson	Cartographic Aid, Dept. of Land and Natural Resources
Donna Scheurin	Consultant, Environmental Protection Agency
Siocy D. Soaz	Medical Record Specialist, Pohnpei Hospital
Donald David	Marine Development, Office of Economic Affairs
William Kostka	Conservation Society of Pohnpei
Bill Raynor	The Nature Conservancy
Francis Hezel	Micronesian Seminar
Alex Nanpei	Public Utilities Corporation
Kenneth Gilmete	Public Utilities Corporation
Stevick Edwin	Public Utilities Corporation
Herson Anson	Sapwohn Village
Rainer Jimmy	Sapwohn Village

Chuuk State

Augustine Mathias	Member, EPA Board and Vice Principal Dept. of Education
Mercy D. Sos	Environmental Specialist, Environmental Protection Agency

Kosrae State

Simpson Abraham	Director, Development Review Commission (CLIMAP Project Officer)
Bruce Howell	Engineer, Public Works
Abraham Bahillo	Engineer, Department of Public Works
Likiak Wesley	Division of Planning and Statistics
Bernie	Construction and Engineering
Carmelo	Construction and Engineering
Erick Waguk	Development Review Commission
Roosten Abraham	Department of Marine Resources

Yap State

Charles Chieng	Chairman, EPA Board and Director Yap Civic Action Program
Francis Itimai	Director, Office of Planning and Budget
Jesse Gajdusek	Deputy Director, Department of Resources Development

Cook Islands

Ministry of Finance and Economic Management

Kevin Carr	Financial Secretary
Bredina Drollett	Manager of Policy Unit
Petero Okotai	Planning Office

Ministry of Works

Ata Herman	Secretary and Chair of Project Liaison Committee
Timoti Tangiruaine	GIS Specialist (CLIMAP Project Officer)
Ben Parakoti	Waterworks Engineer
Mathilda Miria Tairea	Waste Management Project
Adrian Teotahi	Engineering Assistant
Aporo Kirikava	Engineering Assistant
Rene Nooapii	Engineering Assistant

Office of the Prime Minister

Tuaere Tangimetua	
Helen Wong	

Environment Service

Vaitoti Tupa	Secretary
Tania Temata	International Advisor
Pasha Carruthers	Climate Change Officer
Bobby Bishop	Aitutaki Project Officer

Ministry of Agriculture

Poona Samuel	Director of Quarantine

Ministry of Health

Ngapoko Short	Director of Public Health
Tuaine Teokotai	Chief Health Inspector
Tearoa Iorangi	Health Officer

Ministry of Marine Resources

Jo Anderson	Marine Scientist

Ministry of Education

Jane Taurarii	Social Science Advisor

Meteorological Service

Arona Ngari	Director
Nga Rauraa	Chief Meteorological Officer

Disaster Management Office

Mac Mokoroa	Disaster Management Officer

Cook Islands Investment Corporation

Tarita Hutchinson	Chief Executive Officer

Ports Authority

Andrew McBirney	Chief Executive Officer

University of the South Pacific

Rod Dixon	Centre Director

Private Sector

Don Dorrell	Coastal Environmental International Ltd.
Sam Brown	Miro Consultants

WWF

Mona Matepi	Cook Islands Co-ordinator
Pat Fitzgibbon	Environmental Education Specialist

Taporoporo Ipukarea Society (TIS)

Imogen Ingram	President
Ana Tiraa	

Avatiu/Ruatonga Community

Teariki Rongo
Tony Utanga

Traditional Leaders

Dorice Reid	Koutu Nui

International

Richard Creed	Engineer, Idaho, USA
Pete Mason	NIWA, New Zealand
Chris Jones	GDH, Australia

Sea level data for Rarotonga and Pohnpei were supplied by the National Tidal Facility, The Flinders University of South Australia, Copyright reserved.

Executive Summary

Background

The Pacific islands region faces increasing environmental and socioeconomic pressures exacerbated by global climate change and climate variability.[1] Adaptation to climate change and variability (CCV) is ultimately an issue of sustainable development. Even without climate change, Pacific island countries are already severely affected by climate variability and extremes, and they remain extremely vulnerable to future changes in the regional climate that could increase the risks. Countries in the Pacific have clearly recognized the need to (i) reduce their vulnerability to these increasing risks through adaptation, and (ii) strengthen their human and institutional capacities to assess, plan, and respond to these challenges.

Six case studies designed to assist countries to adapt to current and future climate risks have been prepared. The case studies were prepared through a regional technical assistance under the Renewable Energy, Energy Efficiency, and Climate Change (REACH) programme of the Asian Development Bank, and funded by the Canadian Cooperation Fund for Climate Change – Greenhouse Gas Abatement, Carbon Sequestration and Adaptation. The technical assistance was administered by the Asian Development Bank as the executing agency, and implemented in partnership with the Governments of the Federated States of Micronesia and of the Cook Islands (implementing agencies), Maunsell (NZ) Ltd (environmental and engineering consultancy) and the International Global Change Institute, University of Waikato, New Zealand.

The ultimate aim of the case studies is to show *why* and demonstrate *how* reducing climate-related risks is an integral part of sustainable development. The overall goal of a risk-based approach to climate change adaptation is to manage both the current and future risks associated with the full spectrum of atmospheric and oceanic hazards. Through a consultative process the following case studies were selected: (i) the Federated States of Micronesia - “climate proofing” a coastal community in Pohnpei; a roading infrastructure project in Kosrae; and the infrastructure, human health and environment components of the National Strategic Development Plan; (ii) the Cook Islands - “climate proofing” the design of the breakwater for the newly developed Western Basin, Rarotonga; a community inland from Avatiu Harbour; and the National Sustainable Development Strategy.

As part of the case studies, assessments were made of both the risks arising from current climate variability and extremes and from the future, incremental changes in those risks as a result of longer-term changes in climate extremes and variability. While the field studies and other activities to develop the six case studies were undertaken in Pacific Island Countries, the innovative methodologies and tools, as well as the findings, are applicable to all Small Island Developing States, and even to larger developing and developed countries.

Adaptation: Responding to Climate Change

The case studies highlight that adaptation takes place at three levels: i) project/community; ii) sector regulation and compliance; and iii) policy and planning level (short- and mid-term policy making and planning at sub-national level and national strategic development planning). Importantly, the case studies also demonstrate methods for prioritizing adaptation strategies and specific adaptation interventions, in terms of both their costs and benefits. A major goal, and challenge, was to determine, in a rigorous and quantitative manner, the incremental costs of adaptation to climate change.

For both the Cook Islands and the Federated States of Micronesia, climate risk profiles were prepared. Extreme climate events that are relatively

[1] Global climate change refers to a significant long-term change in the earth’s climate system, whereas climate variability refers to short- to medium-term fluctuations in the climate system, and usually includes extreme weather events such as hurricanes, floods, droughts, and other related disasters caused by weather phenomena.

rare at present (likelihood in one year less than 0.05) are projected to become relatively common as a result of global warming (in many cases likelihoods are projected to increase to over 0.20 by 2050). Climate-related risks facing both the case study infrastructure projects and communities are already substantial, but in all cases are projected to increase dramatically as a result of increases in climate extremes and variability. For infrastructure projects it is possible to avoid most of the damage costs attributable to climate change, and to do this in a cost effective manner, if "climate proofing" is undertaken at the design stage of the project. Cost effectiveness can be further enhanced if environmental impact assessment procedures require that all development be "climate proofed". "Climate proofing" communities can also be cost effective if planning and regulatory measures take into account both current and future climate-related risks.

"Climate proofing" national strategic development plans enhances the enabling environment for adaptation and also establishes the requirement for "climate proofing" sector, sub-national (e.g., state, island and community) development plans as well as "climate proofing" individual development projects. In addition, it helps to ensure that actions to reduce climate-related risks are an integral part of, and harmonized with, sustainable development initiatives. Such "climate proofing" at the national policy level is one of the major ways to mainstream adaptation. In the case studies mainstreaming was facilitated further by preparing Adaptation Mainstreaming Guidelines for each of the two countries.

Lesson Learned and Demonstrated

Through preparation of the case studies, many key lessons were learned and demonstrated. Climate change will manifest largely as changes in the frequency and consequences of extreme events and inter-annual and similar variations, rather than as long-term trends in average conditions. While there are uncertainties in projections of greenhouse gas emissions, and of the response of the global climate as estimated by models, confidence in estimates of future changes in climate-related risks is increasing. This is due to the consistency in model-based projections of changes in the likelihood of extreme events and climate variability, as well as increased consistency between these projections and the observed changes in these likelihoods over recent decades.

At a practical level adaptation should focus on reducing both present and future risks related to climate variability and extremes. This is despite the fact that under present international climate change agreements funding is often limited to reducing future risks. In many instances current levels of climate risk are already high, due in large part to increases in risk over the past few decades. Moreover, adapting to current climate extremes and variability prevents precious financial and other resources being squandered on disaster recovery and rehabilitation and is an essential step to being able to withstand the pending changes in climate.

A risk-based approach to adaptation is not only desirable but also practicable. It combines both the likelihood and consequence components of climate-related impacts and can assess risks for both current and anticipated conditions, with the option of examining either specific events or an integration of those events over time. Furthermore, risk assessment and management are common to many sectors – e.g., health, financial, transport, agriculture, energy, and water resources. The existing familiarity of planners and decision makers with risk management therefore helps facilitate the mainstreaming of risk-based adaptation. Risk-based methods also facilitate an objective and more quantitative approach, including cost benefit analyses that result in evaluation of the incremental costs and benefits of adaptation and assist in prioritizing adaptation options. Many players are usually involved in the adaptation process. The risk-based approach provides a framework that facilitates coordination and cooperation amongst the various players, including the sharing of information that might otherwise be retained by information "gate keepers". It also links to sustainable development by identifying those risks to future generations that present generations would find unacceptable.

Most barriers to the successful application of a risk-based approach to adaptation relate to the existence of, and access to, information. While removing such barriers may be difficult, the experience gained in preparing the current case studies provides some grounds for optimism. Before generalized findings and lessons can be drawn from case studies of a risk-based approach to adaptation, many more examples will need to be developed. It is desirable to have internationally consistent assessment methodologies. International bodies, such as the Intergovernmental Panel on Climate Change, play major roles in establishing best practices. They would need to formally endorse and encourage a risk-based approach to adaptation before there will be widespread uptake. Currently, best practice favors the more traditional assessments of vulnerability, and of adaptation options. These have many limitations compared to a risk-based approach, including no formal assessment of the likelihood of future extreme events or variations in climate or of baseline conditions; a focus on individual events (e.g., an extreme rainstorm or a cyclone) or on a future date, rather than on an aggregation of the anticipated climatic conditions over a specified time period into the future; inability to differentiate between the costs of current climate extremes and variability and the future costs of those events plus any systematic trend (i.e., unable to evaluate the incremental costs of climate change); difficulty of incorporating economic, social and wider environmental scenarios into the assessment procedures; no functional link between the vulnerability and adaptation assessments; and no formal procedures for prioritizing adaptation options on the basis of cost and other measures of efficiency and effectiveness.

Until a risk-based approach to adaptation is formally endorsed and encouraged there will also be a lack of documentation and training opportunities. While a risk-based approach requires no greater skills and experience than are called on when using traditional assessment methods, there is a need to build a cadre of in-country expertise. So long as parallel frameworks and methodologies are being advocated, there will be confusion, and arguments for maintaining the status quo. Additional barriers include the need for formal specification of risk-based targets that define future levels of acceptable risk – this requires consultation with, and consensus amongst, key stakeholders, specification of relationships between magnitude and consequence of risk events of relevance, "rules" that specify future social, economic and wider environmental changes; and appropriate discount rates to be applied to future costs and benefits.

For the current case studies, all these barriers were overcome. Future efforts to develop additional case studies, as well as to support the practical application of adaptation measures, can build on both the methodologies and experience gained in preparing the current case studies. Thus the barriers are unlikely to be as imposing as for the initial work.

Implications for Governments and their Development Partners

Governments and other stakeholders are urged to note and act on the finding that the likelihoods of adverse weather and climate conditions are already high and are projected to increase in the future. Similarly, the consequences of these weather and climate events are also already very high, and will likely increase markedly as a result of climate change. Most climate-related risks can be reduced in a cost effective manner. Care should be exercised to ensure that future development does not exacerbate climate-related risks. Experience in both the Cook Islands and the Federated States of Micronesia highlights the importance of the enabling environment for successful adaptation, across all its many dimensions.

Governments and their development assistance partners should ensure that all proposed, new and upgraded development projects are "climate proofed" at the design stage. This should be part of good professional practice, with national and state climate risk profiles being used as the basis for "climate proofing" infrastructure, community and other development projects. Compliance with this requirement should be assessed as part of enhanced environmental impact assessment procedures. Governments should also undertake cost benefit analyses of all major development projects, including determining the incremental costs and benefits. If for a developing country the incremental costs are large, the Government should request developed country donors and other relevant agencies to fund the incremental costs. Governments should also ensure that all regulations (e.g., building code, public health regulations) are "climate proofed" as this will facilitate enforcement of policies and plans that should, themselves, be "climate proofed". These actions can be assisted by preparing and implementing National Guidelines for Mainstreaming Adaptation to Climate Change.

Climate change poses a threat to poverty reduction, water and energy supplies, waste management, wastewater treatment, food security, human health, natural resources and protection against natural hazards. Development also affects the rate and nature of climate change. These linkages between climate change and development are being increasingly recognized. The Asian Development Bank and other development partners need to modify their policies and procedures in ways that ensure that the design and funding implications associated with "climate proofing" infrastructure, community and other development projects are addressed early in the project cycle. Such initiatives mean that "climate proofing" will become an integral part of best practice, rather than a later add on. The Asian Development Bank and other development partners also need to establish and demonstrate such a standard of good practice, with the hope that others will follow. There is a requirement for further development of methods to identify, early in the project cycle, the incremental costs of this "climate proofing". For developing countries, these costs should be met from sources that do not add to their existing or future debt burdens. The Global Environment Facility (GEF) is one such source of funding for adaptation in developing countries.

Key Conclusions

The six case studies give rise to several important conclusions. It is possible to enhance the sustainability (e.g., lifetime) of projects at risk to climate change by "climate proofing" such projects at the design stage. This will normally require an investment that is small relative to the maintenance and repair costs that would otherwise be incurred over the lifetime of the project. Retroactive "climate proofing" is likely to be considerably more expensive than that undertaken at the design stage of a project. Many adaptation options qualify as "no regrets" adaptation initiatives, including being cost effective. Governments and their development partners should respond to these findings by ensuring that all projects are "climate proofed" at the design stage, making this part of good professional practice. Furthermore, governments of developing countries should determine the incremental costs and benefits of all major development projects and request that development partners fund at least the incremental costs. National and sub-national level regulations should be "climate proofed" as this will allow enforcement of policies and plans that should, themselves, be "climate proofed", in accordance with National Guidelines for Mainstreaming Adaptation to Climate Change.

CHAPTER I

Background to the Study

Even without climate change, the smaller island countries in the Pacific are already severely affected by climate variability and extremes. They are also extremely vulnerable to future changes in global and regional climate.

Consequently, since the early 1990s, the Pacific Forum Leaders, through their annual Forum Communiqué, have identified climate change as a priority issue. Their high level of concern was made very apparent in October 2000, when they endorsed the Pacific Islands Framework for Action on Climate Change, Climate Variability, and Sea-Level Rise. They clearly recognized the need to reduce their vulnerability to these increasing risks through adaptation processes, while also strengthening the human and institutional capacities needed to assess, plan, and respond to these challenges. While climate is acknowledged as a priority issue at the highest levels of government, active support has been lacking. Key ministries are concerned largely with matters of socioeconomic development, such as finance and planning; their priorities are based on the belief that climate is an environmental, not a developmental, issue. Mainstreaming adaptation is designed to overcome this inappropriate and counterproductive separation.

Tangible political support for climate-related initiatives is growing, however, mainly because of increasing recognition that the impacts of a changing climate are already being experienced through the increased occurrence of climate extremes such as unusually intense and/or unseasonal cyclones, flooding, droughts, and other natural phenomena. One way to address this challenge is to integrate disaster management into a holistic risk reduction strategy that includes adaptation to climate change, all within the broader context of sustainable development policies and planning. In addition, improving the ability to cope with current variability not only provides short-term benefits through risk reduction and more sustainable development, but also increases the adaptive capacity with respect to the increased risks resulting from future global climate change. This linking of short-term and long-term responses to climate-related risks is critical to achieving an integrated, participatory, and holistic approach to a complicated issue. This holistic framework and methodology is formalized as Climate Change Adaptation through Integrated Risk Reduction (CCAIRR).

The studies described in this book are designed to assist Pacific Developing Member Countries (PDMCs) of the Asian Development Bank (ADB) to adapt to climate variability and change, including extreme events. The CCAIRR framework and methodology have been used to demonstrate a risk-based approach to adaptation and the mainstreaming of adaptation. Two PDMCs, the Federated States of Micronesia and the Cook Islands, were selected to demonstrate how to mainstream this risk-based approach at three levels: national development planning, sector programs, and project activities.

Climate Proofing—A Risk-based Approach to Adaptation is the result of a regional technical assistance (RETA 6064-REG) funded under Climate Change, Renewable Energy, and Energy Efficiency (REACH) by the Canadian Cooperation Fund for Climate Change—Greenhouse Gas Abatement, Carbon Sequestration and Adaptation. The technical assistance was administered by ADB.

CHAPTER II

Introduction to the Study

Just as today's development decisions will influence tomorrow's climate, so too will tomorrow's climate influence the success of today's development decisions. Most development plans and projects have life expectancies that require future climate conditions to be given due consideration. Long-term changes in atmospheric and oceanic conditions will impose both increased and new risks on many natural and human systems, especially as a result of changes in climate variability and in the frequency and magnitude of extreme climatic events.

The overall goal of a risk-based approach to climate change adaptation is to manage both the current and future risks associated with the full spectrum of atmospheric and oceanic hazards. This is best undertaken in a holistic manner as an integral part of sustainable development planning. National, local and sector development should be based on harmonized hazard management strategies and climate change adaptation measures that ensure risks are reduced to acceptable levels. These measures, and the related strategies, will help strengthen all decision-making processes by requiring that specific programs and projects include plans and measures to manage risks associated with future, as well as present, climate variability and extreme events. Such actions will result in the climate proofing of development projects and related initiatives, in support of the wider process of sustainable development.

Climate proofing means identifying risks to a development project, or any other specified natural or human asset, as a consequence of both current and future climate variability and extremes, 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.

This book presents case studies that demonstrate the climate proofing of infrastructure and community development projects, and the mainstreaming of climate change considerations into national strategic development plans. In the context of addressing climate and related risks, the term "mainstreaming" is used to describe the integration of climate change adaptation into ongoing and new development policies, plans, and strategies, including laws and regulations (e.g., environmental impact assessment requirements). Mainstreaming aims to enhance the effectiveness, efficiency, and longevity of initiatives directed at reducing climate-related risks, while at the same time contributing to sustainable development and improved quality of life.

The case studies thus include assessments of both the risks arising from current climate variability and extremes and from future, incremental changes in those risks that will result from longer-term changes in climate. Significantly, the case studies incorporate assessments of adaptation strategies and specific measures that can be used to reduce unacceptable risks, including analyses of their benefits and costs. One aim of these analyses is to determine, in a rigorous and quantitative manner, the incremental costs of adaptation to climate change. The likelihood is increasing that when these costs are clearly identified and quantified by a developing country, they will be met, at least in part, by the international community (e.g., bilateral and multilateral aid providers and financial mechanisms such as the Global Environment Facility (GEF).

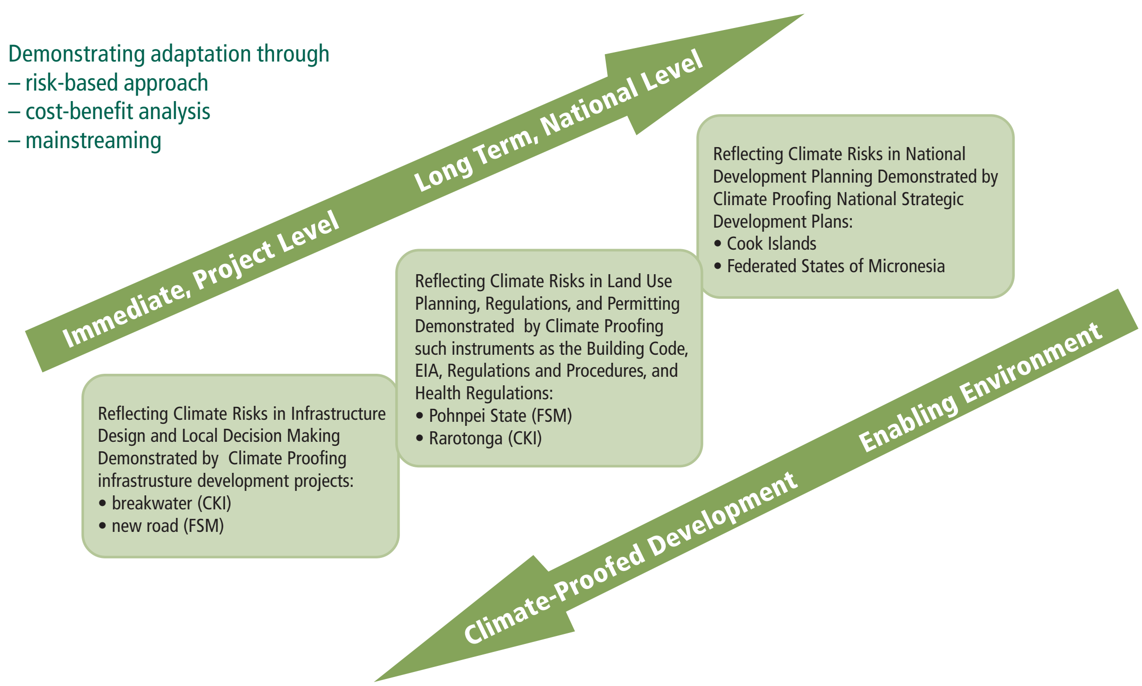
The case studies were chosen to highlight the range of levels at which adaptation takes place, and the linkages between them. The levels are i) project, ii) regulation and compliance, iii) short- and mid-term policymaking and planning at subnational level, and iv) national strategic development planning. Therefore, as shown in Figure II.1, the case studies also demonstrate the importance of mainstreaming adaptation, including strengthening the enabling environment for adaptation to increase the likelihood of successful adaptation at project and community levels.

The field studies and other activities to develop the six case studies were undertaken in the Cook Islands and the Federated States of Micronesia (FSM), as part of RETA 6064-REG Climate Change Adaptation Program for the Pacific (Second Phase, Country Level Activities), 2003. However, the innovative methodologies and tools, as well as the findings, are applicable to all Small Island Developing States and even to larger developing and developed countries.

The case studies have been prepared through a partnership among the Government of Canada (funding provider), the Asian Development Bank (executing agency), the Governments of the FSM and the Cook Islands (implementing agencies), Maunsell (NZ) Ltd (environmental and engineering consultancy) and the International Global Change Institute, University of Waikato, New Zealand. The RETA was funded under REACH by the Canadian Cooperation Fund for Climate Change—Greenhouse Gas Abatement, Carbon Sequestration, and Adaptation.

Figure II.1. Case Studies Demonstrate the Importance of Mainstreaming Adaptation

The case studies cover the continuum between project, subnational planning and regulation, and national strategic development planning, thereby showing the importance of the enabling environment to infrastructure, community, and other development projects. They also demonstrate how a risk-based approach, cost-benefit analysis, and adaptation mainstreaming contribute to the success of adaptation.



Source: CCAIRR findings.

CHAPTER III

Sharing the Findings

Case studies that demonstrate a risk-based approach to adaptation, including its mainstreaming in development planning, are of relevance beyond the Pacific Islands region. They support messages that should be heard and heeded by political, private sector, and community leaders in both large and small, developing and developed countries.

For this reason the case studies, and the methods and tools used in their preparation, are described in this book rather than in a more conventional technical report. The book is designed to appeal to readers with a diversity of backgrounds, current interests, and responsibilities. Both the overarching Summary for Policy and Decision Makers, and the key messages at the start of each chapter, reflect a conscious effort to ensure that the book influences the thinking and actions of those individuals who play critical roles in development planning, whether in government, the private sector, or civil society.

As noted in the Introduction, the case studies cover the spectrum over which adaptation takes place—from projects, through regulations and other mechanisms, short- and medium-term policy making and planning at the subnational level, to national strategic development planning.

Rather than the case studies being grouped nationally, the two project-level case studies are presented first, followed by those related to climate proofing at the community level and then by those concerned with national strategic development planning. One of the many benefits of this sequencing is the ability to identify more readily commonalities and distinctions in both the approaches and the findings. In many respects, these are dependent on the level of the case study. This approach has even greater value because of the marked political, social, economic, and other differences between the Federated States of Micronesia (FSM) and the Cook Islands.

After introductory material on adaptation to climate variability and change, and presentation of the climate risk profiles (CRP) for the areas in which the case studies were located, the reader is taken in Chapter VI directly to the case studies themselves. Again, this is a deliberate initiative, reflecting the assumption that the target readership is likely to be more interested in the case studies and what they reveal than in how it was revealed. For this reason, technical details of the information, methods, and tools used in preparing the studies form part of the case study descriptions, but they are presented in ways that are intended to be informative while not distracting the reader from the important messages that the case studies are intended to convey.

Chapter VII, on key findings and their implications, also caters directly to the interests of the target readership. The key findings derive from the case studies, both individually and collectively.

The reader who has a greater interest in the more technical aspects of the studies is catered for in Chapter VIII, which provides detailed information on the approach, methods, and tools used to prepare the six case studies, as well as in the appendixes.

CHAPTER IV

Why Adapt, and What is Involved?

A. Scientific Consensus on Global and Regional Climate Change, and Implications for Pacific Island Countries

The Intergovernmental Panel on Climate Change (IPCC) reported that globally averaged surface temperatures are projected to increase by between 1.4 and 5.8 degrees Celsius (°C) during this century while sea level is projected to rise by between 9 centimeters (cm) and 88 cm (IPCC 2001). The consensus of scientific opinion is that changes are more likely in the middle of the ranges given above than at the extremes. Model-based projections suggest that, globally, temperatures will increase faster over land than over the oceans, and at higher latitudes rather than lower latitudes.

The Southern Hemisphere will warm more slowly than the globe as a whole, because water sinking near the Antarctic carries heat away from the surface to the ocean depths. This also increases the temperature difference between the tropics and the Antarctic, causing an increase in westerly wind speeds. Global precipitation is projected to increase overall, with a larger percentage of the annual total occurring as intense rainfall events.

Despite the many uncertainties as to the nature and consequences of global warming, the climate of the Pacific islands region will continue to be dominated by the trade winds and convergence zones, and by the interannual variability associated with the El Niño Southern Oscillation (ENSO) (Hay et al. 2003). However, the projected rate of warming

BOX IV.1

Key Points for Policy and Decision Makers

- Even now, but more so in the future, climate variability and extreme events impose untenable social, environmental, and economic costs.
- This highlights the need to mainstream both disaster risk management and adaptation to climate variability and extreme events, in a mutually consistent and supportive manner, by making them integral components of the national risk management strategy and, in turn, of the national development planning process.
- Adaptation is one of two major ways in which climate-related risks can be managed. The other—mitigation—is effective only in the longer term.
- Adaptation has many dimensions and is best viewed as an ongoing and flexible process.
- Generally, the most appropriate forms of adaptation are those that build on current actions to cope with present-day climate variability and extreme events, and that also contribute in a positive manner to sustainable economic development, sound environmental management, social progress, and wise resource use. The latter constitute "no regrets" adaptation initiatives.
- Climate proofing does not always incur additional costs. This is especially the case for no regrets adaptation initiatives.
- Climate Change Adaptation through Integrated Risk Reduction (CCAIRR) provides both a framework and a methodology that result in development and implementation of adaptation strategies and measures that are coordinated, integrated ("bottom-up" as well as "top-down"), and cost effective.

Source: CCAIRR findings.

for the Pacific Islands region (by between 0.6°C and 3.5°C in this century) is much larger than the observed changes during the last century and is very likely to have been without precedent during at least the last 10,000 years. The projected increase should be compared to the temperature difference, for the region, of around 3–4° C between the middle of the last Ice Age and the present day. During the present century, the climate may become more "El Niño-like", with central and eastern equatorial Pacific sea surface temperatures projected to warm more than the western equatorial Pacific, and with a corresponding mean eastward shift of precipitation. During future ENSO events, anomalously wet areas could become even wetter, and unusually dry areas even drier. While there is no evidence that tropical cyclone numbers will change with global warming, a general increase in tropical cyclone intensity (lower central pressures, stronger winds, and higher peak and mean precipitation intensities) appears likely, as does an eastward extension in the area of formation.

While local sea levels change in response to many factors, including local uplift or sinking of the Earth's crust, and variations in air pressure and wind velocity, it is expected that even those areas in the Pacific currently experiencing a relative fall in sea level will, by the end of this century, experience a rising relative sea level. However, interannual variations in sea level associated with ENSO, and storm surges associated with tropical cyclones, are likely to be of greater significance in the coming decades.

To date much attention has focused on global warming causing gradual, long-term changes in average conditions. However, the most immediate and more significant risks are likely to arise from changes in the nature of extreme events (e.g., flooding, tropical cyclones, storm surges) and climate variability (e.g., drought, prevailing winds accelerating coastal erosion). Present-day problems resulting from increasing demand for water, increasing pollution of water, and current patterns of extreme events and climate variability will be exacerbated by climate change over the next few decades (Hay et al. 2003). Since most good quality land in the Pacific islands region is already under intense cultivation, increasing population numbers combined with climate change impacts will threaten food security, as will the increasing reliance on imported food and the consequent vulnerability to short-term breaks in supply and world food shortages due to climate events.

Significantly, the natural ecosystems and the people of the Pacific have many attributes that make them inherently resilient, as they have developed mechanisms to cope with past changes in natural, social, and economic conditions. However, although terrestrial and freshwater ecosystems have been able to evolve and adapt over time both to climate extremes and variability and to human pressures, the indications are that changes in climatic conditions coupled with unsustainable use will render terrestrial and freshwater ecosystems increasingly vulnerable in the longer term.

Similarly, many of the likely impacts of climate change on coastal zones and marine ecosystems are already familiar to island populations, and some have experience in coping with them. However, in most countries and for most coastal and marine areas, coping with climate extremes and variability will be even more demanding over the next few decades.

The human health risks resulting from climate variability and change will frequently arise through initial impacts on ecosystems, infrastructure, the economy, and social services. The increasing "urbanness" and centralization of Pacific island populations is increasing the risks arising from climate variability and change, while repairs and rehabilitation for rural populations after an extreme event may well receive decreasing priority. The possibility of more extreme events, such as tropical cyclones and storm surges, coupled with currently projected rates of sea-level rise and flooding, places critical infrastructure—health care and social services, airports, port facilities, roads, vital utilities such as power and water, coastal protection structures, and tourism facilities—at increased risk.

In summary, many countries in the Pacific islands region are already experiencing disruptive changes consistent with the anticipated consequences of global climate change, including increased frequency and severity of coastal erosion, floods, droughts, storm surges, groundwater degradation, salinization, coral bleaching, more widespread and frequent occurrences of vector-borne diseases, and periods of exceptionally high sea levels. These and other changes constitute the climate-related risks that often require responses that go under the label of "adaptation".

B. Adaptation

Adaptation is, in large part, an ongoing and flexible process designed to reduce the exposure of society to risks arising from climate variability, including extreme events. It reflects the fact that the risks associated with current climatic variability and extremes typically impose severe costs on economies and societies, as well as the environment. In many circumstances, current levels of adaptation are far from adequate, given the high costs imposed by variations and extremes in climate.

In the context of future changes in climate, including changes in variability and the frequency and magnitude of extreme events, the process of adaptation is concerned with reducing not only present risks but also the additional (i.e., "incremental") risks accruing from the ongoing emissions of greenhouse gases.

Risk is a familiar concept. Formally, it is the combination of the likelihood and consequences of an event (e.g., occurrence of a tropical cyclone, ocean surface temperatures exceeding a given threshold). Risk is used widely in such sectors as finance; insurance (e.g. life, property); health care; and the control of pests, diseases, and genetically modified organisms.

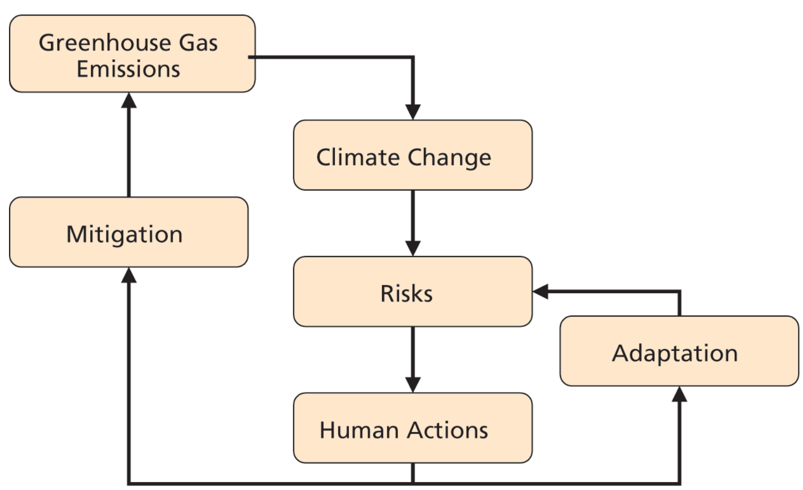
Most countries already have policies and plans to manage financial risks, human health risks, biosecurity risks, agricultural risks, transport sector risks, and energy supply risks. Logically, responses to climate variability and change (including extreme events) should also be included and addressed in the same portfolio of national risks. Such an approach would strengthen decision-making processes by requiring that specific programs and projects include strategies and measures to manage risks arising from climate variability and change.

Adaptation is one of two major ways in which climate-related risks can be managed. As Figure IV.1 indicates, the other is mitigation. But even if global greenhouse gas emissions were to be stabilized near their current levels, atmospheric concentrations would increase throughout the 21st century, and might well continue to increase slowly for several hundred years after that.

Thus, mitigation can reduce climate-related risks only in the longer term. In the meantime, unacceptable climate-related risks to natural and human systems will have to be managed through adaptation.

Figure IV.1. Adaptation and Mitigation

Adaptation aims to reduce climate-related risks (the likelihood and/or consequence components), while mitigation aims to reduce the rate at which climate change occurs.



Source: CCAIRR findings.

Effective management of climate-related risks, through both mitigation and adaptation, prevents precious resources from being squandered on disaster recovery and rehabilitation. If adaptation is reactive, as opposed to planned, the range of response options is likely to be narrower; adaptation may well prove more expensive, socially disruptive, and environmentally unsustainable. Moreover, many disaster and climate change response strategies are the same as those that contribute in a positive manner to present-day efforts to implement sustainable development, including enhancement of social equity, sound environmental management, and wise resource use. Such adaptation initiatives are termed "no regrets" options, since they are also appropriate responses to the present-day and emerging stresses on social, cultural, economic, and environmental systems. No regrets adaptation strategies are beneficial and cost effective, even if no climate change occurs.

Thus, identifying and undertaking actions to adapt to climate extremes and variability has economic and social value, both in dealing with today's climate-related concerns and as an essential step toward building long-term resilience to withstanding future changes in climate-related risks. In short, adaptation must reflect current risks as well as the new risks associated with future climate change.[1]

People will, as a result of their own resourcefulness or out of necessity, adapt to climate variability and change (including extreme events), based on their understanding and assessment of the anticipated or observed effects, and on the perceived options and benefits for response; in some cases such adaptations will be adequate, effective, and satisfactory. For many circumstances, however, such adaptation may not be satisfactory or successful. An external entity, such as central or local government, may then be needed to facilitate the adaptation process to ensure that obstacles, barriers, and inefficiencies are addressed in an appropriate manner. Furthermore, while many climate-related risks and losses are manifested locally, measures to alleviate them have important national and international dimensions.

Adaptation has many dimensions and is also best viewed as an iterative process. As such, it involves

- assessing the risks to human systems as well as natural systems;
- quantifying the consequence component of risk in social, environmental, and economic terms;
- explicitly assessing adaptation options in terms of their costs and benefits in reducing unacceptable risks;
- identifying the most effective adaptation option(s);
- developing policies and action plans to reduce risks to acceptable levels; and
- identifying the most effective mechanisms and modalities to mainstream adaptation programs into development decision making and economic planning.

Significantly, adaptation also comprises key elements such as

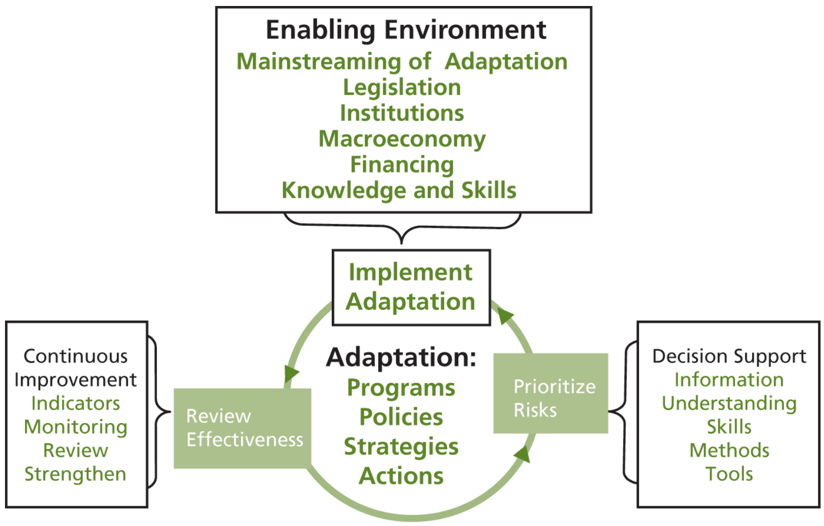
- capacity building and awareness raising to understand and undertake adaptation;
- developing tools for the assessment of risks and adaptation options;
- the undertaking of required assessments;
- mainstreaming adaptation into development policies, strategies, and plans based upon the results of the assessments, including the prioritization of adaptation options;
- provision of adequate funding, from internal and/or external sources; and
- implementing the adaptation options through development plans, programs, and projects.

These elements of the adaptation process are depicted in Figure IV.2. Climate Change Adaptation through Integrated Risk Reduction (CCAIRR) captures the multiple dimensions of adaptation and thus serves as a framework for the actions that ensure successful adaptation outcomes.

The CCAIRR framework and associated methods underpinned preparation of the case studies described in the following pages. The framework is

1 In some formal contexts, such as those relating to the United Nations Framework Convention on Climate Change, adaptation relates only to climate *change*. At an operational level, a more inclusive definition is reflective of how climate-related risks are, and should be, managed in practice.

Figure IV.2. The CCAIRR Framework and Methodology for a Risk-based Approach to Mainstreaming Adaptation



Note: CCAIRR = Climate Change Adaptation through Integrated Risk Reduction.

Source: CCAIRR findings.

operationalized through the activity of climate proofing, which includes a risk-based approach to adapting to climate variability and change, including extreme events. Implementing the adaptation process using this framework results in risk management responses (i.e., adaptation initiatives) that are coordinated, integrated, and cost effective. Further details on CCAIRR may be found in Chapter VIII, "Approach, Methods, and Tools for an Integrated, Risk-Based Approach to Adaptation".

Assessment of climate-related risks, and the cost-benefit analyses of specific adaptation measures, have been facilitated by the use of "SimClim", an "open framework" modelling system to integrate data and models for evaluating the risks of, and adaptation to, climate variability and change, including extreme events. User-friendly, Windows-based interfaces allow users to import climate (and other) data for geographical areas and spatial resolutions of their own choice and to attach impact models for relevant sectors (e.g., agricultural, coastal, healthcare, water resources). By selecting among emission scenarios, climate change patterns derived using global climate models, climate sensitivity values, and time horizons, the user has considerable flexibility for generating scenarios of future climate changes that can be used to drive risk assessment and adaptation models. SimClim contains a custom-built geographical information system for spatial analyses and presentation of results. It also includes tools for examining site-specific time-series data, including analysis of extreme events and estimation of return periods. Further details on SimClim are provided in Chapter VIII.

CHAPTER V

Climate-related Risks in the Case Study Countries

A. Background on the Case Study Countries

The Cook Islands

The Cook Islands comprises 15 small islands and atolls. The country has a total land area of 244 square kilometers (km^2) dispersed over an exclusive economic zone of 1.8 million km^2 of the South Pacific Ocean (Map V.1). The islands are predominantly coastal entities and because of their size and isolation, and the fragile nature of island ecosystems, their biological diversity is among the most threatened in the world.

The Cook Islands is divided into northern and southern groups, stretching over some 1,000 km of ocean. The southern islands are generally younger volcanic islands, while the northern group is made up of coral atolls. Islands in the southern group are generally larger and more heavily populated. The total population of the Cook Islands is 18,600, while that of the capital island (Rarotonga) is 13,200. This is the largest island, though only 6 km wide.

The climate of the Cook Islands is considered to be of a maritime tropical nature, dominated by the easterly trade winds. The rainfall regime exhibits a marked seasonality, with a dry season from May to October, during which only one third of the 2,000 millimeters (mm) annual rainfall occurs. The other two thirds falls during the wet season (November to April). The wet season is also the tropical cyclone season and is associated with the easterly shift of the South Pacific Convergence Zone (SPCZ) over the country.

BOX V.1

Key Points for Policy and Decision Makers

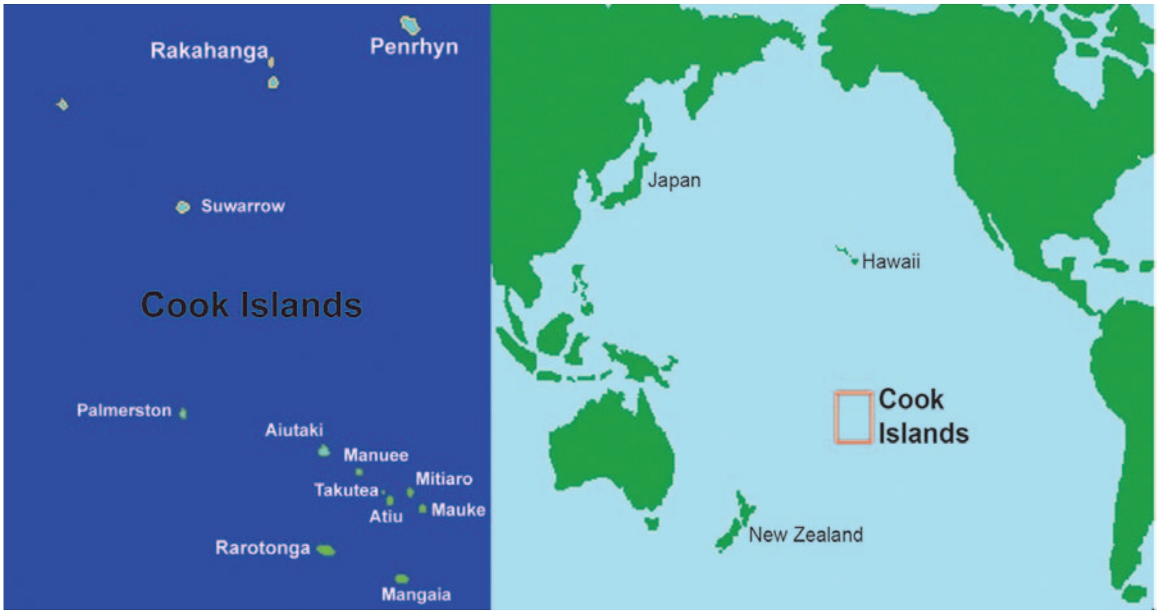
- Both the Cook Islands and the Federated States of Micronesia (FSM) comprise a mixture of relatively large and hilly islands, coral atolls, and raised coralline islands.
- While the climates of both countries are characterized as maritime tropical, FSM usually experiences warmer and wetter conditions. Both countries experience a marked seasonality in precipitation.
- The two countries also experience large interannual variations in rainfall, associated with the El Niño Southern Oscillation;
- Tropical cyclones (typhoons) are more common in the Cook Islands.
- The consequence component of climate risk is site or sector specific.
- The likelihood component of climate risk, however, is usually evaluated for a country, state, island, or similar geographical unit.
- For both countries, extreme climate events that are relatively rare at present (likelihood less than 0.05) are projected to become relatively common as a result of global warming. In many cases, likelihoods are projected to increase to over 0.20 by 2050.

Source: CCAIRR findings.

The monthly average temperatures range between 21°C and 28°C. Extreme temperatures have been recorded in the mid-30s and mid-teens. The climate of the Cook Islands experiences large interannual variability, especially during ENSO events.

The occurrence of tropical cyclones tends to be more frequent during an El Niño event, when

Map V.1. The Cook Islands



warmer than normal sea surface temperatures occur between latitudes 10° and 15° South and the SPCZ migrates eastward in the vicinity of the Cook Islands and French Polynesia. During an El Niño event, the southern Cook Islands experiences a reduction in rainfall, to as little as 60% of normal, while in the northern Cook Islands rainfall increases to as much as 300% *above* normal.

Tropical Cyclones Martin and Pam, during the 1997/98 ENSO, caused extensive damage to property and infrastructure and brought human suffering, including loss of lives. During the same period, the southern group of islands experienced prolonged drought. In the southern Cook Islands, cyclones are seldom associated with heavy rainfall.

The Federated States of Micronesia

The Federated States of Micronesia (FSM) comprises four states: Yap, Chuuk (formerly Truk), Pohnpei (formerly Ponape), and Kosrae (formerly Kusae), in the western Pacific Ocean between the equator and 14° North, and between 136° and 166° degrees East (Map V.2). The states stretch about 2,700 km in geographic sequence from west to east. The country has a total population of about 106,000.

The land area of the FSM comprises 607 islands, which have a combined area of only 701 km^2. Of these hundreds of islands, a number are relatively large and mountainous or hilly, while the rest are small, flat coral atolls or raised coralline islands. The latter are associated with 7,190 km^2 of lagoons. The marine area within the FSM's exclusive economic zone totals over 2.6 million km^2 and includes abundant and varied resources.

The climate of the FSM is typical of many tropical islands. Temperatures are relatively uniform, averaging in the mid to high 20°C range; humidity averages over 80%. Rainfall is high, varying from about 3,000 mm per year on drier islands to over 10,000 mm per year in the mountainous interior of Pohnpei. Most islands have a pronounced wet season (June to October) and dry season (November to May). For Pohnpei, the "dry" season contracts to January to March.

During an ENSO event, the FSM suffers drought conditions during the winter and spring months.

Map V.2. The Federated States of Micronesia

With a severe El Niño episode, drought can begin as early as late autumn and extend into the following summer. The stronger the El Niño, the longer-lasting the drought conditions are likely to be. Whether an El Niño event is "typical" or stronger than usual, Yap and western Chuuk, being in the western part of the FSM, tend to be affected somewhat earlier and, in most cases, more harshly than eastern Chuuk and the eastern states of Pohnpei and Kosrae.

The western region of the FSM is subject to the occasional (one in 20 years return period) tropical cyclone (typhoon). These can cause severe damage. A typhoon that struck Pohnpei on April 24, 1997 caused many landslides, damage to vegetation as well as infrastructure, and 19 deaths. When El Niño conditions prevail, typhoons tend to form farther to the east and northeast than usual. The typical directions of the storm tracks taken by these typhoons are to the north, northwest, or west. During an El Niño event the FSM is most vulnerable to typhoon activity during November and December, when typhoons have the greatest likelihood of forming directly east, then tracking west, and gathering strength before traveling across the FSM.

B. Characterizing Risk

Formally, risk is the combination of the consequence of an event and the likelihood (i.e., probability) of that same event. As illustrated by the examples in Table V.1, the full extent of a risk is evident only when both the likelihood and consequence components are considered together.

While the consequence component of a risk will be site or sector specific, the likelihood component generally will be applicable both over a larger area and to many sectors. This is due to the spatial scale and pervasive nature of weather and climate. Thus the likelihood of, say, an extreme event or climate anomaly is often evaluated for a country, state, small island, or similar geographical unit. While the likelihood may well vary within a given unit, information is often insufficient to assess this spatial variability, or the variations are judged to be of low practical significance. In such instances the main challenge is to determine the likelihoods using observed and other data, and to use climate change scenarios to develop projections of how the likelihoods might change in the future.

Table V.1 A Risk Register, Based on Hypothetical Examples

Risk Type	Risk Event	Consequence	Likelihood Probability	Risk	Rank
Natural	Typhoon/ Cyclone	Widespread damage and deaths	1 in 10 year	High	1
Human	Industrial Explosion	Several die	1 in >100 year	Low	3
Combined	Landslide	Damage to road and environment	1 in 50 year	Medium	2

Source: CCAIRR findings.

The remainder of Chapter V provides examples of such analyses, for both the FSM and Cook Islands. Since the case studies were located in the FSM states of Pohnpei and Kosrae, and on Rarotonga in the Cook Islands, the results are presented for those geographical units.

Chapter VI presents the results of characterizing the consequence components of the risks, as part of the detailed description of the case studies.

Summary Climate Risk Profile for Pohnpei and Kosrae

The likelihood (i.e., probability) components of climate-related risks in Pohnpei and Kosrae are evaluated, for both present-day and future conditions. Changes into the future reflect the influence of global warming. The risks evaluated in this way are extreme rainfall events (both hourly and daily), high sea levels, strong winds, extreme high air temperatures, and drought.

A summary of the climate risk profile (CRP) is presented here. The full CRP, including descriptions of the data sources and methods used, may be found in Appendix 1.

Table V.2 presents the average time between occurrences of specified extreme events, for both Pohnpei and Kosrae. These values, also known as return periods, are given for the present and for the projected future.

The information can also be presented as the likelihood that the specified event will occur within a given time period. In Table V.2, a time horizon of 1 year has been used. Graphs provided in Appendix 1 present the likelihoods for other time horizons.

While all the chosen events are relatively rare at the present time, global warming will cause marked increases in the frequency of all these extreme events except wind gusts.

Extreme high rainfall amounts are more common in Pohnpei than Kosrae, and this difference persists into the future, with global warming.

An analysis of observed rainfall for Pohnpei for 1953–2003 shows that most of the low rainfall months (below the fifth percentile, which is often used as an indicator of drought) are concentrated in the latter part of the period of observation, indicating that the frequency of drought has increased markedly since the 1950s. The years with a high number of months below the fifth percentile coincide with El Niño events. A similar analysis of projected daily rainfall amounts for Pohnpei reveals that the frequency of low rainfall months will generally remain at these higher levels for the 21st century.

Table V.2. Return Period and Likelihood of Occurrence in 1 Year[1], for Given Extreme Events in Pohnpei and Kosrae, for the Present and Projected Future

Event and Location	Present		2025		2050		2100	
	RP	LO	RP	LO	RP	LO	RP	LO
Rainfall—Daily Total at least 300 mm								
Pohnpei	21	0.05	9	0.11	4	0.23	2	0.65
Kosrae	38	0.03	21	0.05	12	0.08	4	0.22
Rainfall—Daily Total at least 200 mm								
Pohnpei	23	0.04	12	0.08	7	0.14	4	0.25
Kosrae	28	0.04	21	0.05	16	0.06	11	0.09
Sea Level—Hourly Average at least 120 mm above mean sea level								
Pohnpei	61	0.02	21	0.05	5	0.20	1	1.0
Wind Gust—Extreme at least 25 m/sec								
Pohnpei	8	0.13	10	0.10	9	0.10	0.9	0.11
Maximum Temperature—Daily at least 35°C								
Pohnpei	24	0.04	11	0.09	6	0.17	2	0.50

RP = return period in years; LO = likelihood of occurrence.

[1] A likelihood of 0 equals zero chance while a likelihood of 1 equates to a statistical certainty that the event will occur within a year.

Source: CCAIRR findings.

Summary Climate Risk Profile for Rarotonga

The likelihood components of climate-related risks in Rarotonga are evaluated, for both present-day and future conditions. Changes in the future reflect the influence of global warming. The risks evaluated in this way are extreme rainfall events (both hourly and daily), drought, high sea levels and wave heights, strong winds, and extremely high air temperatures.

A summary of the CRP is presented in Table V.3. The full CRP, including descriptions of the data sources and methods used, may be found in Appendix 2.

Table V.3 presents the return periods for Rarotonga of specified extreme events. The information is also presented in terms of the likelihood that the specified event will occur within a time horizon of 1 year. Graphs provided in Appendix 2 present the likelihoods for other time horizons.

While all the chosen extreme events are relatively rare at the present time, global warming will cause marked increases in the frequency of all of them.

An important point to consider is whether these likelihoods have changed during the recent past. Any such changes might signal the impact global warming has had on climate-related risks, although direct attribution of any changes to global warming would require detailed investigations that are beyond the scope of the present study.

The long rainfall record for Rarotonga provides an opportunity to investigate changes in likelihoods over time. Table V.4 shows that, between the periods 1929–1959 and 1970–2003, a substantial increase

Table V.3. Return Period and Likelihood of Occurrence in 1 Year[1], for Given Extreme Events in Rarotonga, for the Present and Projected Future

Event and Location	Present		2025		2050		2100	
	RP	LO	RP	LO	RP	LO	RP	LO
Rainfall—Daily Total at least 300 mm	38	0.03	26	0.04	19	0.05	11	0.09
Rainfall—Hourly Total at least 100 mm	91	0.01	57	0.02	25	0.04	13	0.08
Height of Sea Surge – Extreme at least 6 m above mean sea level	10	0.10	8	0.13	7	0.15	5	0.21
Wind Gust – Extreme at least 42m/sec	29	0.03	16	0.06	14	0.07		
Maximum Temperature – Daily at least 34ºC	29	0.03	14	0.07	9	0.12	3	0.29

RP = return period in years; LO = likelihood of occurrence.
[1] A likelihood of 0 = zero chance; a likelihood of 1 = a statistical certainty that the event will occur within a year.
Source: CCAIRR findings.

Table V.4. Probability Components for Daily Rainfall of at least 250 mm, Rarotonga

Time Period	Return Period (years)	Likelihood in Any One Year
1929–1959 (observed)	66	0.02
1970–2003 (observed)	17	0.06
2025 (projected)	13	0.08
2050 (projected)	10	0.10
2100 (projected)	6	0.17

Source: CCAIRR findings.

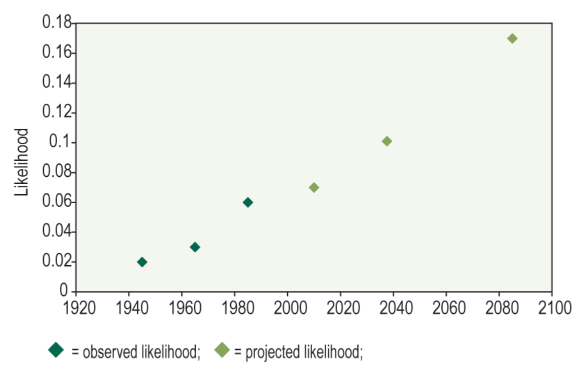
occurred in the likelihood of a daily rainfall of 250 mm or more. This finding is not surprising given that, of the six days since 1929 that had precipitation amounts over 200 mm, all but one was later than 1966.

An obvious question arises: are the past changes in the probability component consistent with the changes projected to occur in the future as a result of global warming?

Table V.4 also shows projected return periods and likelihoods. The trend of increasing likelihood that was apparent in the historical data for much of the last century is projected to continue, in a consistent manner, through the present century.

The likelihood results in Table V.4 are presented graphically in Figure V.1. A consistency between the

Figure V.1. Observed and Projected Likelihoods of a Daily Rainfall of at Least 250 mm Occurring in a Year, Rarotonga

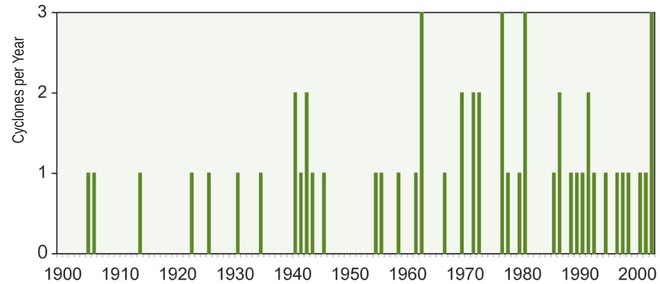


Source: CCAIRR findings.

observed and projected changes is readily apparent. This does not prove the existence of a global warming signal in the historical data, however. Once again, more detailed analyses are required before any such attributions might be made.

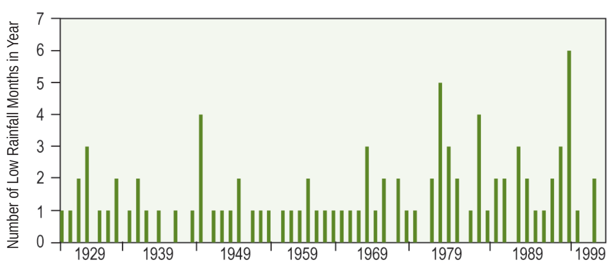
While the frequency of heavy rainfall events in Rarotonga is clearly increasing, so too is the frequency of low monthly rainfall totals. Figure V.2 shows the number of months in each year when the precipitation was below the 10th percentile. It is clear that in the latter part of the last century Rarotonga experienced unprecedentedly low rainfall conditions. In 1998 alone, 4 consecutive months had rainfall below the 10th percentile. In that same year, 6 months had rainfall below the 10th percentile, with 3 below the fifth percentile. All the low rainfall years, namely 1982/83, 1992/93 and 1997/98, coincided with El Niño events.

Figure V.3. Number of Tropical Cyclones per Year Passing Close to, and Affecting, Rarotonga



Sources: Kerr (1976), Revell (1981), Thompson et al. (1992), d'Aubert and Nunn (1994), Fiji Meteorological Service (2004) and Ready (pers. comm.).

Figure V.2. Number of Months in each Year (1929–2003) when the Precipitation for Rarotonga was Below the 10th Percentile



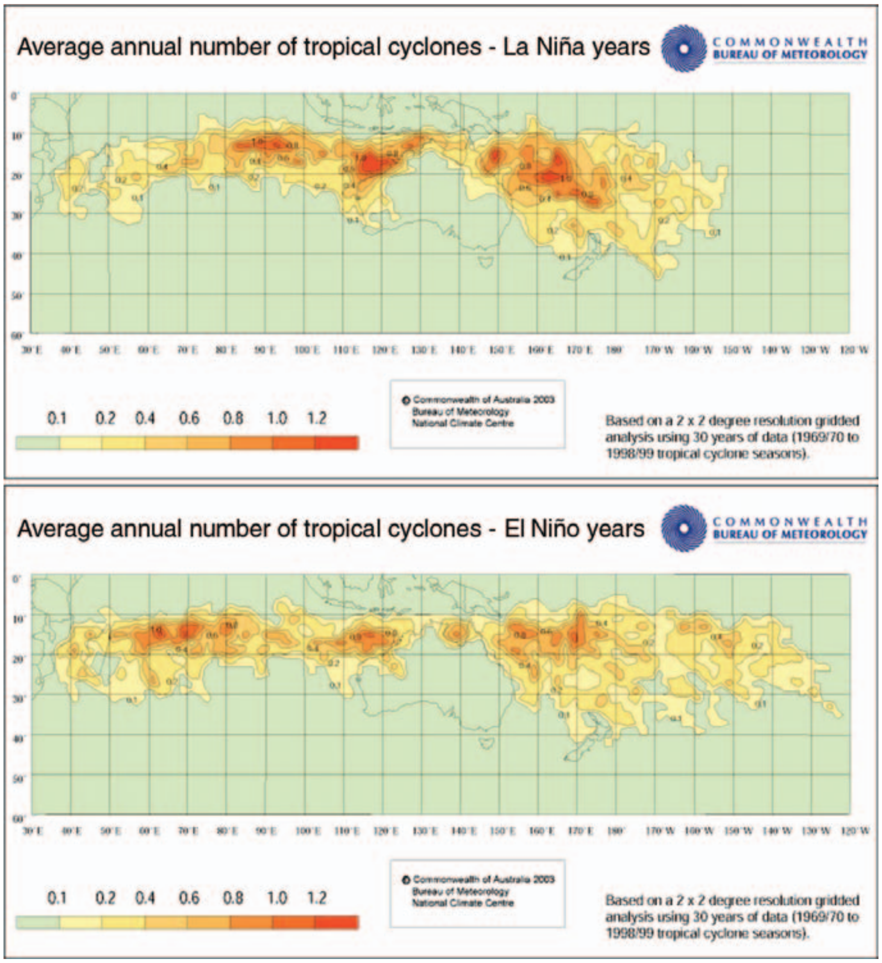
Source: CCAIRR findings.

The number of tropical cyclones passing close to, and affecting, Rarotonga, appears to have increased during the last century, as indicated in Figure V.3. However, since observing and reporting systems improved substantially over the time period, it is unwise to read too much into the marked contrast in frequency between the first and second halves of the 20th century. The record for the last few decades is much more reliable, and hence the doubling in decadal frequencies between the 1950s and 1990s may well be closer to the truth. It is certainly consistent with the fact that, since the 1970s, the tendency has been for more frequent El Niño episodes, without intervening "La Niña" events. The duration of the 1990–95 El Niño is unprecedented in the climate records of the past 124 years.

Studies by Australia's Bureau of Meteorology reveal the consequences of the weakened trade winds and eastward movement of the warm waters of the western tropical Pacific during El Niño events (Figure V.4). Because convective systems (e.g., thunderstorms and rainstorms) and tropical cyclones preferentially occur over warmer waters, changes in the pattern of sea surface temperatures is reflected in the distribution of rainfall and tropical cyclones.

A possible consequence of the increased persistence of El Niño conditions in recent decades is the apparent intensification of tropical cyclones. Table V.5 shows a systematic increase in upper 10th-percentile heights of open water waves associated with tropical cyclones occurring in the vicinity of Rarotonga.

Figure V.4. Average Annual Number of Tropical Cyclones for La Niña Years (Top Figure) and El Niño Years (Bottom Figure)



Source: Australian Bureau of Metereology n.d.

Table V.5. Open Water Wave Height (Average of Top 10%) Associated with Tropical Cyclones Recently Affecting Rarotonga

Cyclone (name and year)		Wave Height (m)
Charles	(1978)	11
Sally	(1987)	10
Val	(1991)	14
Pam	(1997)	14
Dovi	(2003)	17
Heta	(2004)	17
Meena	(2005)	17
Nancy	(2005)	22
Percy	(2005)	19
Olaf	(2005)	16

Source: Dorell (pers.comm.)

CHAPTER VI

The Case Studies

A. Introduction

Before the details regarding the six case studies are presented, the consultative procedures used to identify potential case studies, and select the final six, will be described. Details of the principles and practices followed in implementing the case studies will also be provided.

As noted in Chapter II, the six case studies are presented in the following order:

- infrastructure development projects (Kosrae and Rarotonga);
- community development planning and regulations (Rarotonga and Pohnpei); and
- national strategic development plans (FSM and Cook Islands).

This ordering is designed to help the reader gain a wider appreciation of how climate proofing operates at the three levels, by identifying the similarities and procedures for community development planning and regulation. The sequencing is also

BOX VI.1
Key Points for Policy and Decision Makers

- Five principles underscored preparation of the case studies, to ensure stakeholder buy-in and sustained uptake of the findings:
  - ➢ All activities were to be undertaken in an inclusive, transparent, and participatory manner.
  - ➢ Wherever possible, existing information and other resources were to be used.
  - ➢ Local experts were expected to work alongside and at times lead their international counterparts.
  - ➢ All outcomes were to have high relevance to key stakeholders, add value to current and planned initiatives, and be sustainable.
  - ➢ Selection of the case studies was to be in accordance with criteria established initially by the Asian Development Bank and subsequently expanded through consultation with stakeholders in each country (governments, nongovernment organizations (NGOs), private sector, and communities).
- In addition to the technical and policy-oriented work, considerable effort was devoted to a key dimension of adaptation, namely capacity building, including awareness raising and action and institutional strengthening.
- Climate-related risks facing both the infrastructure projects and the communities are already substantial, but in all cases are projected to increase substantially as a result of increases in climate extremes and variability.
- For infrastructure projects, it is possible to avoid most of the damage costs attributable to climate change, and to do this in a cost-effective manner, if climate proofing is undertaken at the design stage of the project.
- Cost effectiveness can be further enhanced if environmental impact assessment procedures require that all development be climate proofed.
- Climate proofing communities can also be cost effective if planning and regulatory measures take into account both current and future climate-related risks.
- Climate proofing national strategic development plans
  - ➢ enhances the enabling environment for adaptation;
  - ➢ establishes the requirement for climate proofing sector and subnational (e.g., state, island and community) development plans, as well as individual development projects (i.e., mainstreaming adaptation); and
  - ➢ ensures that actions to reduce climate-related risks are an integral part of, and harmonized with, sustainable development initiatives.

Source: CCAIRR findings.

intended to assist the reader to identify differences in the climate proofing process that arise from the contrasting social, political, environmental, and economic contexts of the case studies.

The key findings arising from the case studies are presented in the next chapter, along with a discussion of their implications.

Additional details regarding the methods and tools used in developing the case studies may be found in Chapter VIII.

B. Case Study Identification and Selection Procedures

The six case studies that were to demonstrate a risk-based approach to adaptation and the mainstreaming of adaptation were selected in a consultative process involving stakeholders in the Federated States of Micronesia (FSM) and the Cook Islands. In both countries the stakeholders were represented by government officials, leaders of nongovernment organizations (NGOs), and individuals active in the private sector.

Criteria used in the selection were also developed as part of the same consultative process (Box VI.2). In addition, the Asian Development Bank (ADB) prescribed that, for each country, the case studies must cover the spectrum from strategic planning to project-level activities. Moreover, at least one of these activities had to be funded by an agency other than ADB. This was to ensure that not all the activities were closely associated with ADB policies and procedures.

The other criteria reflected the need for the case studies to produce self-evident results within 1 year. The results had to be of direct benefit to governments, the private sector, and civil society, both in the participating countries and in the wider Pacific region.

Discussions with stakeholders in both countries resulted in identification of a wide range of climate-related risks, affecting many sectors, both individually and collectively, in a crosscutting manner. Examples from the FSM included landslide events, malfunction of septic tanks and latrines, reduced fish catches, and damage to coastal infrastructure. For the Cook Islands, additional risks were identified, including tourism downturn and decline of the pearl industry. The high interdependency of sectors and community support systems in both countries

BOX VI.2

Criteria for Selection of Case Studies

- Criteria given in the Terms of Reference from the ADB:
  - ➢ Three case studies were to demonstrate a risk-based approach to adaptation and the mainstreaming of adaptation.
  - ➢ At least one must be
    - related to a strategy or plan,
    - related to a project,
    - related to an activity (strategy, plan or project) not funded by ADB), or
    - related to the coastal zone.
  - ➢ Development or implementation of activity (strategy, plan, or project) is imminent, with at least the design phase due for completion by the end of the time available to prepare the case studies.
- Case studies must involve assets at risk to climate change, especially to variability and extreme events.
- Some or all of the required information is already available, or is easily acquired.
- Case studies must deal with mainline sectors, and hence have buy-in from governments.
- Implications of the case studies will ideally extend beyond individual sectors—i.e., crosscutting.
- Case studies must complement and add value to
  - ➢ related projects, and
  - ➢ development activities, regardless of climate change.
- Case studies must not duplicate existing activities.
- Case studies must maintain a balance of capital and Outer Island coverage.
- The results of addressing climate change must be amenable to cost-benefit analysis, including social and environmental costs and benefits.
- Case studies must maintain links with the national implementing agency and/or other ministries.
- Case studies must attract strong interest from the private sector and/or civil society.
- Case study findings must be made widely applicable, nationally and in the region.

Source: CCAIRR findings.

resulted in stakeholders requesting that, other than for the project level, all case studies cut across sectors and reflect a range of climate-related risks.

Figure VI.1 identifies the sectors and support systems in the FSM considered to be exposed to current and future climate-related risks and the three specific case studies chosen to demonstrate the risk-based approach to mainstreaming adaptation.

As shown in Figure VI.1, the outcome of the consultations was a suite of case studies for the FSM, namely:

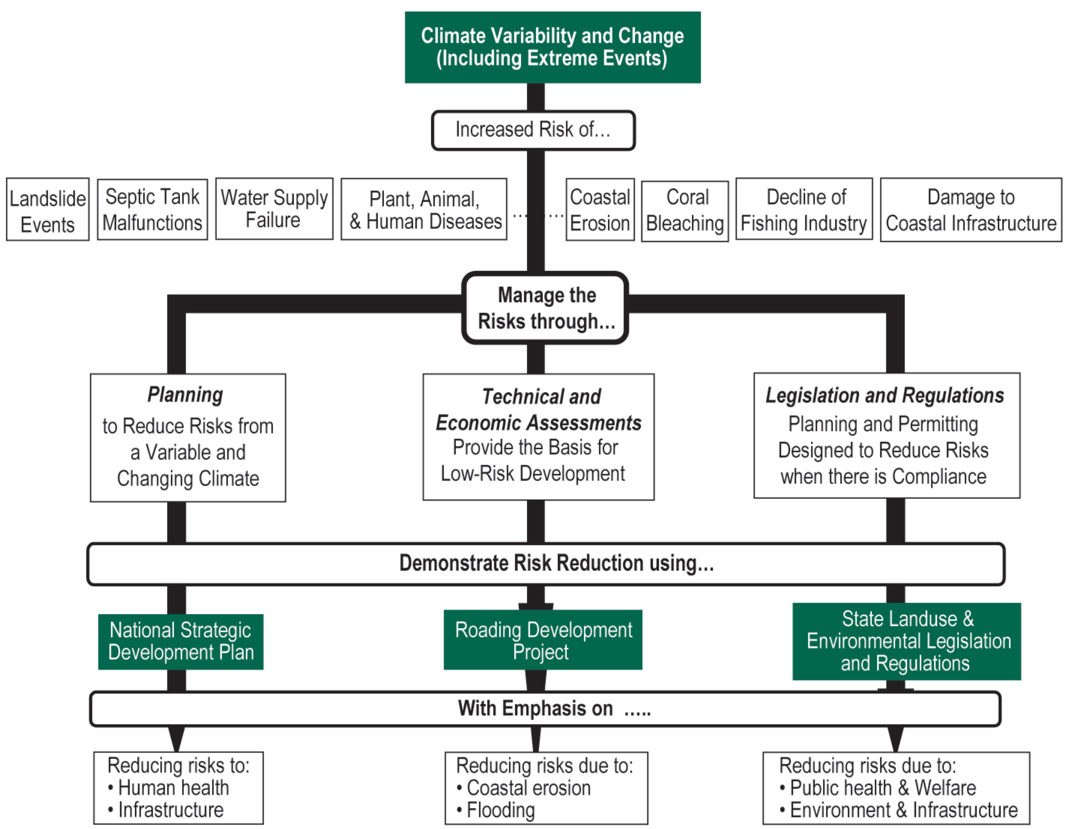
- climate proofing Sapwohn, a coastal community in Pohnpei;
- climate proofing a roadbuilding infrastructure project in Kosrae; and
- climate proofing the infrastructure, human health care, and environment components of the FSM National Strategic Development Plan.

The results of similar consultations in the Cook Islands are shown in Figure VI.2, including the agreed case studies, namely

- climate proofing the design of the breakwater for the newly developed Western Basin, Rarotonga;
- climate proofing Avatiu-Ruatonga, a community inland from Avatiu Harbour; and
- climate proofing the Cook Islands National Development Strategy.

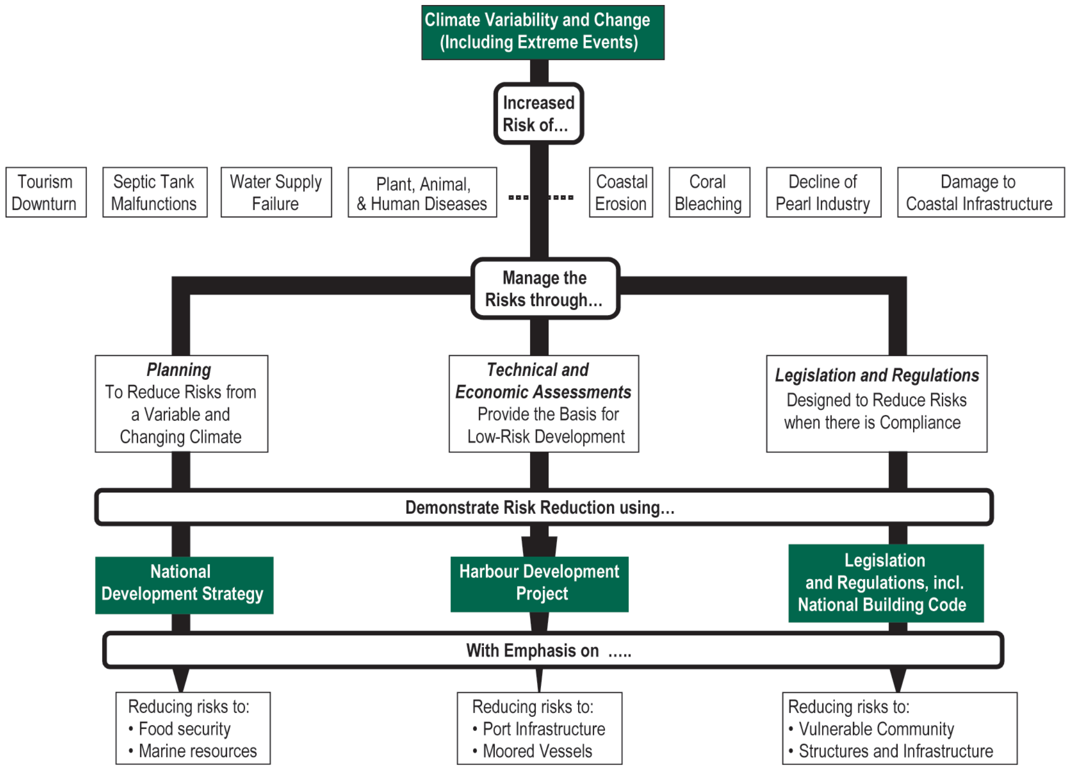
For each country the case studies form an integrated package based on activities ranging from

Figure VI.1. Sectors and Support Systems Considered to be at Risk, and the Three Case Studies Chosen to Demonstrate the Risk-based Approach to Mainstreaming Adaptation (FSM)



Source: CCAIRR findings.

Figure VI.2. The Sectors and Support Systems Considered to be at Risk, and the Three Case Studies Chosen to Demonstrate the Risk-based Approach to Mainstreaming Adaptation (Cook Islands)



Source: CCAIRR findings.

project level to national strategic development planning. Identifying climate-related risks (including those related to sea level and state), and determining how best to manage them through adaptation measures, will add value to planned project activities and help enhance the sustainability of development, at community through to national levels.

The ultimate aim of the case studies was to show why and demonstrate how reducing climate-related risks is an integral part of sustainable development. Implementation of specific risk-reduction measures at project and local levels can be facilitated if land-use planning and associated regulations and permitting procedures for community and infrastructure development projects incorporate requirements designed to reduce risks related to climate extremes, variability, and change. This strengthening of planning and regulatory provisions is, in turn, assisted by ensuring that national policy frameworks and strategies address the potential for climate-related risk events to have large adverse social, environmental, and economic consequences.

In this way, a favorable enabling environment is created for the implementation of specific adaptation measures that will reduce climate-related risks.

C. Implementation of the Case Studies

In addition to the requirement that the case studies comply with the previously listed selection criteria, four fundamental principles underscored preparation of the case studies:

- all activities were to be undertaken in an inclusive, transparent, and participatory manner;
- wherever possible, existing information and other resources were to be used;
- local experts were expected to work alongside and at times lead their international counterparts; and
- all outcomes were to have high relevance to key stakeholders, add value to current and planned initiatives, and be sustainable.

These principles are consistent with, and in fact underscore, the CCAIRR methodology that was followed in preparing the case studies. In order to comply with these principles, and reflecting the CCAIRR methodology, the case studies involved more than characterizing climate-related risks and determining the most effective and efficient methods for reducing these to acceptable levels.

Two key dimensions of the CCAIRR methodology that are fundamental to successful adaptation, and illustrate the integrated and comprehensive approach taken to implement the case studies in the two host countries, are i) capacity building, including awareness raising and institutional strengthening, and ii) provision, enhancement, and application of data, tools, and knowledge.

Capacity Building, Including Awareness Raising and Institutional Strengthening

Careful consideration was given to the selection of the implementing agencies in the two countries. As shown in Table VI.1, several considerations were identified. This resulted in the selection of the Ministry of Works as implementing agency for the Cook Islands. For the FSM, the implementing agency was the Department of Transport, Communications, and Infrastructure. The equivalent implementing agency at the state level in Pohnpei was the Environmental Protection Agency; in Kosrae it was the Development Review Commission. In both countries, close working relationships were also established with environmental and other relevant agencies.

Table VI.1. Factors Considered When Selecting the Implementing Agencies

Characteristic	Reason
Development focus	This will help ensure achievement of a key project outcome, namely mainstreaming adaptation responses as demonstrated through development case studies.
Infrastructure responsibility	Major climate change risks and opportunities are infrastructure related. The central tenet of this TA is to make a real difference at a practical level.
Established office facilities and counterpart staff	The TA team needs to work alongside counterpart staff in the implementing agency, in order to achieve another key project outcome, namely to enhance local capacity in mainstreaming adaptation to climate change.
Already facilitating coping	Adaptation is typically most effective when it is complementary to existing efforts to cope with extremes, variability, and change.

TA = technical assistance.
Source: CCAIRR findings.

Since training is an important component of the CCAIRR methodology, preparation of the case studies also included on-the-job training for national counterparts, based on learning by doing. International experts worked alongside counterpart staff in the implementing agency, among others, in order to achieve another key project outcome, namely building local capacity in mainstreaming adaptation to climate change. These activities complemented more formal "transfer and apply" workshops that were conducted as part of completing the case studies.

As part of the effort to build local expertise in a risk-based approach to adaptation and to mainstream adaptation, a close working relationship was also established with individuals who had responsibility for preparing and implementing development policies, plans, and projects. The aim was to help achieve the major benefits that accrue if the risks associated with climate variability and change (including extreme events) are taken into consideration at an early stage in the planning and project cycles. The training and relationship building was also part of a deliberate strategy to ensure minimal turnover of in-country personnel who had key roles to play in ensuring the success of the case studies.

Another part of the strategy was to ensure government "buy-in" for the project, especially with reference to accepting the approach, methodologies, and selection of case studies; providing active and effective oversight of the project; assigning staff to work alongside the consultants; allowing learning by doing; and providing in-kind support such as appropriate work space, communications facilities, and information resources. Effort was also devoted to ensuring that actions related to the case studies were harmonized with the ongoing activities of government, the private sector, and NGOs. In this way synergies were maximized and duplication was avoided.

Throughout the preparation of the case studies, there was also a commitment to communicating the project findings in ways that maximized awareness among stakeholders, encouraged constructive feedback, and laid the foundation for effective uptake of the project findings. This was part of a comprehensive awareness-raising and action-promotion program. Both broad and targeted activities were undertaken in each country on a regular basis, in order to raise awareness of the case study activities among governments, the private sector, and civil society. As indicated in Box VI.3 and Figure VI.3, such activities were undertaken in cooperation with the media, community-based organizations, educational institutions, the private sector, and government.

Stakeholder oversight of the preparation of the case studies in the two countries was via Project Liaison Committees. Where possible and appropriate, these were based on existing groups. In the FSM, the terms of reference of the National Climate Change Country Team (NCCCT) were modified to reflect responsibility for overseeing the case studies. The Country Team was also strengthened and its representation widened through the addition of individuals from NGOs and the private sector. In the Cook Islands, most members of the Project Liaison Committee were members of the NCCCT and/or the project advisory committee for an infrastructure

BOX VI.3

Example of Program for Awareness-Raising and Action-Promotion Workshop

- Welcome and Opening Comments—Minister for Environment
- The need for public awareness and action—Outer Island Environmental Officer
- Climate-related risks to communities in Rarotonga, and implications for action—John Hay
- Environment Service's strategies for promoting climate change awareness and action— National Climate Change Coordinator
- Using climate change as a theme to support environmental education in the Cook Islands—official from Education Ministry
- Using environmental education as the delivery mechanism for adaptation and mitigation measures—nongovernment organization representative
- Using the Climate Change Adaptation Program for the Pacific findings to raise awareness, change attitudes, and promote adaptation actions—Teresa Manarangi-Trott
- Question & answer and discussion
- Brainstorming—elements of an action strategy to promote environment awareness, change attitudes, and foster action related to climate change.

Source: CCAIRR findings.

Figure VI.3. Feature story in the *Cook Islands News*, 5 February 2004

COOK ISLANDS NEWS THURSDAY 5 FEBRUARY 2004

Proofing for climate change

What does the Ruatonga meeting house have to do with climate proofing?

The area between the meeting house along the main road to Putua Road in Panama, and inland to the ara metua, has been selected to be part of a case study involving climate proofing on Rarotonga.

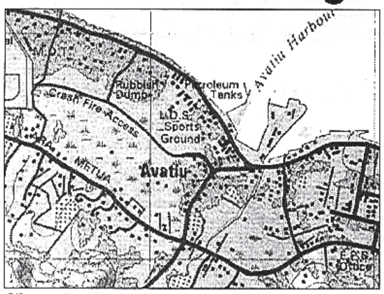
"Climate proofing is shorthand for saying that we need to identify the added risks resulting from global warming and take early action to reduce the risks to acceptable levels," says Timoti Tangiruaine, the project officer at the Ministry of Works attached to the project.

"In other words, recognising that it is better to plan for, rather than react to, climate change."

Two case studies focus on the Avatiu/Ruatonga/Panama area. One is aimed at climate proofing the new breakwater planned for the Avatiu wharf extension, while the other looks at the existing land uses and any development planned for the area inland from the harbour.

"Global warming will raise the sea level and likely increase the frequency and severity of both storm surges and storm waves. All pose risks to the planned breakwater," says Tangiruaine.

"Storm surges also bring a growing risk of flooding and destruction to the areas inland from Avatiu harbour, especially in conjunction with the generally higher sea levels resulting from global warming."



Climate change survey area map.

The studies are being undertaken jointly by the International Global Change Institute of the University of Waikato and Maunsell Ltd, working in collaboration with the Ministry of Works, Ports Authority, Environment Services and Cook Islands Investment Corporation as well as other interested parties.

The project team is currently collecting and analysing the information needed to assess the levels of risk and to identify how best to address those risks.

In May both local and international experts will share the findings in a national and training workshop designed to show how planning and policy-making in the Cook Islands should and can take climate change risks into account in all projects.

For more information the public is encouraged to contact Tangiruaine or local consultant Teresa Manarangi-Trott at the Ministry of Works. — *Moana Moeka'a*

development project. To help ensure high participation, meetings of the Project Liaison Committees were usually scheduled to precede or follow other related meetings. On one occasion, the Cook Islands NCCCT and the Project Liaison Committee held a joint meeting. In both countries, a senior representative of the implementing agency chaired meetings of the Project Liaison Committees. These individuals also acted as formal liaison persons between the respective governments and the team preparing the case studies.

Institutional strengthening is also a key focus of the CCAIRR methodology. For example, when preparation of the case studies was in its early stages, the Governor of Pohnpei State established an Inter-Agency Task Force to Assess and Manage Weather- and Climate-related Risks. The role of the Task Force is to oversee the ongoing program of climate risk assessments and implementation of adaptation in Pohnpei. When he established the Task Force, the Governor decreed that it would have oversight for the coordination and cooperation required to ensure timely and cost-effective assessments of, and responses to, the weather- and climate-related risks facing Pohnpei. He also required that the Task Force never disrupt the existing allocation of responsibilities and resources afforded to government agencies. Rather, the Task Force is a mechanism for exploring and implementing collaborative activities that are of mutual benefit to the agencies involved, as well as to the people of Pohnpei.

The Task Force comprised senior representatives of the following state agencies: Environmental Protection Authority, Department of Land and Natural Resources, Office of Economic Affairs (Marine Development), Department of Public Safety (Disaster Office), Public Utilities Corporation, Pohnpei State Hospital, Transportation and Infrastructure Office (Public Works), and the Department of Treasury and Administration. The Director of the Task Force, who is also Director of the Pohnpei State Environmental Protection Agency, is a member of the National Climate Change Country Team for the FSM, and chairs its meetings on a rotational basis.

A member of the CCAIRR team conducts a SimClim training session in Pohnpei.

Members of the team from the Cook Islands' Ministry of Works played key roles in the case studies undertaken in that country.

At the technical level the Task Force was assisted by the Pohnpei CCAIRR Team, made up of technical specialists, key individuals from NGOs, and community representatives.

Providing, Enhancing, and Applying Data, Tools and Knowledge

Implementing a risk-based approach to adaptation is an information-intensive task. As noted above, one of the principles guiding preparation of the case studies was that, wherever possible, existing information was to be used. Complying with this principle was, at times, a major challenge, but the resulting benefits went way beyond those related to efficiency. Many had to do with effectiveness, often in terms of improved communication and cooperation between information gatekeepers as well as among stakeholders. In both countries, preparation of the case studies resulted in the identification of one government agency (Mapping and Survey Division, Pohnpei Department of Lands and Natural Resources; Geographic Information Systems Division, the Cook Islands Ministry of Works) as the central repository of information to be used, not only for undertaking risk assessments to support adaptation to climate change, but also for the land use and related assessments that underpin state-of-the-art approaches to national development planning. This recognition, along with widespread buy-in to the process of preparing the case studies, resulted in relevant information repositories being identified and made readily available by their custodians, despite previous histories of unwillingness to share data and other information, even between government agencies.

At times, however, it was necessary to collect new information, since its absence would jeopardize the quality of the risk assessments and adaptation studies. A case in point was the high-resolution (spatial and elevation) data required to determine the flood risks faced by the Aviatiu-Ruatonga and

Survey Crew, Sapwohn Case Study

Sapwohn communities. For the Sapwohn case study, existing survey data held by the Pohnpei Department of Lands and the Public Utilities Commission were supplemented by spot heights obtained using a Total Station Survey System. For the Avatiu-Ruatonga study area, existing spot heights from conventional surveys were supplemented with new spot heights obtained using Global Positioning Satellite (GPS) equipment (Figure VI.4).

D. Case Study One: Climate Proofing a Roadbuilding Infrastructure Project in Kosrae, Federated States of Micronesia

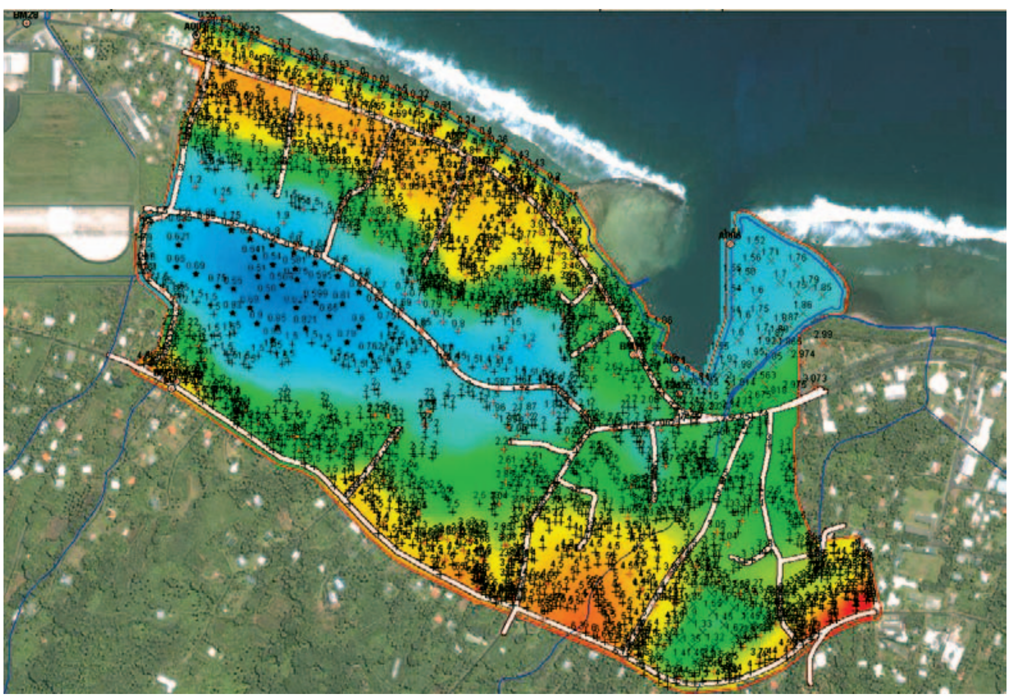
The infrastructure development plan for Kosrae includes completion of the circumferential road. At present, a 16-km gap occurs, designated RS4. Funds for the roadbuilding project will be provided under the Compact of Free Association with the United States of America. Construction of at least a portion of the road, the northern portion up to but not including the Yela Valley crossing (Figure VI.5), was scheduled for 2004.

The proposed alignment of the road skirts the mangrove, hugging the coastline at the foot of the steeper slopes (see photo).

Most of the proposed road is 7 to 10 m above mean sea level, with the lowest point about 4 m above mean sea level. On the inland, steeper side of the road, small drainages require that provision be made for handling peak runoff flows so as to prevent damage to the road and associated infrastructure.

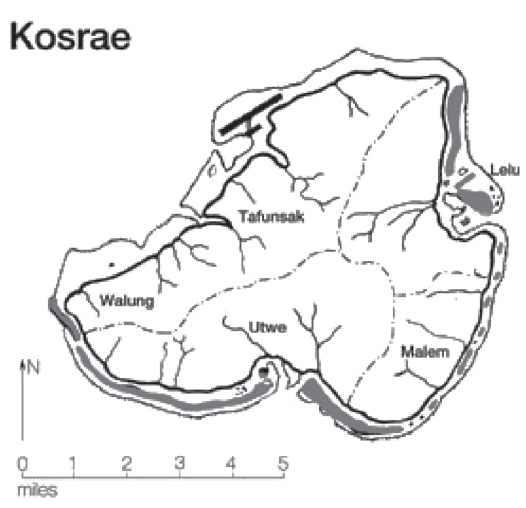
The primary purpose of the project is to complete the road around the island of Kosrae and provide all-weather land access to the remote village of Walung (population 230) in the southwest (Figure VI.5). It is the only community without reliable links to the other municipalities. The existing coastal road

Figure VI.4. Heights above Mean Sea Level for the Avatiu-Ruatonga Study Area



Note: Heights were derived using a combination of existing spot heights based on conventional survey methods and new spot heights obtained using GPS equipment.
Source: CCAIRR findings.

Figure VI.5. Kosrae's Circumferential Road



Note: The portion of the road that is still to be Completed (RS4) will run along the northwest coast of the island, from Tafunsak to just north of Walung. A possible alignment is shown in red in the right hand image. The Yela Valley is indicated by a red oval in the left hand map.
Source: CCAIRR findings.

The Yela Valley. The proposed road alignment is either through the mangrove (foreground), across the berm, through the *ka (Terminalia carolinensis)* swamp, or around the valley rim (background).

currently covers about two thirds of the island's circumference.

Completion of this link will also allow easier access at the present undeveloped interior of the island along the western coast, providing scope for agriculture and new settlement in the area. At present, the timing and extent of future development along the western coast due to the new road is extremely uncertain. Development is unlikely to be significant along the road segment under study, but the plans are to construct power lines to join Walung to the existing electricity distribution system from two directions along the new route. This will convert the present "radial" configuration of the power distribution system in Kosrae to a more reliable ring-main, with benefits for the whole island.

Three major issues are connected to the climate-related risks to completion and maintenance of the circumferential road in Kosrae:

- determining the hydraulic design features for the road up to, and beyond, the Yela Valley crossing;
- choosing among the options for routing across the Yela Valley, of which there are currently five; and
- determining the hydraulic design features for each of the above options.

The choice of a route across the Yela is problematic, due to the need to traverse or circumnavigate a large freshwater swamp that is dominated by *Terminalia carolinensis* (locally known as *ka*) and flooded by the Yela River. The Yela ka swamp is officially designated as an Area of Biological Significance.

The Yela watershed is the largest and perhaps the most valuable intact landscape remaining in Kosrae. With the largest remaining stand of *T. carolinensis* in the world, the natural beauty of the wild and undisturbed wetland attracts tourists, even if seeing it requires hiking for some distance from the ends of the existing roads.

Stakeholder consultations resulted in the decision to focus on the first of the above three issues, with some consideration being given to the climatic implications for the choice of options across the Yela, though not in detail. Some initial assessments are included in Table VI.2.

Yela Valley: portion of the Stand of *Terminalia carolinensis, or* ka.

While the third issue was potentially an appropriate focus for the case study, it was decided that including it was not practicable. The decision as to which, if any, route option would be pursued may not be reached in the foreseeable future. Subsequent to that decision, and in compliance with government requirements, an environmental impact statement and a detailed design will have to be prepared.

Thus this climate proofing case study relates only to the 9.8-km portion of RS4 that lies north of the Yela Valley. The as yet unbuilt portion is 6.6 km in length. The remainder (3.2 km) has already been constructed, with drainage works designed for an hourly rainfall of 178 mm.

Climate change scenarios were used to develop projections of how the likelihood of extreme rainfall events might change in the future. Projections used the Hadley Centre (United Kingdom) global climate model (GCM), with best judgement of model sensitivity, as this gave results intermediate between those provided by three other GCMs, namely those developed by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), Japan's National Institute for Environmental Science (NIES), and the Canadian Climate Centre (CCC) (see Appendix 1). Similarly, the SRES A1B greenhouse gas emission scenario was used when preparing the rainfall projections, as this scenario is close to the middle of the envelope of projected emissions and greenhouse gas concentrations.

Table VI.2. Implications of Possible Changes in Future Climatic Risks for Options for the Location and Design of the Road through the Yela Basin

Location of Road	Sea-Level Rise	Increase in Rainfall
No road across Yela	Allow ecosystems (mangrove and *ka* swamp) to migrate naturally in concert with inundation and salinity changes.	None
Through the mangrove swamp	Roadbed and culvert freeboard should be increased to accommodate risk of extreme high sea-level events, thus increasing fill and cost.	Bridgehead freeboard should be increased to accommodate risk of extreme high rainfall and flow events, thus increasing cost.
Across the berm	"Hardening" the berm could create a permanent barrier and prevent berm and mangrove from naturally migrating as a result of rising sea level.	Culvert numbers and/or sizes should be increased to accommodate higher peak flows and bridgehead heights should be higher, thus increasing cost.
Through the *ka* swamp	Increased backwater effects from higher sea level, which have implications for culvert, bridge, and roadbed heights	Culvert numbers and/or sizes should be increased to accommodate higher peak flows and bridgehead heights should be higher, thus increasing cost.
Around the rim	None	Increased risks of flood damage and scouring associated with higher flow and velocity from increased runoff

Source: CCAIRR findings.

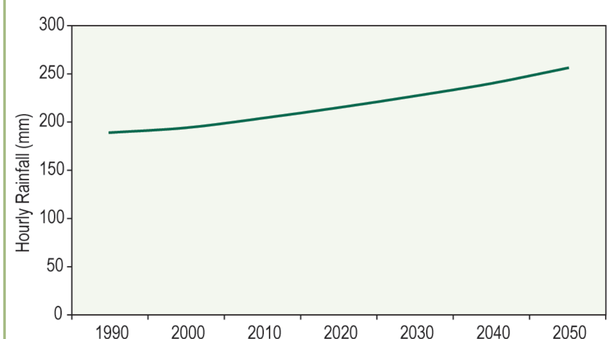
As noted, the drainage works for the original road design (both built and yet-to-be-built sections) were based on an hourly rainfall of 178 mm. This value was thought to have a recurrence interval of 25 years, but was derived using hourly rainfall data for Washington, DC, USA, since no hourly rainfall data exist for Kosrae. The observed data were adjusted subjectively to approximate Kosrae conditions.

The current case study used hourly rainfall data for Pohnpei, adjusted by the ratio of the mean annual rainfalls for Kosrae and Pohnpei. On the basis of these data, an hourly rainfall of 178 mm has a recurrence interval of 23 years.

The design rainfall was intended to be the hourly rainfall with a return period of 25 years. For present conditions this is 190 mm. But Figure VI.6 reveals that by 2050 the hourly rainfall with a 25-year return period will have increased to 254 mm.

A recommendation was made to the Kosrae state government that the design of the road be modified so the drainage works can accommodate an hourly rainfall of 254 mm. This recommendation was accepted, and a climate-proofed design was prepared and costed.

Figure VI.6. Hourly Rainfall (mm) with a Return Period of 25 Years, Kosrae



mm = millimeters.
Source: CCAIRR findings.

Table VI.3. Construction Costs for the As Yet Unbuilt 6.6-km Section of RS4 (2004 $)

	Original Design	Climate Proofed Design
Road Surface	1,254,000	1,254,000
Drainage Works	640,000	1,151,000
Total	1,895,000	2,406,000
Incremental Cost		511,000

Source: CCAIRR findings.

Table VI.4. Total Construction, Maintenance, and Repair Costs of the As Yet Unbuilt Sectionof RS4 (2004 $)

	Original Design	Climate Proofed Design	Net Benefit of climate proofing
No climate change	4,475,000		
With climate change	7,803,000	4,986,000	2,817,000
Internal Rate of Return			11%

Note: Net present values ($) over 50 years, with discount rate of 3%

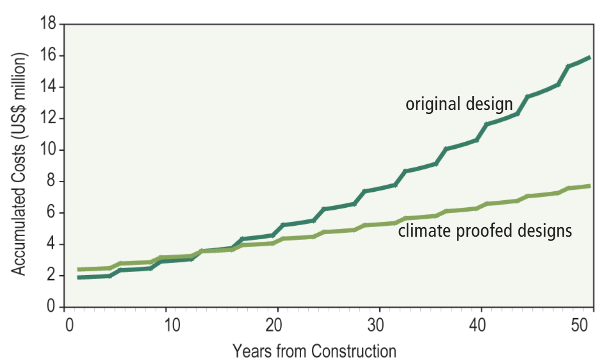
Source: CCAIRR findings.

The results shown in Table VI.3 indicate that the incremental cost of climate proofing the road design and construction for the as yet unbuilt section is in the vicinity of $500,000.

A cost-benefit analysis of climate proofing the road took into account the following when determining the net present values and internal rate of return shown in Table VI.4:

- construction costs (with and without climate proofing);
- maintenance costs over 50 years (with and without climate proofing); and
- a discount rate of 3%, to allow for differing importance attached to current and future investments (the choice of discount rate is discussed in Chapter VIII.

Figure VI.7. Accumulated Costs (Construction, Repairs, and Maintenance) for the As Yet Unbuilt Section of RS4



Source: CCAIRR findings.

Figure VI.7 illustrates the above results. While the capital cost of the climate-proofed road will be higher than if the road were constructed to the original design, the accumulated costs, including repairs and maintenance, will be lower after only about 15 years. This is because the repair and maintenance costs for the climate-proofed road will be lower.

As noted above, a 3.2-km portion of RS4 has already been constructed, including the drainage works. The design for these was based on an hourly rainfall of 178 mm for a 25-year recurrence interval. It is informative to consider the cost of retroactively climate proofing this section of road (i.e., using a design rainfall of 254 mm). The results are presented in Table VI.5.

The information presented in Tables VI.3 and VI.5 show that it is more costly to climate proof retroactively: $776,184 for a 3.2-km section of existing road ($243,000 per km) as opposed to $511,000 to climate proof 6.6 km of new road ($77,000 per km).

A cost-benefit analysis (Table VI.6) reveals that even the retroactive climate proofing is still a cost-effective investment, with an internal rate of return of 13%.

The governments of the FSM and the state of Kosrae were informed of these findings, as well as of possible funding options for climate proofing the as yet unbuilt section of road. The options included

- not climate proofing the road, since:
  - more important investments may have to be made (e.g., in health care),
  - the climate may not change in the way that is projected, and
  - an extreme event (e.g., hourly rainfall of 178 mm) can happen at any time; it is only possible to consider average recurrence intervals;
- using internal funds—i.e. from the state budget;
- using national funds;
- using Compact II funds on the basis that the true ("most likely") costs of the project have increased;
- seeking additional funding from international aid provider agencies such as
  - the Global Environment Facility (GEF);
  - multilateral financial institutions (e.g., ADB);
  - bilateral donors (e.g., Government of Canada); and
  - public-private partnerships, possibly including a road toll.

Table VI.5. Construction Costs of 3.2-km Built Section of RS4 (2004 $)

	As Built	Climate Proofed Design
Road Surface	518,000	
Drainage Works	406,000	776,000
Total	924,000	
Incremental Cost		776,000

Source: CCAIRR findings.

Table VI.6: Total Construction, Maintenance, and Repair Costs of 3.2-km Built Section of RS4 (2004 $)

	Original Design	Climate Proofed Design	Net Benefit of Climate Proofing
No climate change	3,504,000		
With climate change	6,833,000	3,875,000	2,958,000
Internal Rate of Return			13%

Note: Net present values ($) over 50 years, with discount rate of 3%
Source: CCAIRR findings.

The last option is a possibility, since the high ecological value of the Yela Valley might encourage a philanthropic organization to fund the additional construction costs required to ensure that the road is climate proofed, and in addition is not going to place valuable ecosystems at risk.

Based on the information available to it, the Kosrae state government decided it would not proceed with construction of the section of RS4 north of the Yela valley until additional funds were available to complete the climate proofing.

At the final Tripartite Meeting that reviewed the case studies, it was agreed to ask ADB to assist in securing funding for the incremental costs for climate proofing the road that is yet to be built. As a result, both the national and Kosrae state governments have written to ADB requesting such assistance.

At the time of writing, support was growing for developing a proposal to the GEF for funding the incremental costs of completing the entire RS4, some 16 km of road. In addition to climate proofing the road, GEF would be asked to meet the incremental costs of "biodiversity proofing" it, including ensuring the continued protection of the valued ecosystems in the Yela Valley. Prior to commencing construction, all the environmental and other approvals required by the State of Kosrae would, of course, have to be in place.

Information on GEF funding of adaptation projects is provided in Chapter VII, "Key Findings and Their Implications."

E. Case Study Two: Climate Proofing the Design of the Breakwater for the Newly Developed Western Basin, Avatiu Harbor, Rarotonga

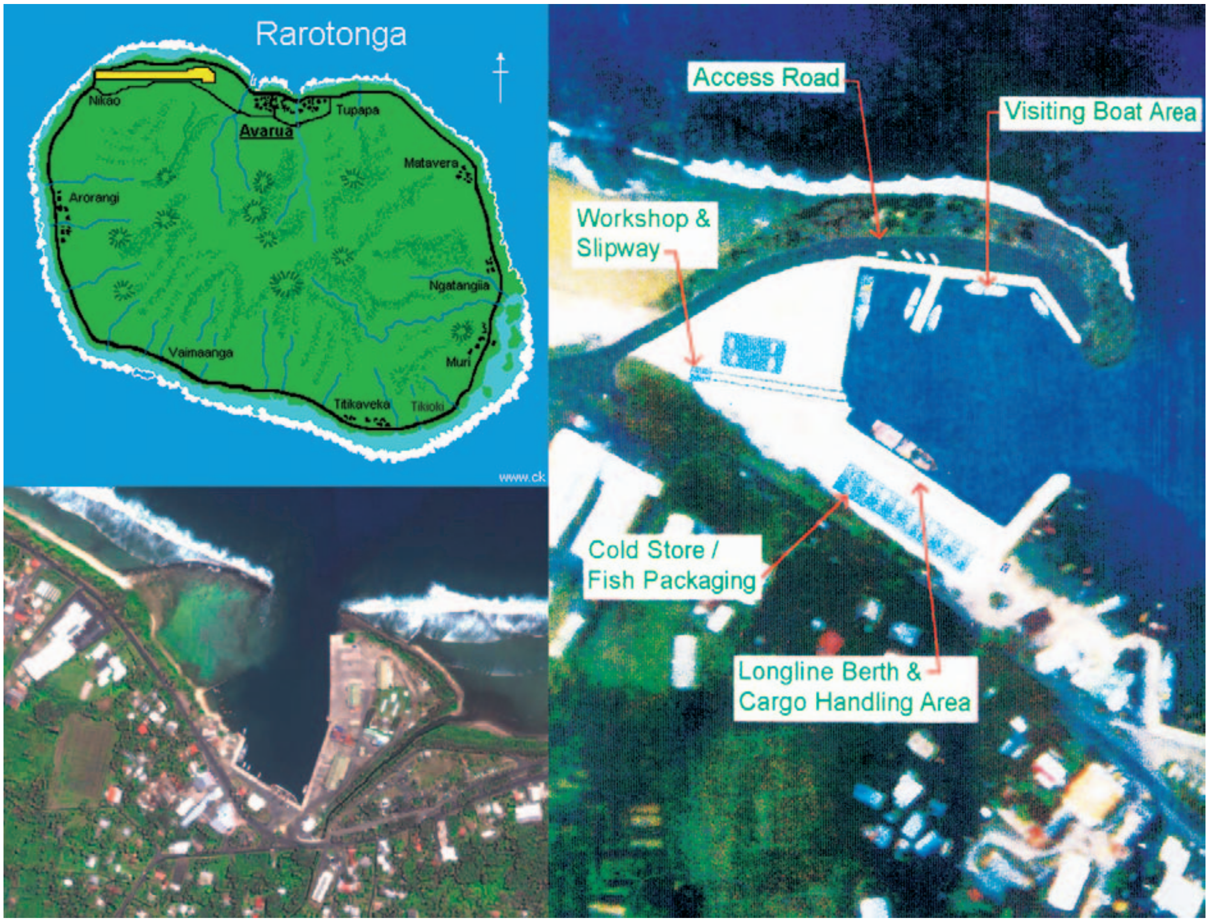
The domestic tuna industry is becoming a key export earner for the Cook Islands. The number of commercial fishing vessels increased from three in 2001 to 17 in 2002 and 44 in 2003. This and future expansion of the long-line fishing industry is constrained by a lack of appropriate infrastructure, and in particular by lack of berth space and other facilities within Avatiu Harbor. The Cook Islands Ports Authority is in the process of developing the Western Basin to accommodate extra vessels, provide sufficient wharf space to minimize delays in offloading fresh fish, and allow the fishing vessels to use the harbor in most sea conditions other than those associated with cyclones.

As shown in Figure VI.8, the Western Basin is adjacent to, and directly west of, the existing Avatiu Harbor. It is on an existing area of reclamation on the reef flat, approximately 100 m wide. In the 1980s, construction of a western breakwater was undertaken, but had not been completed by 1987, when Cyclone Sally occurred. The incomplete breakwater was damaged, in part because of the absence of a planned lining of armored basalt boulders. The internal components of the breakwater were stripped and spread over the reef flat.

The three major components of the current development are excavation of the harbor basin in the tidal reef flat; reconstruction of the western breakwater; and development of facilities including wharves, quays, and ancillary services. The harbor basin is being formed by blasting and excavating the reef down to a nominal 4 m below mean sea level, and by reconstructing a breakwater approximately 350 m long and 20 m back from and parallel to the reef edge. The Basin is intended to be usable by fishing boats and yachts in all southeasterly trade wind and swell conditions. The Basin is not designed to be operable during cyclone conditions. In such circumstances, all small vessels will be hauled ashore and moved inland while all larger vessels will be put to sea.

The design brief for the Western Basin states that the breakwater and quay walls should be designed for a nominal design life of 60 years. Fixtures should be robust enough to withstand a cyclone with a 10-year return period, though the brief acknowledges that any fixture that suffers a direct hit by a boulder or coral head carried in a storm wave during a sea surge is likely to be damaged. When Cyclones Val and Sally impacted Rarotonga, seven-ton rocks were picked up by storm waves and became projectiles, causing damage inland. The brief acknowledges that fixtures will sustain severe damage in a cyclone with a 50-year recurrence interval. It goes on to say that the main quay should be designed to withstand, with only

Figure VI.8. Location of, and Plan for, the Western Basin of Avatiu Harbor



minimal damage, the wave forces associated with a cyclone with a 50-year return period. Cyclone wave heights should be based on a 50-year return period, a calculated significant wave height of 10.75 m (10th percentile wave heights of 13.65 m).

A solid breakwater such as a rock revetment is considered unsuitable for the Western Basin breakwater because of the likely disruption to longshore movement, meaning that during a sea surge the previous wave cannot escape, causing an additional setup to the level of the top of the breakwater, potentially causing serious damage. In order to ensure that this additional setup does not occur, the breakwater must be sufficiently permeable to ensure that the previous wave can flow away, restoring the water level. More suitable alternatives are a monolithic breakwater with a degree of permeability that allows secondary routes for seawater to escape from the harbor, or concrete armor units such as "coastal protection energy dissipators" (COPEDs), or tetrapods.

The Western Basin is being developed in stages, based on demand and commensurate with development of the fishing industry and availability of funding. The first stage, involving an expenditure of NZ$1 million sourced through a government grant, overseas aid grant, cash reserves, and a loan, was for a wharf facility without added protection against storms over what is provided by an existing breakwater. Even this level of protection, however, is considered to be considerably greater than that provided to boats moored in Avatiu Harbor.

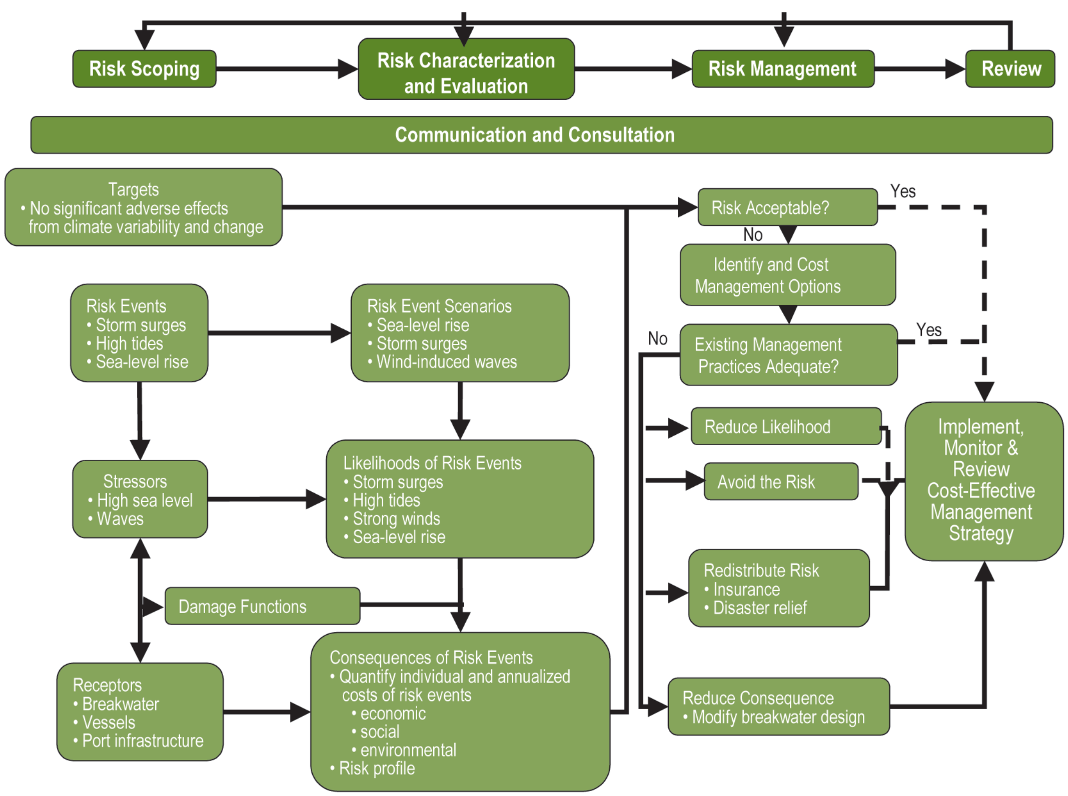
A separate feasibility study is being undertaken by parties not involved in the present case study. The feasibility study relates to the design and construction of a permanent breakwater system for the Western Basin.

Had the feasibility study proceeded as originally planned, the risk characterization and management procedures shown in Figure VI.9 would have been used in the Western Basin breakwater case study. As shown in that diagram, the following were to be the principal steps:

- determine design water level and waves (wave height, period, and incident direction), taking into account climate change scenarios, sea-level rise and the implications for extreme events, including likely changes in their frequency and magnitude;
- calculate wave transformation from offshore (deep water) to the breakwater and harbor;
- determine conditions for wave run-up on the breakwater side and wave over-topping;
- identify design options that will reduce risks (including those to breakwater, vessels, and port infrastructure) to acceptable levels, including
  - ❑ height and cross-section of breakwater, and
  - ❑ configurations and weight of armor blocks that will be resistant to wave forces; and
- calculate the costs and benefits for each design option, including incremental costs and benefits associated with taking into account the climate change scenarios.

Regrettably the companion feasibility study was delayed, so that the present case study involves only the first of the above steps.

Figure VI.9. Planned Risk Characterization and Management Procedures for the Western Basin Breakwater Study



Source: CAIIRR findings.

Figure VI.10 illustrates the linkages between climate change, tropical cyclones, coastal impacts, and decision information for risk designs. The black parts refer to the cyclone-generated sea conditions, the blue parts to the components of elevated sea level and runup that impact coastal areas, the yellow parts to the key parameters of climate change that affect those relationships, and the orange parts to the major inputs to risk design for adaptation.

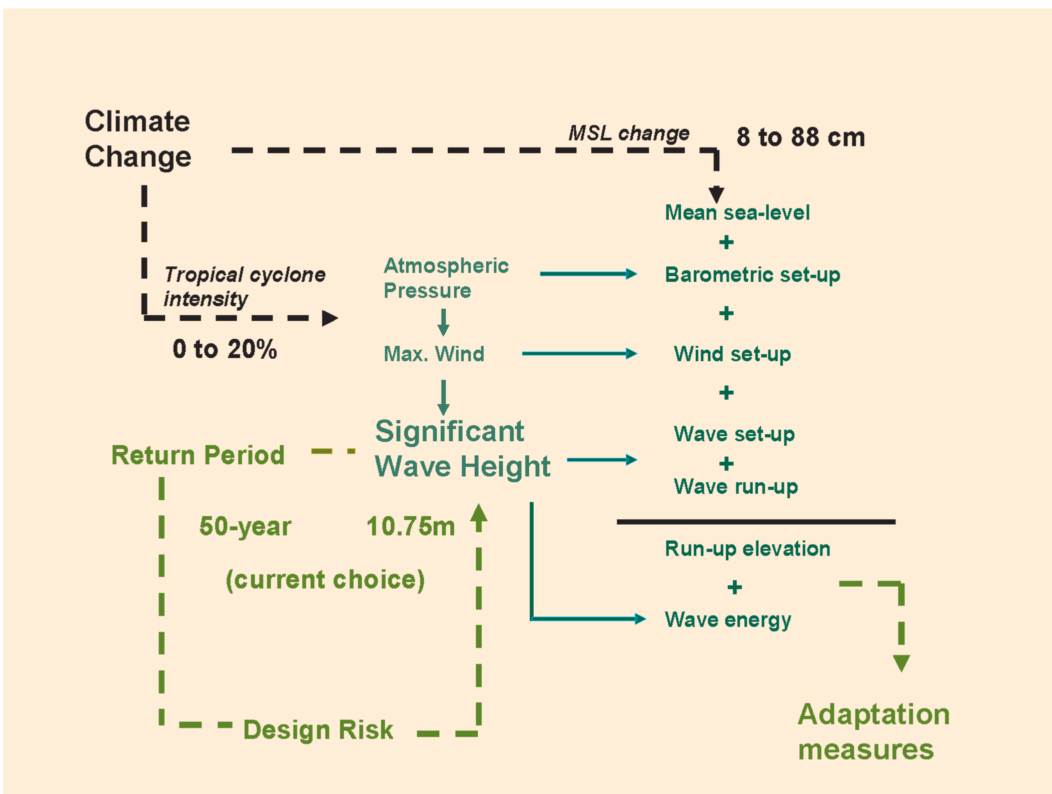
For the Western Basin breakwater, the challenge was to provide assessments of possible future changes in i) cyclone intensity, as translated to changes in significant wave height, H_S; and ii) mean sea level, as a component of change in total water elevations during cyclones. As suggested by Figure VI.10, these changes would provide input for climate proofing the design of the breakwater.

As shown below, the resulting calculations built on the substantial foundation of past engineering reports related to coastal protection in the study area.

Changes in Significant Wave Height

The relationship between maximum wind speed and significant wave height for a given return period was determined using past studies of tropical cyclone risks for the study area. The results are shown in Table VI.7. In this table the relationship between maximum cyclone wind speed (in m s^{-1})

Figure VI.10. Linkages Among Climate Change, Tropical Cyclones, Coastal Impacts, and Adaptation Measures



Main Components: Black Lettering = cyclone-generated sea conditions; Dark green lettering = elevated sea levels and run-up that impact coastal areas; green lettering = key parameters of climate change that affect those relationships; and orange lettering = major inputs to risk design for adaptation.

Source: CAIIRR findings.

and return period (years) is based on the work of Kirk (1992), who developed the following relationship:

$$U^{1.899} = 1{,}456.265 + 2{,}046.05 \text{ Log } Y$$

The relationship is based on the observational record and presumably represents "current" climate. As previously noted, however, the historical record suggests that the frequency and intensity of cyclones in the vicinity of Rarotonga are increasing.

Table VI.7. Relationship Between Wind Speed and Significant Wave Height for Given Return Periods for the Avatiu Harbour Area

Return Period (years)	Climate Proofed Design	
	Wind speed (ms^{-1})	Wave Height, Hs (m)
2	28.5	2.34
5	33.9	5.54
10	37.5	7.37
13	38.8	8.10
25	41.9	9.40
50	44.9	10.75
100	47.8	11.98

Source: JICA 1994.

For the present study, consideration was given to the impacts of global warming on changes in cyclone intensity and, hence, significant wave heights. The literature is equivocal regarding the way in which global warming will affect cyclone frequency and intensity. Various methods and studies yield different answers, but with some indication that changes in intensity could be region specific. Nonetheless, a major review conducted by a panel of the world's leading experts on the subject concluded that tropical cyclone intensities (as measured by maximum cyclone wind speed) are apt to increase as a result of global warming (Henderson-Sellers et al. 1998). This view was confirmed in the most recent Intergovernmental Panel on Climate Change (IPCC) assessment report (Giorgi and Hewitson 2001).

For the present case study, two methods were used to generate time-dependent scenarios of wind– speed change. The first related a change in wind speed to the corresponding degree of global warming, subsequently scaling this ratio by the time-dependent projection of global temperature change, viz.:

$$\triangle U_{t-1990} = (\triangle U_{2x} / \triangle T_{2x}).*.\triangle U_{t-1990}$$

where

t = future year of the scenario,
$\triangle U$ = wind speed change ($m\ s^{-1}$),
$\triangle T$ = global mean temperature change,
$\triangle T_{2x}$ = global temperature change under equivalent doubling of atmospheric CO_2, and
$\triangle U_{2x}$ = wind speed change under equivalent doubling of atmospheric CO_2.

In order to generate a maximum cyclone wind speed for some future time t, the observed wind speed was perturbed by this change, viz:

$$U_t = \triangle U_t * U_{obs}$$

where

U_{obs} is the observed maximum cyclone wind speed.

To implement this method, a value for $\triangle U_{2x} / \triangle T_{2x}$ was required. Henderson-Sellers et al. (1998) estimate an increase of 10–20% in cyclone intensity based on maximum potential intensity models, but unfortunately do not provide an indication of the corresponding global temperature change. IPCC (Giorgi and Hewitson, 2001) estimates 5–10%, but again fail to give a corresponding global temperature change. In reviewing the literature, Lal (2002) concludes that cyclone intensities are projected to increase by 10–20% for a 2–4° increase in sea-surface temperature.

In light of these findings, a range of 2.5–10% increase in cyclone intensity per degree of warming was used to implement the first of the two methods. This information was incorporated into SimClim as three options for cyclone intensity change (low, mid, and high), as were the relationships between maximum cyclone wind speed, significant wave height, and return periods based on observational data. The options were linked to the SimClim scenario generator. Using SimClim, the following parameter values were selected to create the scenario for the future change in significant wave height:

- future year: 2065 (in keeping with the specifications that the breakwater should be have a 60-year design life and assuming construction in 2005);
- cyclone intensity change per degree of global warming: mid-range value;
- emission scenario: SRES A2;
- climate sensitivity: best judgment; and
- risk design: 50-year return period (in keeping with the given specifications).

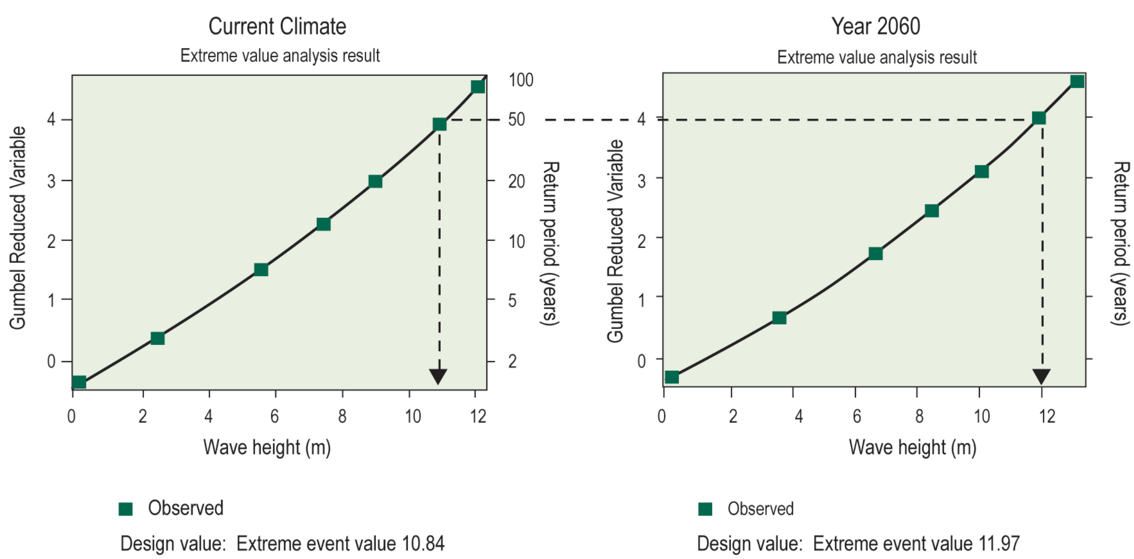
The results are presented in Figure VI.11. Under current climate conditions, the 50-year significant wave height is estimated to be about 10.8 m. Under the climate projected for the year 2060, the 50-year significant wave height increases to about 12.0 m.

The second method was based on daily maximum wind speed for the GCM grid that includes Rarotonga, as estimated by the Canada Climate Modelling Centre GCM2, using the A2 emission scenario and best judgment of model sensitivity.

While the GCM data show changes in the maximum wind speed over time (1961–2100), spatial smoothing of the data means that the values underestimate the extreme wind speed at a specific location. Consequently, the GCM output was scaled so that the maximum speed estimated for the 1972–1998 period (16.7 m s^{-1}) coincided with the maximum gust observed over the same period at Rarotonga (42.4 m s^{-1}). While land-based measurements of wind speed will normally underestimate the wind speed in the adjacent open waters, no further adjustment to the data was made due to the fact that the tropical cyclone generating the maximum wind gust of 42.4 m s^{-1} passed directly over Rarotonga. Moreover, the wind gauge that measured this gust is in a very exposed location only a few meters from the coast of the island towards which the cyclone tracked.

Table VI.8 presents the same information as Table VI.7, but also includes the return periods based on an analysis of the observed maximum hourly wind gust data and the adjusted GCM wind speed data.

Figure VI.11. Results of Significant Wave Height Calculations, Using SimClim



Source: CCAIRR findings.

Table VI.8. Estimates of Return Periods for Given Wind Speeds

Wind Speed (m/sec)	Return Period (yr)				
	Kirk (1992)	Observed (1972–1998)	GCM Based Maximum Wind Speed Data		
			1961–1990	1991–2020	2021–2050
28.5	2	2	1	1	1
33.9	5	5	2	2	2
37.5	10	11	3	4	4
38.8	13	14	5	5	6
41.9	25	29	18	16	14
44.9	50	57	60	45	31
47.8	100	113	120	95	64

GCM = global climate model.

Sources: Kirk and Dorrell 1992, CCAIRR findings.

Strong agreement can be seen between the return period estimates of Kirk and those based on observed data (even though they are not necessarily cyclone-related), suggesting that the Rarotonga anemometer provides extreme gust estimates that are reasonably representative of open water conditions. Comparison of the return period estimates for the 1961–1990 GCM data with the observed data also reveals good agreement, though the GCM data tend to show slightly shorter return periods for lower extreme wind speeds and slightly longer return periods for higher extreme wind speeds.

Arguably the most important finding arising from this analysis is the suggestion that over the coming 50 years or so the return periods for the most extreme wind speeds will shorten significantly, by approximately half by 2050.

Sea-Level Change

Regardless of the method used to estimate the current and projected significant wave heights with a 50-year return period, the risk of damage to the breakwater in the future will also be influenced by changes in mean sea level. The following method was used to estimate the change in sea level as a consequence of global warming.

$$\triangle Z_{i,t\text{-}1990} = \left[\frac{\triangle Z_{g,\,t\text{-}1990} \ \mathrm{x} \ \triangle Z_{r,\,t\text{-}1990}}{\square Z_{2x}} \right] + Z_{nc,\,t\text{-}1990}$$

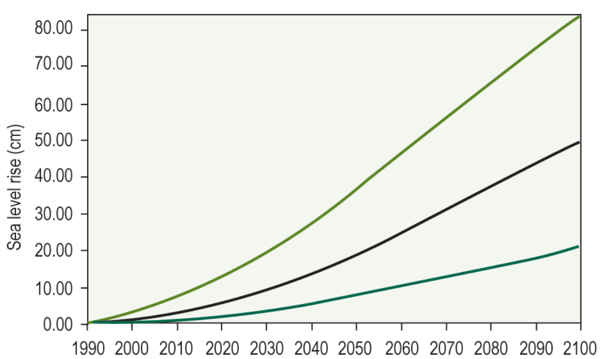
where

- $\triangle Z_{i,t\text{-}1990}$ is the projected sea level change (in cm) at location i, from 1990 to future year t;
- $\triangle Z_{g,\,t\text{-}1990}$ is the change in global mean sea level (in cm) as projected by simpler climate models for a given emissions scenario and, as reported, for example, in IPCC (2001);
- $\triangle Z_{r,\,t\text{-}1990}$ is the change in regional sea level (in mm) pertaining to location i, as projected by a GCM;
- $\square Z_{2x}$ is the global mean sea-level change (in mm) for an equivalent doubling of atmospheric carbon dioxide concentration (or, for transient runs of GCMs, the global mean value as averaged over the last several decades of the GCM simulation); and
- $Z_{nc,\,t\text{-}1990}$ is the local, nonclimate-related change in sea level, usually due to vertical land movements that affect relative sea level.

The above calculations were undertaken using SimClim. The sea level projections include both a regional component based on the Canadian GCM results and a local component based on trends in mean sea level as estimated from tide gauge data. After accounting for the climate-related rise, a local trend of about 1.7 mm yr^{-1} seems to be observed, most probably related to vertical land movement.

The resulting projections of sea-level rise, based on the SRES A2 scenario, are shown in Figure VI.12. For this scenario, by the year 2060 mean sea level is projected to be 50 to 80 cm higher than today.

Figure VI.12. Projected Values of Sea-level Rise for Rarotonga, Relative to the Current Mean Sea Level



Note: Green, orange, and blue lines show estimates for high, best judgment and low levels of model sensitivity, respectively.

Source: CCAIRR findings.

In summary, when climate proofing the design of a breakwater, two of the key considerations are (i) how global warming will affect changes in cyclone intensity and frequency (and hence changes in the return periods of design wind speeds and of significant wave heights), and (ii) mean sea-level change. An example of the design calculations that are dependent on such estimates is given in Table VI.9.

The brief for the development of the Western Basin indicates that the breakwater should be designed for a nominal design life of 60 years. Given this specified design life, the preceding projections of return periods for extreme winds (and hence significant wave heights), and of sea-level rise, the breakwater design should be based on a significant wave height of at least 12 m and allow for a sea-level rise of at least 0.5 m.

Table VI.9
Estimated Wave Run-up Elevation for Conditions Representative of Cyclone Sally for a Coastal Segment Adjacent to Avatiu Harbor, with Future Sea-level Rise Added (Current Return Period of Approximately 13 Years)

	Elevation (m)
Significant Wave Height	8.1
Tide	0.4
Barometric Effect	0.3
Wind Set-Up	0.16
Wave Set-Up	1.35
Surf Beat	0.7
Wave Height and Run-Up Height	2.99
Sea-Level Rise	0.5
Total Run-up Elevation	**6.4**
Rate of Overtopping (tons per minute)	*2,500*

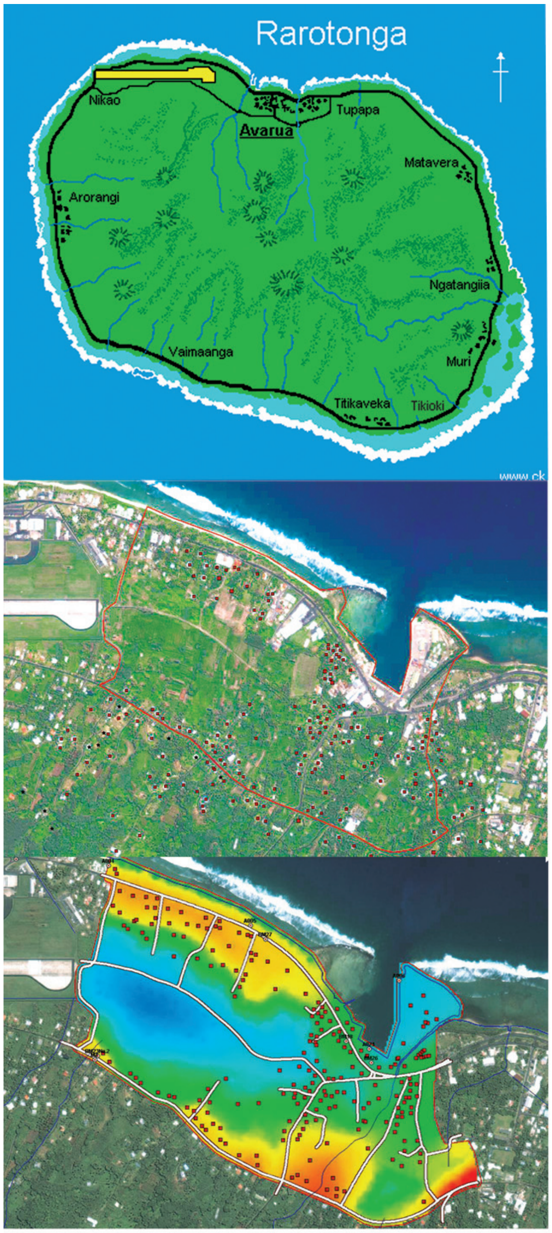
Source: JICA 1994 and Dorrell (personal communication).

F. Case Study Three: Climate Proofing Avatiu-Ruatonga, a community inland from Avatiu Harbor, Cook Islands

The community of Avatiu-Ruatonga is located on the northern coast of Rarotonga, between the national capital of Avarua and the international airport. The main port for the Cook Islands is located within the study area. Figure VI.13 shows the location of the study area, land elevations, and locations of residential commercial and other structures.

Except in the vicinity of Avatiu Harbour, the land consists of a narrow coastal reef flat and a narrow beach ridge (elevation 3–4 m). Behind the beach ridge is lower-lying land, much of which is swamp, and part of which is used to grow taro. At the southern boundary of the study area the land begins to rise steeply; in the southeastern portion of the study area elevations are already above 9 m. The land further to the south forms the steep catchments of the streams that flow into the study area and discharge into the ocean just to the east of Avatiu Harbour.

Figure VI.13: Location of the Avatiu-Ruatonga Study Area, showing (Lower Figure) Land Elevations and Locations of the 221 Structures



Source: CCAIRR findings.

The resident population of 396 occupies 127 dwellings. In addition, there are 9 unoccupied dwellings, 64 commercial buildings, 10 community buildings, and 6 storage facilities. Government buildings are three in number and joint government-commercial two. There are several bulk liquid storage tanks. Collectively, all structures have an estimated replacement value of NZ$47,750,000.

Most of these structures are located on higher land, the exceptions being the port buildings and the predominantly residential buildings located inland from the harbor. Some of the latter are built on land with elevations at or just below sea level. Many of these structures, and others in adjacent low-lying areas, are flooded as a result of heavy rainfall events and/or high sea levels. The latter are usually related to storm surge events, which also damage structures at higher elevations close to the coast.

The remainder of this section will elaborate on the likelihood components of these specific risk events and subsequently describe in detail the associated consequence components, as well as the costs and benefits of implementing a number of risk reduction measures (i.e., adaptation).

Other climate-related risks identified during risk analysis were drought, strong winds, and outbreaks of infectious diseases associated with adverse weather conditions. These will be addressed as part of the third Cook Islands case study since such risks are best characterized and managed at island or national scale.

Flooding Associated with Heavy Rainfall Events

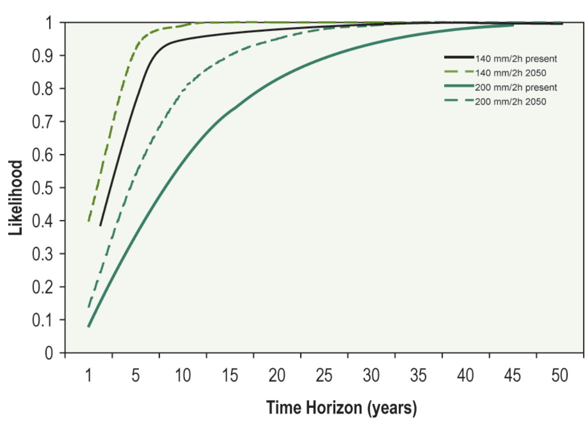
Hourly rainfall data at the Rarotonga Aero long-term weather station (located near the coast at the western end of the airport runway) for the period 1970–1979 were used to estimate the likelihood of heavy rainfall events associated with flooding in the study area. These data were adjusted to represent the rain falling over the catchments, which have a total area of 1.35 km^2. The multiplier was based on the relationship between the long-term mean rainfall at Rarotonga Aero) and that measured at a short-term monitoring site in the upper catchment. Rainfall totals over 2-hour periods were analyzed, reflecting the time of concentration for the Avatiu Stream.

Likelihoods for 2-hourly rainfall totals of 140 and 200 mm were determined for both the present and for 2050. For the latter projections the CSIRO

GCM with SRES A1B emission scenario and best judgment of model sensitivity, was used. Compared to a number of other GCMs, the CSIRO model verifies more favorably in the South Pacific region.

Figure VI.14 shows that 140 mm of rain over a 2-hour period is highly likely under current conditions and is comparatively insensitive to the global warming projected to occur over the next 50 years. Annual recurrence intervals are 3 and 2.5 years, respectively. By contrast, 200 mm of rain over a 2-hour period is at present a relatively rare event, with an annual recurrence interval of 12 years. Global warming makes a significant difference to the likelihood, especially for time horizons between 5 and 30 years. The annual recurrence interval for this scenario is 7 years.

Figure VI.14. Likelihood of Two-hour Rainfall Totals of at Least 140 mm and 200 mm for the Present and for 2050, for Given Time Horizons



mm = millimeters
Source: CCAIRR findings.

Using a combination of information from topographic maps and a digital elevation model (DEM), a basic Excel spreadsheet-based flood model was developed for the Avatiu-Ruatonga case study area. This model used the Rational Method to estimate flows in the Avatiu Stream and in two other minor streams running into the study area. The discharge capacity of the bridge under the Main Road was calculated, as well as the capacity of a 900-mm pipe that drains part of the low-lying swamp area into the harbor. The level of flooding upstream of the Main Road bridge was estimated based on the difference between stream flows and the bridge's capacity. The "storage" volume of the swamp area was calculated using the DEM data, allowing flooding levels to be estimated by calculating the volume of water discharged into this area less the estimated volume being discharged to the harbor.

Initial runoff parameters in the model were determined using recorded rainfall and stream flow data from the Avatiu site. Validation of the model was undertaken by comparing model outputs with observed flood extent and depths for the last major rainstorm to affect the area. This was on January 8, 2001. Total storm rainfall was 293.8 mm over a period of 14.5 hours. Analyses indicated that the peak two-hour intensity of this storm (the time of concentration for the catchment) has an annual recurrence interval of between 1 and 2 years, under present conditions.

The spatial extent of flooding as observed in 2001, as well as the model-based estimate of the extent of flooding resulting from an event of this magnitude, is shown in Figure VI.15. In general, a good agreement is observed across the study area.

At present, a 2-hour precipitation total of 200 mm has a return period of around 12 years. By 2050, however, the return period is projected to decrease to only 7 years. Or, stating it another way, by 2050 the 2-hour precipitation total with a return period of about 12 years is projected to be 236 mm.

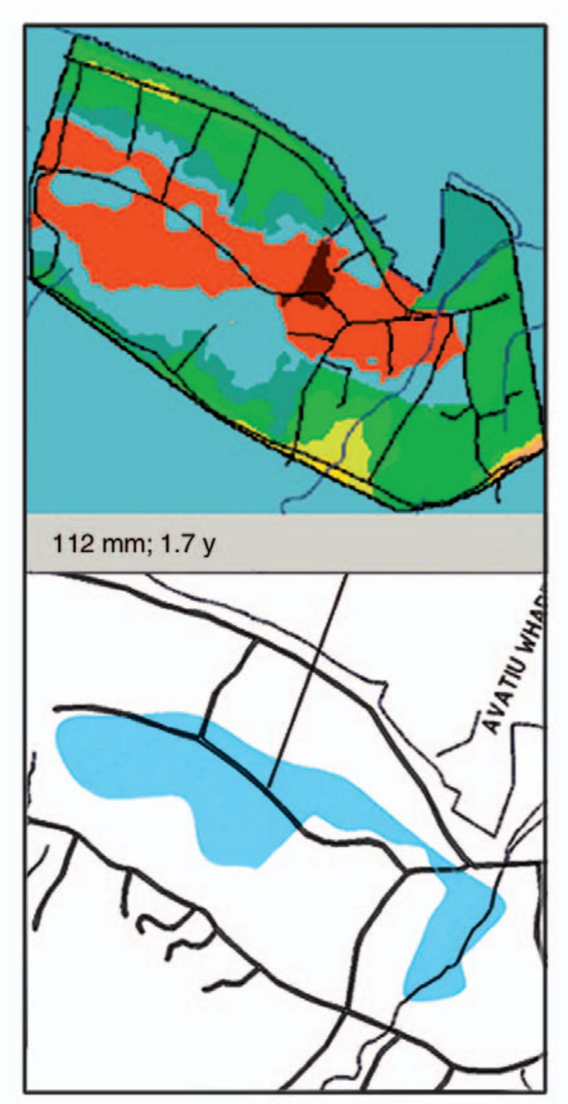
As shown in Figure VI.16, both the area flooded and the depth of flooding increase for this 236-mm event. The area flooded has increased from 355,000 m^2 to 371,000 m^2 and the maximum flood depth from 1.6 m to 1.7 m.

However, the full consequences of the increased likelihood of more frequent and intense rainstorms can be seen when the impacts of all the changes in the precipitation regime are integrated over, say, the next 50 years (Table VI.10).

It is apparent that the Avatiu-Ruatonga area is already experiencing high damage costs as a result of extreme rainfall events. These will be exacerbated by climate change, and also by an airport extension that has also been proposed, unless flood reduction measures are put in place.

The model was also used to identify the key hydraulic controls on the flooding being experienced

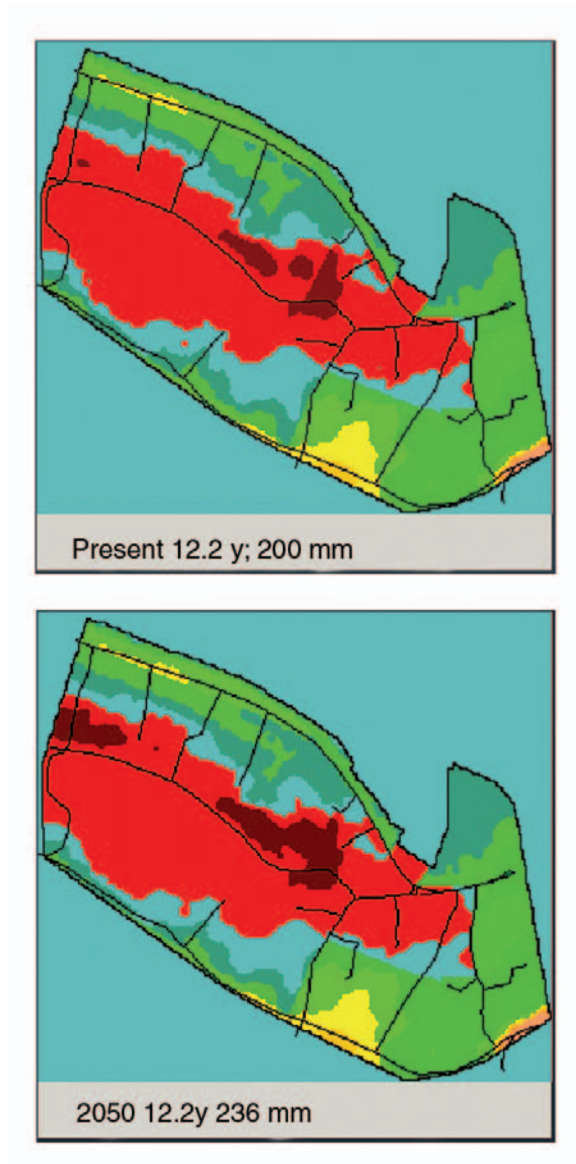
Figure VI.15. Calculated (Top) and Observed Areal Extent (Bottom) of Flooding Associated with the Rainstorm of January 8, 2001



mm = millimeters

Source: CCAIRR findings.

Figure VI.16. Flooded Areas and Depths for a 2-Hour Rainstorm with a Return Period of 12 years, for the Present and for 2050



mm = millimeters.

Note: Calculated flood depths greater than 1 m are shown in red; those less than 1 m are shown in brown.

Source: CCAIRR findings.

Table VI.10. Projected Costs of Flooding for Avatiu-Ruatonga, as a Consequence of All Heavy Rainfall Events Occurring over the Period Indicated

(NZ$ million)

	No Climate Change Discount Rate		With Climate Change Discount Rate		With Airport Extension Discount Rate	
	0%	3%	0%	3%	0%	3%
To 2050	23.77	13.04	25.52	13.72	26.94	14.77
To 2100	49.06	16.38	66.85	18.64	55.60	18.56

Note: Damage cost calculations for airport extension assume no climate change and a 75% reduction in the swamp water storage capacity.
Source: CCAIRR findings.

in Avatiu-Ruatonga. These were found to be the capacity of

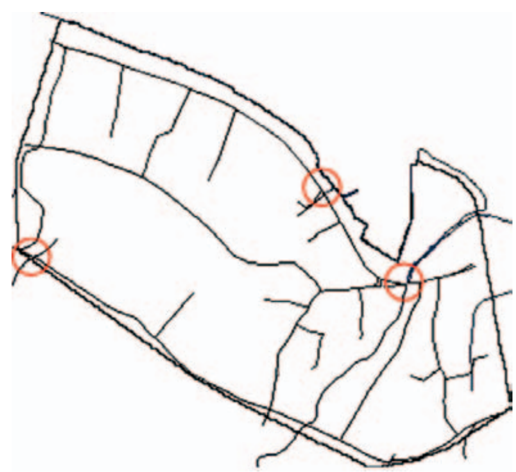
- the bridge where the Main Road crosses Avatiu Stream;
- the drain from the sports field to Avatiu Harbour; and
- the drain along the south side of the airport: when the flow exceeds the drain capacity, some runoff is diverted into the swamp in order to avoid flooding the airport runway (Figure VI.17).

Costs determined for realistic increases in the flow capacity at these control points were as follows:

- Excavate the stream bed over a distance of 150 m above and below the bridge. The cost is NZ$1,620 for every meter the stream bed is deepened and is assumed to be recurring every 3 years. Additional costs may be incurred if damage prevention is needed due to increased flow velocities when the stream is in flood.
- Increase size of the culvert between the sports field and the harbor. The cost is NZ$64,286 for a 1.2–diameter culvert and NZ$78,571 for a 1.4–diameter culvert.
- Build a larger bridge at western end of the airfield. This will increase the cross sectional area from 4.62 m to 16.8 m at a cost of NZ$140,000.

The cost effectiveness of each of these adaptation options was investigated in turn. The results are presented in Table VI.11 and show a high benefit-cost ratio for deepening the stream bed, even under present conditions. Thus this adaptation qualifies as a "no regrets" adaptation initiative.

Figure VI.17: The Study Area, showing Locations of Key Hydraulic Controls on the Flooding



Note: Left red circle: location where water is diverted into the swamp; center red circle: sports field drain; right red circle: bridge where the main road crosses Avatiu Stream.
Source: CCAIRR findings.

Another approach to reducing damage costs is to introduce changes to the building code, and to land use planning and environmental impact

Table VI.11. Benefit Cost Analysis for Reduction of Flood Damage from Heavy Rainfall, Avatiu-Ruatonga, over Next 50 Years

Adaptation Option	Reduction in Damage Costs (%)		Adaptation Cost (NZ$ million)	Benefit/Cost
	No CC	With CC		No CC
Deepen stream bed 1 m	90	82	0.014	834
Increase culvert to 1.4 m	0	0	0.098	0.58
No diversion into swamp	1	1	0.140	0.96

No CC = without climate change; with CC = With climate change. Discount rate = 3%.
Source: CCAIRR findings.

assessment regulations. These would provide that when new buildings are constructed, or existing buildings are substantially renovated, these works are required to reduce the flood risk.

Several realistic regulatory and voluntary measures were identified and their cost effectiveness assessed, including the following:

- require that the minimum floor height of new and renovated buildings be sufficient to avoid flooding for a rainfall event of a given return period;
- encourage building in areas where flood depth will be less than a given amount for a rainfall event of a given return period;
- require that all new buildings have a specified minimum floor elevation; and
- require that homeowners adapt, i.e., relocate, when the perceived risk of flooding is greater than 10%.

Table VI.12 illustrates how damage costs will be reduced over a 50-year period for examples of the application of the above measures.

For the selected scenarios, all regulatory measures appear cost effective, even under present conditions, and also qualify as no regrets adaptation initiatives.

Flooding from Sea Surge

Since the study area is also subject to coastal flooding from tropical cyclones, similar analyses were undertaken to assess damage costs associated with sea surges and the nature of interventions that would reduce the risk to an acceptable level. The last major event to hit the area was Cyclone Sally in 1987, although several more severe events occurred earlier in the 20th century.

As with the breakwater case study, the sea surge risk modeling made use of the extensive coastal engineering studies that were carried out during the 1990s in order to provide design data for coastal protection works. Table VI.13 is based on these reports, particularly JICA (1994), including the results produced by various models.

With these values, a chain of relationships—from wind speed, wave height to total water run-up elevation and their associated return periods—was established and related to the potential wave overtopping for a site with a given height for the beach ridge. Scenarios of future changes in tropical cyclone intensity enter into the chain by way of changing wind speed; changes in sea level enter into the chain by changing total wave run-up elevation. Flood depth and extent were calculated by determining the total run-up elevation and overtopping volume for a

Table VI.12. Cost and Consequent Change in Damage Costs for Selected Regulatory and Voluntary Measures, for New/Renovated Buildings Only, Over Next 50 Years

Measure	Change in Damage Costs: No Climate Change NZ$ million	Change in Damage Costs: No Climate Change %	Change in Damage Costs: With Climate Change NZ$ million	Change in Damage Costs: With Climate Change %	Direct Cost of Intervention (NZ$ million): No CC	Direct Cost of Intervention (NZ$ million): With CC
Require sufficient floor height that no flooding occurs in 25-year storm.[1]	-1.36	-10.4	-1.53	-11.1	0.34	0.42
Encourage new (relocate) building (only from aging) where flood depth <0.5 m in 25-year storm.	-0.75	-5.8	-0.66	-4.8	Nil	Nil
Require new buildings (only from aging) to have a minimum floor elevation of 1 m.	-1.35	-10.6	-1.54	-11.3	Nil	Nil
Require that homeowners relocate when flood risk is greater than 10% (and not from aging).	-0.85	-6.5	-0.88	-6.4	Nil	Nil

No CC = without climate change; with CC = With climate change. Discount rate = 3%.

[1] Adaptation cost based on NZ$500 per m^2 of floor area per m raised; only for aging properties with longevity of 50 years

Source: CCAIRR findings.

Table VI.13. Relationships Between Cyclone Parameters and Coastal Risk Parameters for a Site Representative of a Segment of the Avatiu Coastline

Return Period (yr)	Cyclone parameters				
	Wind speed (m/sec)	Wave Height, Hs (m)	R-U Elev. (m)	O-T Height (m)	O-T Vol (m^3/sec/m)
2	28.5	2.34	*1.92*	*0.00*	0.000
5	33.9	5.54	*4.54*	*0.91*	0.016
10	37.5	7.37	*6.04*	*2.41*	0.050
13	38.8	8.10	6.64	3.01	0.064
25	41.9	9.40	*7.71*	*4.08*	0.094
50	44.9	10.75	*8.81*	*5.18*	0.150
100	47.8	11.98	9.84	6.21	0.185
	Beach Height:			3.63	

Note: R-U = run-up; O-T = over-topping; O-T Vol = over-topping volume. Italicized values are interpolated from the adjacent values.

Source: JICA 1994.

cyclone with a given return period. The overtopping height was determined as the difference between run-up elevation and the height of the beach ridge. The water was distributed over the study area (downslope) with a negative exponential function, calibrated on the basis of evidence of the areal extent and depth of salt water flooding during Cyclone Sally.

Figure VI.18 shows the area and depth of flooding if a 1-in-25-year event occurred today or in 2050. The area modeled for sea surge flooding extends from the western edge of Avatiu Harbor to the eastern boundary of the larger Avatiu-Ruatonga case study area adjacent to the airport, and inland from the ocean edge.

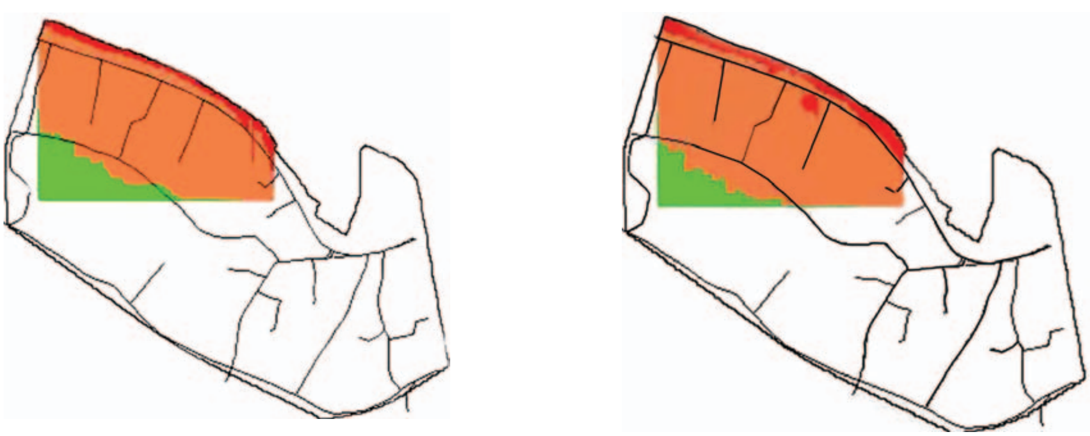
The damage costs incurred in the area modeled as a result of the ensemble of sea surge events projected to occur over a future time period can also be calculated. The method used was analogous to that used to determine the damage costs from flooding associated with heavy rainfall events occurring over a specified time period into the future.

Table VI.14 summarizes the key results of the calculations. It is apparent that sea surges are a major risk to structures, infrastructure, and other assets in the study area, and of course also to the people who reside and/or work there.

For this case study, too, several realistic regulatory and voluntary measures were identified and their cost effectiveness assessed, including the following:

- require that the minimum floor height of new and renovated buildings is sufficient to avoid flooding for a rainfall event of a given return period;
- encourage building in areas where flood depth will be less than a given amount for a rainfall event of a given return period;
- require that all new buildings have a specified minimum floor elevation; and
- require that homeowners adapt, i.e., relocate, when the perceived risk of flooding is greater than 10%.

Figure VI.18. Depth and Spatial Extent of Flooding from a Sea Surge with a Return Period of 25 years, for Current Conditions and in 2050



Left = current conditions; right = conditions in 2050.

Note: Sea-level rise projections use the Canadian GCM-1 with the A1B emission scenario, best judgment of model sensitivity, and high sensitivity to increase in cyclone intensity. Red is flooding over 5 m, brown is flooding under 5 m, and green is unflooded areas.

Source: CCAIRR findings.

Table VI.14. Projected Costs of Sea Surge Flooding of a Selected Area of Avatiu-Ruatonga
(NZ$ million)

	No Climate Change Discount Rate		With Climate Change Discount Rate	
	0%	3%	0%	3%
To 2050	56.10	30.77	78.50	40.75
To 2100	79.32	26.48	153.56	40.49

Source: CCAIRR findings.

Table VI.15 illustrates how damage costs will be reduced over 50 years, for examples where the above measures are applied. All the adaptation interventions qualify as no regrets options.

In Table VI.16 a totally unrealistic adaptation measure is used to highlight the scale of intervention that would be required to protect assets if some or all of the above regulatory and voluntary measures are not implemented. The hypothetical scenario involves building a 5-m-high sea wall at the shoreline, at a cost of NZ$5,000 per meter.

Table VI.15. Cost and Consequent Change in Damage Costs for Selected Regulatory and Voluntary Measures, for New/Renovated Buildings Only, Over Next 50 Years

Measure	Reduction in Damage Costs: No Climate Change NZ$ million	No Climate Change %	With Climate Change NZ$ million	With Climate Change %	Direct Cost of Intervention (NZ$ million) No CC	With CC
Require sufficient floor height that no flooding occurs in 25-year storm.[1]	1.22	4.0	3.11	6.9	1.12	1.20
Encourage new (relocate) building (only from aging) where flood depth <0.5 m in 25-year storm.	1.20	3.9	1.90	4.0	0	0
Require new buildings (only from aging) to have a minimum floor elevation of 1 m.	0.98	3.2	1.97	4.1	0	0
Require that homeowners relocate when flood risk is greater than 10% (and not from aging).	0.77	2.5	4.19	8.8	0	0

No CC = without climate change; With CC = with climate change. Discount rate = 3%.

[1] Adaptation cost based on NZ$500 per m^2 of floor area per m raised; only for aging properties with longevity of 50 years

Source: CCAIRR findings.

Table VI.16. Cost and Consequent Change in Damage Costs for Hypothetical Scenario, A 5 m-High Sea Wall at the Avatiu Shoreline

	No Climate Change			With Climate Change			Cost of Intervention (NZ$ million)	
	NZ$ million	%		NZ$ million	%		No CC	With CC
	20.32	66		26.92	66		0.75	0.75

No CC = without climate change, With CC = with climate change. Discount rate = 3%. Time horizon = 2050.
Note: Sea-level rise projections use CGM 1 with SRES A1B emissions scenario, best judgment of model sensitivity, and high sensitivity to cyclone intensity.
Sea wall cost = NZ$5,000 per meter length
Source: CCAIRR findings.

G. Case Study Four: Climate Proofing Sapwohn, a Coastal Community in Pohnpei, Federated States of Micronesia

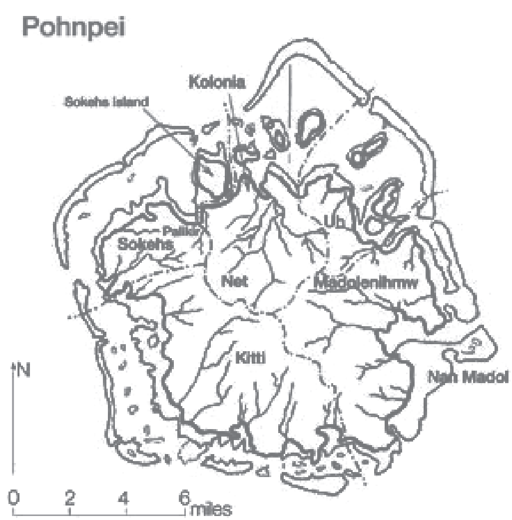
In its entirety, Sapwohn Village on Sokehs Island (Figure VI.19) has a population of 1,234, living in 259 dwellings (2000 Census). The community was established after Pingilap, an outer island of Pohnpei, was devastated by a typhoon in 1905. The "environmental refugees" were eventually relocated to Sokehs Island and allocated land that became vacant after the 1907 uprising. Most of the houses, commercial buildings (small stores), and community structures (church and *nahs* [meeting places]) are built on a narrow strip of relatively flat land that runs between the shore and the steep slopes of Sokehs Mountain.

The case study covered the area shown in Figure VI.20. The resident population of 776 occupies 144 dwellings. In addition, there are 15 unoccupied dwellings, seven commercial buildings (two are unoccupied), four combined residential and commercial buildings, four community buildings, and four *nahs* (meeting places). No government buildings are located in the study area. Collectively all structures have an estimated replacement value of $15,063,000.

At present, many structures are flooded regularly, as a result of heavy rainfall events and/or high sea levels. The remainder of this section will elaborate on the likelihood components of these specific risk events, and subsequently describe in detail the associated consequence components, as well as the costs and benefits of implementing a number of risk reduction (i.e, adaptation) measures.

Figure VI.19

Location of Sokehs Island, Pohnpei



Source: CCAIRR findings.

Other climate-related risks identified during risk analysis were drought, strong winds, and outbreaks of infectious diseases associated with abnormal weather conditions. These will be addressed as part of the third FSM case study, since such risks are best characterized and managed at island or national scale.

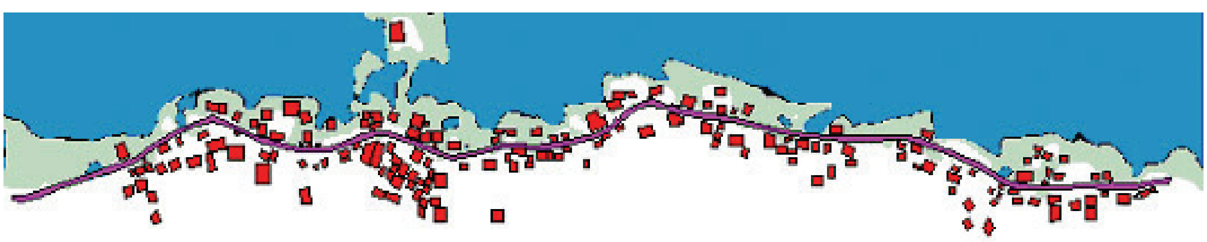
The Village of Sapwohn is located along the western shoreline of the embayment.

Climate-change scenarios were used to develop projections of how the likelihoods of extreme rainfall events might change in the future. Projections were based on the Hadley Centre (United Kingdom) GCM with best judgment of model sensitivity, as this gave results intermediate between those provided by three other GCMs, namely those developed by Australia's CSIRO, Japan's NIES, and Canadia's CCC. Similarly, the SRES A1B greenhouse gas emission scenario was used when preparing the rainfall projections, as this scenario is close to the middle of the envelope of projected emissions and greenhouse gas concentrations. For sea level, the Canadian GCM was used to develop projections. In all cases, best judgement was used for model sensitivity.

Sokehs Village is located close to the shoreline, below the steep slopes of Sokehs Mountain.

Part of Sapwohn Village, showing the short distance between the shoreline and the steep slopes of Sokehs Mountain.

Figure VI.20. The Study Area in Sapwohn Village, Showing the Location of all Structures



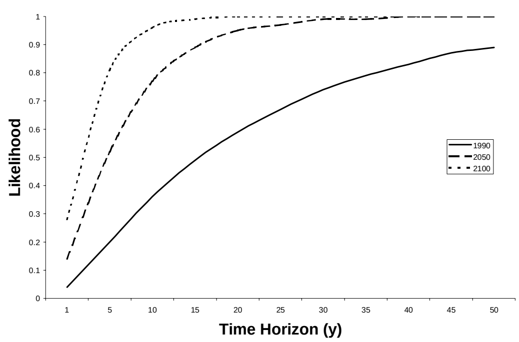
Source: CCAIRR findings.

Flooding Associated with Heavy Rainfall Events

Figure VI.21 shows the likelihood of a hourly rainfall of 200 mm occurring within a given time horizon. The likelihood of such an event will increase markedly as a result of global warming.

While some of the flooding associated with such heavy rainfall events is due to overtopping of small channels that drain the slopes of Sokehs Mountain, most is due to overland flow originating from the hill slopes above the community.

Figure VI.21. Likelihood of an Hourly Rainfall of 200 mm occurring in Pohnpei within the Indicated Time Horizon (Years)



0 = no chance; 1 = statistical certainty.

Source: CCAIRR findings.

On the basis of the study area's topography and of the lack of strong channelization of flow, an assumption was made that sheet flow occurs down the full length of the slope. The study area was divided into five subcatchments based around two "gullies." The subcatchments with gullies were allocated a greater catchment area as a reflection of the channelization that occurs with these gullies. A simple Excel-based "conceptual model" was developed, using first principles (including the Rational Method) to estimate flood depths for different segments of the study area. The estimates were based on 1-hour rainfall intensities for given return periods. The model was validated using observed flooding depths associated with a storm in October 2003.

The simple model used in the case study is based on limited information inputs and has undergone very limited ground investigation of possible hydrodynamics within the flood area. This model has been developed to assist in understanding how climate change (i.e., changing rainfall patterns) may alter flood risks, and how adaptation measures may reduce unacceptable risks. The modeling results should not be used in any way to determine or estimate precise levels or spatial extent of flooding. More detailed modeling using appropriate hydraulic and hydrodynamic models is required if location-specific flood risk estimates are to be derived.

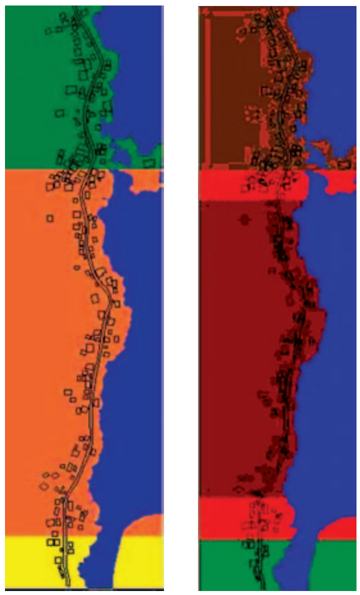
The spatial distributions of flooding for individual and ensemble rainfall events were estimated for the current climate and for scenarios of future climate. Consultations with stakeholders identified one option to reduce flood depths, namely through constructing a diversion channel above the flood area. The costs and benefits of this potential adaptation measure have been determined, and are described in detail below. The effectiveness of both regulatory and voluntary adaptation measures has also been assessed.

Figure VI.22 presents estimated depths of flooding in the case study area associated with an hourly rainfall with a return period of 25 years, for current conditions and for 2050. Under current conditions, the 25-year hourly rainfall (210 mm) results in flooding up to a depth of between 0.4 and 0.6 m for most of the area. A small area is flooded to less than 0.2 m. By 2050, the 25-year hourly rainfall is projected to increase to 393 mm. This results in a substantial increase in flood risk. Maximum flood depths will be over 1 m, with all areas being flooded to at least 0.2 m.

However, the full consequences of the increased likelihood of more frequent and intense rainstorms can be seen when the impacts of all the changes in the precipitation regime are integrated over, say, the next 50 years (Table VI.17).

While the area is already experiencing high damage costs as a result of extreme rainfall events, it is apparent that these will be exacerbated dramatically by climate change, even in the next few decades. Measures to reduce the flood risks, and especially their effectiveness at reducing the risks in a financially sound manner, need to be considered.

Figure VI.22. Flooded Areas and Depths for a 1-Hour Rainstorm with a Return Period of 25 years, for Present Day (Left) and 2050 (Right)



Left = present time; right = 22050. Color coding for calculated flood depths: yellow = < 0.2 m, green = 0.2 to 0.4 m, orange = 0.4 to 0.6 m, light brown = 0.6 to 0.8 m, dark brown = 0.8 to 1.0 m; and red = > 1.0 m.
Source: CCAIRR findings.

Table VI.17. Projected Costs of Sapwohn Flooding as a Consequence of Heavy Rainfall
($ million)

	No Climate Change Discount Rate		With Climate Change Discount Rate	
	0%	3%	0%	3%
To 2050	18.21	9.99	30.84	15.59
To 2100	37.59	12.55	90.47	23.01

Source: CCAIRR findings.

Consultations with stakeholders, most notably community leaders and residents of the study area, resulted in a number of adaptation measures being identified as potential ways to reduce the flood risk to acceptable levels. Their preference was for "no regrets" options.

The flood modeling confirmed that runoff from the steep slopes above the community is a major contributor to flood risk. Accordingly, the effectiveness of drainage works that would divert this runoff away from the built-up areas was explored. The effectiveness of changes to building practices, land use planning, and environmental impact assessment regulations was also investigated. This included changes to require when new buildings are constructed, or existing buildings are substantially renovated, the work will include measures to reduce the flood risk.

In addition to the flood diversion option, several realistic regulatory and voluntary measures were identified and their cost effectiveness assessed, including the following:

- require that the minimum floor height of new and renovated buildings be sufficient to avoid flooding for a rainfall event of a given return period;
- encourage building in areas where flood depth will be less than a given amount for a rainfall event of a given return period;
- require that all new buildings have a specified minimum floor elevation; and
- require that homeowners adapt, i.e., relocate, when the perceived risk of flooding is greater than 10%.

Table VI.18 illustrates how damage costs will be reduced over a 50-year period for examples of the application of the above measures.

For the selected scenarios, both the diversion works and the regulatory measures qualify as "no regrets" interventions, including being cost effective.

Table VI.18. Cost and Consequent Change in Damage Costs for Selected Regulatory and Voluntary Measures over Next 50 Years

Measure	Change in Damage Costs				Direct Cost of Intervention ($ million)	
	No Climate Change		With Climate Change			
	$ million	%	$ million	%	No CC	With CC
Divert 50% of runoff from a 25-year storm at US$10 per cubic meter	-4.08	-4.1	-8.34	-53	0.87	1.62
Require sufficient floor height that no flooding occurs in 25-year storm.[1]	-1.64	-16	-3.92	-25	0.44	0.94
Encourage building where flood depth is <0.5 m in 25-year storm.	-1.02	10	4.1	-25	Nil	Nil
Require that all buildings have a minimum floor elevation of 1 m.	-2.23	-22	-0.89	-7		
Require that homeowners relocate when flood risk is greater than 10%.	8.62	86	21.58	172	8.62	21.58

No CC = without climate change; with CC = with climate change. Discount rate = 3%. Adaptation cost based on $100 per m^2 of floor area per m raised; only for aging properties with longevity of 50 years.

No CC = without climate change, With CC = with climate change.

Source: CCAIRR findings.

It is instructive to consider the incremental costs of the adaptation measures. Table VI.19 highlights these, and compares them to the incremental benefits of undertaking adaptation.

In both cases, climate change will impose significant incremental costs on the community, but the incremental benefits of addressing the increased risks attributable to climate change are larger, by at least a factor of four.

Flooding from High Sea Levels

The study area is also subject to coastal flooding resulting from high tides. Rarely are these a consequence of a tropical cyclone (typhoon). Rather the high ocean water levels are usually associated with king tides, strong onshore winds, and the La Niña phase of ENSO.

Similar analyses to those for rainfall-induced flooding were undertaken in order to assess both the

Table VI.19. Incremental Costs and Benefits of Selected Adaptation Measures
($ million)

	Incremental Benefit	Incremental Cost
Divert 50% of runoff from a 25-year storm at $10 per cubic meter	4.52	0.75
Minimum floor height such that no flooding in 25-year storm[1]	2.28	0.50

Discount rate = 3%.
[1] Adaptation cost based on $100 per m^2 of floor area per m raised; only for aging properties with longevity of 50 years.
Source: CCAIRR findings.

damage costs associated with high sea levels and the nature of interventions that would reduce the risk to an acceptable level.

Figure VI.23 shows the area and depth of flooding if a 25-year event occurred today or in 2050.

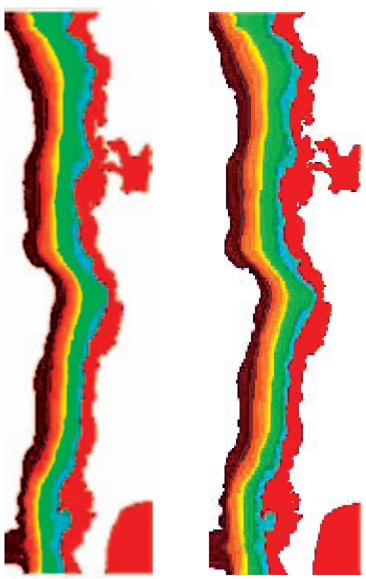
The damage costs arising within the area modeled as a result of the ensemble of high sea-level events projected to occur over a future time period can also be calculated. The method used is analogous to that used to determine the damage costs from flooding associated with heavy rainfall events occurring over a specified time period into the future. Table VI.20 summarizes the key results of these calculations.

Table VI.20. Projected Costs of Flooding of Sapwohn Village as a Result of High Sea Levels
($ million)

	No Climate Change Discount Rate		With Climate Change Discount Rate	
	0%	3%	0%	3%
To 2050	10.04	5.51	10.54	5.72
To 2100	20.72	6.92	23.34	7.38

Source: CCAIRR findings.

Figure VI.23. Spatial Extent of Flooding (Shown in Red) from High Sea Level with a Recurrence Interval of 25 Years



Current conditions (left): maximum depth 2.3 m; in 2050 (right): maximum depth 2.6 m.

Source: CCAIRR findings.

It is apparent that high sea levels (including high tides) present a significant risk to structures, infrastructure, and other assets in the study area, and of course also to the people who reside and/or work there.

In this case study, too, several realistic regulatory and voluntary measures were identified and their cost effectiveness assessed. The measures included:

- requiring that the minimum floor height of new and renovated buildings be sufficient to avoid flooding for a storm surge event of a given return period;
- encouraging building in areas where flood depth will be less than a given amount for a storm surge event of a given return period;
- requiring that all buildings have a specified minimum floor elevation; and
- requiring homeowners to adapt when the perceived risk is greater than 10%.

Residents of Sapwohn Village are already implementing some of these measures on a voluntary basis, as is shown in the photos on page 54.

Table VI.21 illustrates how damage costs will be reduced over a 50-year period for examples of the application of the above measures.

For the selected scenarios all measures qualify as "no regrets" adaptation initiatives, including being cost effective.

A raised threshold prevents damage from minor flooding even though the floor of the dwelling is at ground level.

A recently constructed house in an area of high flooding risk has its living space elevated well above ground level.

Table VI.21. Cost and Consequent Reduction in Damage Costs for Selected Regulatory and Voluntary Measures, for New/Renovated Buildings Only, over the Next 50 Years

Measure	Reduction in Damage Costs				Direct Cost of Intervention ($ million)	
	No Climate Change		With Climate Change			
	$ million	%	$ million	%	No CC	With CC
Require sufficient floor height that no flooding occurs in 25-year storm.[1]	1.79	34	1.88	35	0.02	0.02
Encourage new (relocate) building (only from aging) where flood depth <0.5 m in 25-year storm.	0.58	11	0.63	12	Nil	Nil
Require new buildings (only from aging) to have a minimum floor elevation of 1 m.	1.79	34	1.88	35	Nil	Nil
Require that homeowners relocate when flood risk is greater than 10% (and not from aging).	0.58	11	0.63	12	Nil	Nil

No CC = without climate change; With CC = with climate change. Discount rate = 3%.

[1] Adaptation cost based on $100 per m^2 of floor area per m raised; only for aging properties with longevity of 50 years

Source: CCAIRR findings.

H. Case Study Five: Climate Proofing the Infrastructure, Human Health, and Environment Components of the FSM National Strategic Development Plan

Background

In early 2003, the FSM began preparing a Strategic Development Plan (SDP) that outlines the county's broad economic strategy and sector development policies. In addition to being the country's primary national economic planning mechanism, the SDP is also a requirement under the Amended Compact of Free Association with the United States. That agreement requires the FSM to prepare and maintain a strategic multiyear rolling development plan that is updated through the annual budget process.

The plan also outlines the activities and deliverable outputs that, under reasonable assumptions, can be expected to lead to the achievement of the identified strategic goals. Associated with each output is a quantifiable performance measure, so that during plan execution it will be possible to monitor whether the activities and outputs have been fully implemented.

The SDP comprises a set of sector chapters. Each chapter begins with a review of the sector, including an assessment of the current situation and sector performance; analysis of problems, issues and constraints; and assessment of the sector's development potential. Building on the introductory review, the second section presents the sector's strategic goals, which are supported by a descriptive rationale. Each strategic goal is further elaborated, if needed, through appropriate sector policies. In order to assess performance toward attainment of the strategic goals, a list of the associated outcome performance measures is presented and is discussed at the end of the section. Where it is meaningful to do so, outcome baseline and target measures have been specified at a national level. Since many outcomes are state specific, the associated baselines and targets are frequently unspecified.

The third section details the sector Strategic Planning Matrix (SPM) and indicates the activities and outputs associated with each strategic goal. The SPM is the heart of the strategic plan and provides a working manual for each sector. Since activities and outputs are state specific, the associated targets have been specified only when meaningful. The fourth section describes the SPM and the linkage between activities and outputs and the strategic goal. The linkage indicates how the delivery of the activities and outputs is assumed to contribute to the attainment of the strategic goal. This section also provides an assessment of linkage risks and weaknesses, to facilitate the anticipated ex post performance evaluation efforts. A fifth and final section references the Infrastructure Development Plan (IDP), and identifies the list of infrastructure projects that are critical to the fulfillment of the sector strategy. The list distinguishes between those projects whose major function is to support sector development directly and those whose purpose is indirect or crosscutting.

Preparation and implementation of the IDP meets another requirement under the Amended Compact. The IDP is the FSM's long-term planning document for public investment in infrastructure. The document has been drafted to cover a 20-year period, while recognizing that priorities outlined, and the specific projects in each sector, will be updated through the annual budget process. While the IDP is a requirement of funding under the Compact infrastructure sector, the plan is comprehensive and anticipates funding of projects from the FSM's own revenues, from its bilateral partners, from international financial institutions, and from other development partners.

Together, the SDP and IDP provide a comprehensive economic strategy for the FSM at a critical time in its development as an increasingly self-reliant nation.

A critical step in the preparation of the SDP and IDP was the convening of the third FSM Economic Summit from 28 March to 2 April 2004. For the summit, nine sector committees were established:

- Private Sector Development,
- Public Sector Management,
- Education,
- Health,
- Agriculture,
- Fisheries,

- Tourism, and
- Environment and Gender.

The infrastructure sector had previously been incorporated into the process through preparation of a draft IDP. The draft IDP was reviewed and amended by a special subcommittee of sector representatives. Each sector was also asked to review sector-specific components of the IDP to ensure consistency with the strategic planning matrices.

Each sector committee reviewed the relevant draft chapters of the SDP as well as the strategic planning matrices and prepared an acceptable planning matrix that had wide endorsement from all states of the Federation. The revised matrices were presented to the Summit for endorsement and subsequent integration into the SDP.

ADB provided technical assistance to the FSM for the preparation of both the SDP and the IDP.

The Case Study

Climate proofing at the national policy level is one of the major ways to mainstream adaptation. It helps to strengthen the enabling environment for adaptation while also integrating adaptation planning and implementation into existing and new development policies, plans, and actions.

Climate proofing at the national policy level was assisted by the preparation of Adaptation Mainstreaming Guidelines for the FSM. The Guidelines for the FSM are presented in Appendix 3. In addition, a general description of the approaches and methods used when mainstreaming adaptation in national development planning and implementation can be found in Chapter VIII.

In the case of the FSM, climate proofing the SDP and the associated IDP was guided by a number of considerations, including

- advice from the Project Liaison Committee and other stakeholders to focus on sectors known to face risks related to climate variability and change, including extreme events,
- the benefits of using the detailed findings from the other case studies,
- the ability to undertake additional studies to evaluate sector-dependent climate risks,
- the opportunity and ability to establish an effective dialogue with those individuals and groups responsible for preparing the draft materials for the SDP and IDP, and
- the ability to synchronize the sector activities for the SDP with the climate proofing initiatives.

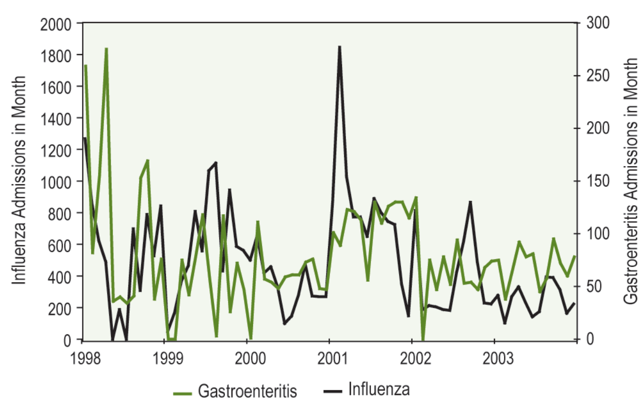
As a result, the climate proofing activities focused on three sectors: health care, environment, and infrastructure.

In addition to the detailed findings of the case studies, climate proofing the SDP and IDP drew on the results of several studies. These are presented below.

Examples of Impact of Climate Change on Health

Monthly data on the number of patients admitted to Pohnpei hospital with infectious diseases were examined to determine whether weather and climatic conditions had an influence. Significant relationships were found for two diseases, influenza and gastroenteritis. Figure VI.24 shows the variation in admission numbers for the period 1998–2003. The month-to-month variations

Figure VI.24. Monthly Admissions to Pohnpei Hospital for Influenza and Gastroenteritis



0 = no chance; 1 = statistical certainty.

Source: CCAIRR findings.

are considerable. Details of the extent to which these variations are linked to climate variability and extremes are presented below.

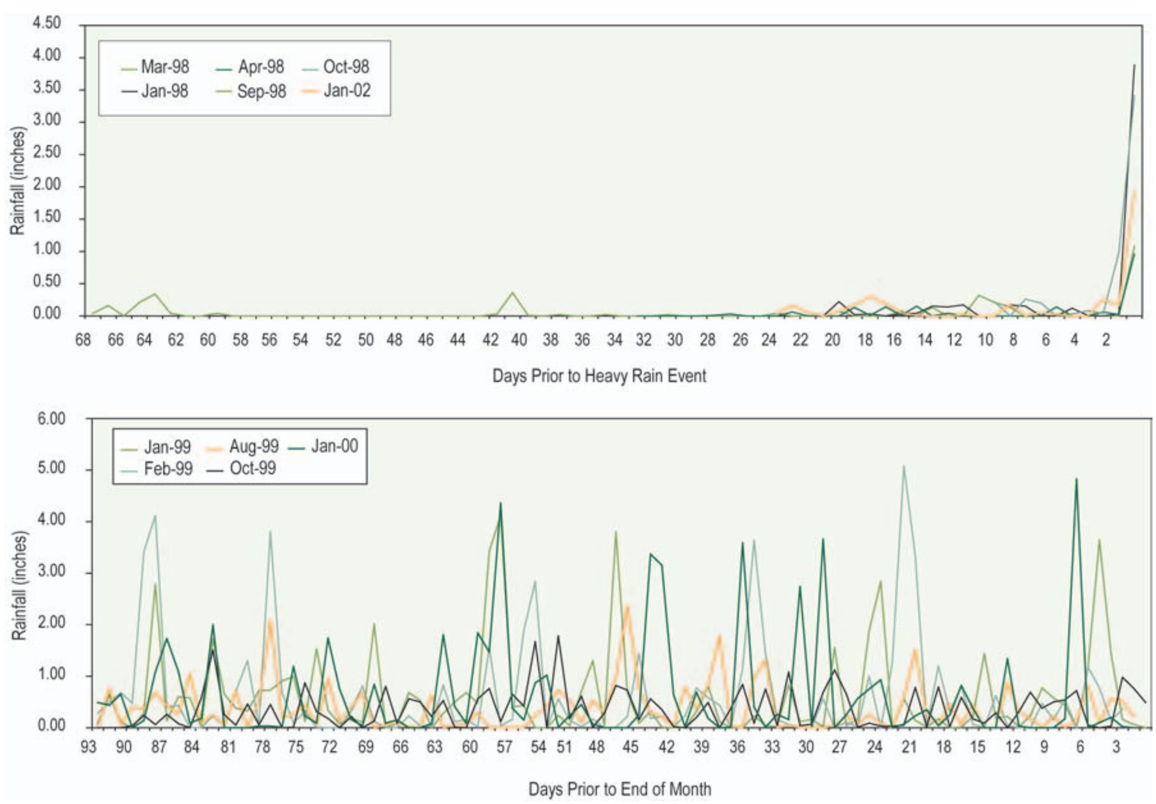
The 6 months of the study period that showed gastroenteritis admissions more than one standard deviation above normal were January 1992 and January, March, April, September, and October 1998. All six months are characterized by an extended period when daily rainfall amounts were consistently low, with each period ending in a heavy rainfall event. These characteristics are depicted in the upper graph of Figure VI.25. It shows a composite of the rainfall data for the 6 individual months, including each of the terminating heavy rainfall events and the preceding periods of low rainfall.

The lower graph in Figure VI.25 shows the daily rainfall amounts during the 5 months when gastroenteritis admissions were more than one standard deviation below normal. These were January, February, August, and October 1999 and January 2000.

On the basis of this analysis, outbreaks of gastroenteritis in Pohnpei can be shown to be associated, to some degree, with prolonged periods of low rainfall that end in a heavy rainfall event of at least 25 mm in a day.

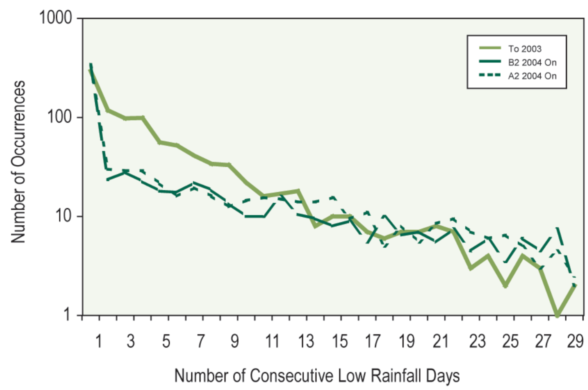
Observed daily rainfall data (1953–2003) and projected daily rainfall data (Canadian GCM with A2 and B2 emission scenario) were analyzed to determine if global warming might alter the frequency of conditions associated with outbreaks of gastroenteritis. The results are shown in Figure VI.26. For both emission scenarios, the number of occurrences of long periods of low rainfall followed by a heavy rainfall event increases. Thus, the incidence of gastroenteritis outbreaks may well increase as a consequence of global warming.

Figure VI.25. Antecedent Rainfall Conditions for the Months with High (Upper) and Low (Lower) Numbers of Gastroenteritis Admissions to Pohnpei Hospital



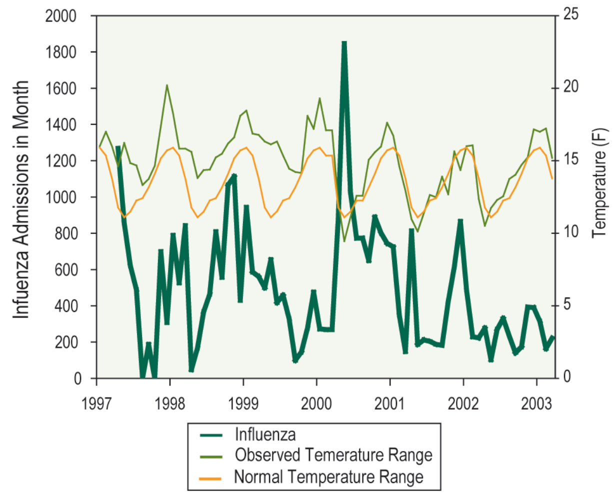
Source: CCAIRR findings.

Figure VI.26. Number of Occurrences in 50 Years of Periods of Low Rainfall Ending in a Heavy Rainfall Event; Observed and Projected Rainfall Data for Pohnpei



Source: CCAIRR findings.

Figure VI.27. Monthly Admissions to Pohnpei Hospital for Influenza, and Observed and Normal Mean Daily Temperature Ranges for Pohnpei



Source: CCAIRR findings.

Figure VI.27 suggests that outbreaks of influenza in Pohnpei are associated, in part, with periods when the mean daily temperature range for the month (the difference between the mean daily maximum and minimum temperatures) is increasing faster than normal.

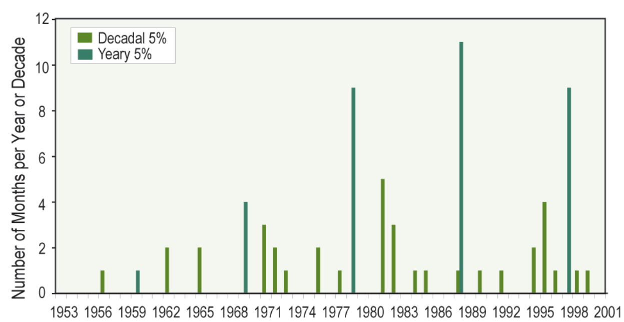
Climate and Infrastructure

Preceding sections of this book, and notably the case studies, provide information on climate-related risks of relevance to the design and implementation of infrastructure development projects in the FSM, including risks related to extreme rainfall and to high sea level.

Prolonged periods of drought also pose a risk to water supply, waste water, hydroelectric, and similar infrastructure projects.

Figure VI.28 presents, for Pohnpei, the number of months in each year (1953–2003), and each decade, for which the observed precipitation was below the fifth percentile. A monthly rainfall below the fifth percentile is used here as an indicator of drought.

Figure VI.28. Number of Months in Each Year or Decade for which Precipitation in Pohnpei was Below the Fifth Percentile



Source: CCAIRR findings.

Most of the low rainfall months are concentrated in the latter part of the period of observation, indicating that the frequency of drought has increased since the 1950s. The years with a greater number of months with rainfall below the fifth percentile coincide with El Niño events.

The results of a similar analysis, in this case for rainfall estimates (1961–1990) and projections

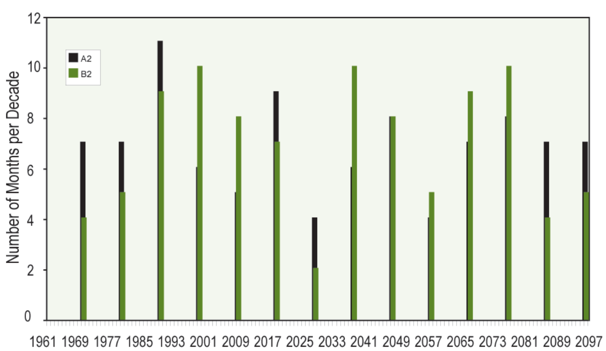
(1991–2100) by the Canadian GCM, are shown in Figure VI.29. The results are presented for both the A2 and B2 emission scenarios. The GCM-based results replicate the increased frequency of months with extreme low rainfall during the latter part of the last century. The results also indicate that, regardless of which emission scenario is used, the frequency of low rainfall months will generally remain as high as it was in the latter part of the last century.

Figure VI.30 shows the annual maximum wind gust recorded in Pohnpei for the period from 1974 to 2003.

Strong wind gusts also pose a threat to infrastructure. Table VI.22 presents return periods for extreme high winds in Pohnpei, based on observed data. Also shown are return periods for 1991–2020 and for 2021–2050. The latter are estimated from projections of maximum wind speed using the Canadian GCM 2 with the A2 emission scenario.

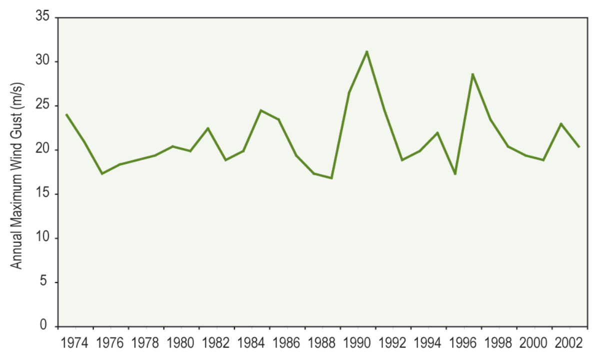
Figure VI.31 depicts the influence of global warming on the likelihood of a maximum wind gust of 28 m/sec for Pohnpei.

Figure VI.29. Number of Months per Decade for which Precipitation in Pohnpei is Projected to be Below the Fifth Percentile



Source: CCAIRR findings.

Figure VI.30. Annual Maximum Wind Gust Recorded in Pohnpei 1974–2003



Source: CCAIRR findings.

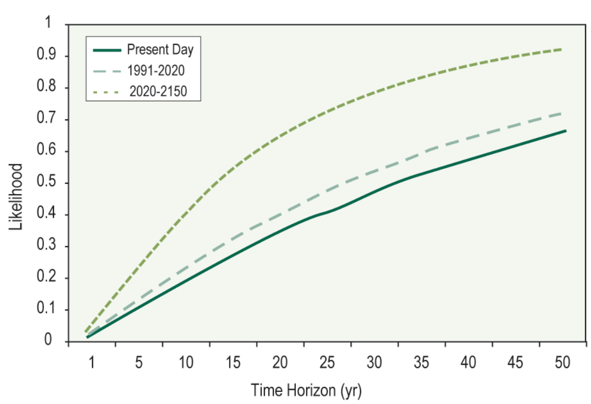
Table VI.22. Return Periods for Maximum Wind Speed, Pohnpei
(Years)

Wind Speed (m/sec)	Hourly		Daily	
	1974-2003	1961-1990	1991-2020	2021-2050
20	2	2	2	2
25	8	10	10	9
28	20	47	40	20

Note: daily values based on Canadian GCM 2, with A2 emission scenario.
Source: CCAIRR findings.

Recent Wind Damage in Pohnpei

Figure VI.31. Likelihood of a Maximum Wind Gust of 28 m/sec occurring within the Indicated Time Horizon in Pohnpei (years)



Source: CCAIRR findings.

Climate Proofing the National Strategic Development Plan

The case studies, as well as the above findings, provided strong reasons for climate proofing the FSM's SDP. The task was a cooperative effort involving relevant government officials; the ADB consultants; and other key players who drafted the SDP for the sectors identified during the consultations as being the appropriate foci for climate proofing, namely infrastructure, health care, and environment.

Examples of the way in which the Plan provides an enabling environment that fosters climate proofed development, and the links with sustainable development, are provided below.

a. Infrastructure

Criteria by which to rank projects nationally across sector and state include

- impact of the project on the national economy;
- cost benefit of project, taking into account economic and social benefits;
- contribution of the project toward the health and safety of the community;
- contribution of the project toward development of the FSM workforce to meet the social and economic challenges;
- contribution of the project to institutional strengthening and restructuring of government infrastructure agencies;
- contribution of the project to promoting private sector development;
- viability, sustainability, potential social benefit, environmental impact, and risk exposure of the infrastructure development project.

Risk Assessments Related to Natural Hazards. These studies should be conducted at the state level and focus on existing risks to infrastructure (e.g., typhoons, landslides, drought) as well as determining how those risks will be increased as a result of changes in the future, including the consequences of global climate change. The study will develop guidelines and identify and recommend other measures to ensure the exposure of infrastructure to current and future risks are reduced to acceptable levels.

- Strengthen and adapt new building and other relevant regulations and codes of good practice.

- Infrastructure located, built and maintained in line with codes and practices that ensure full functionality for the projected lifetime.

- Infrastructure designed, located, built and maintained to avoid unacceptable risks to infrastructure associated with natural hazards, including weather and climate extremes, variability and change.

- Conduct risk assessments at state level and develop national- and state-level guidelines to ensure risks to infrastructure development projects are identified and addressed in a cost effective manner at the design stage (Office of the President, FSM 2004).

b. Health Care

- Climate variability and change, including sea-level rise, are important determinants of health and of growing concern in the FSM (as it is in all Pacific Island countries). The impacts are mostly adverse. Climate variability and change can result in reduced quality and quantity of water supplies, loss of coastal resources, reduction in ecosystem productivity and a decline in agricultural productivity. Potential health impacts which have been identified include: vector-borne diseases (such as dengue fever and malaria), water-borne diseases (such as viral and bacterial diarrhea), diseases related to toxic algae (such as ciguatera fish poisoning which is important in the FSM where the protein source is predominantly fish), food-borne diseases, food security and nutrition, heat stress, air pollution, and extreme weather and climate events (such as cyclones, high tides, droughts and storm surges). Especially on atoll islands of the FSM, storm surges can result in injury and drowning. The adverse impacts of many of these events will be exacerbated by sea-level rise. Thus climate change should be an important consideration when assessing environmental health issues and the consequential priorities for the health of people in the FSM.

Conduct assessments of climate-related health risks, including vector-borne and water-borne diseases, and institute relevant early warning and public education programs.

Strengthen surveillance and monitoring functions of the environmental health program (water, hygiene, sanitation, and food safety), including risks related to climate variability and change.

Public health risks related to climate variability and change documented and findings included in relevant health, education and public awareness programs (Office of the President, FSM 2004).

c. Environment

- ❖ **Strategic Goal 1:** Mainstream environmental considerations, including climate change, in economic development (National Environmental Management Strategy, FSMClimate Change Communication, National Biodiversity Strategy and Action Plan, Compact Environmental Strategy).

- ❖ Strategies and plans that address unacceptable risks to the natural environment and built assets, including those arising from natural hazards such as weather and climate extremes, variability and change.

- ❖ Develop and implement integrated environmental and resource management objectives that enhance resilience of coastal and other ecosystems to natural hazards such as those associated with extreme weather events, climate change, high tides and sea-level rise.

- ❖ All the FSM communities will develop and implement risk reduction strategies to address natural hazards such as those related to current weather and climate extremes and variability, while at the same time preparing for anticipated impacts of climate change.

- ❖ Identify structures, infrastructure, and ecosystems at risk and explore opportunities to protect critical assets.

- ❖ Integrate considerations of climate change and sea-level rise in strategic and operational (e.g. land use) planning for future development, including that related to structures, infrastructure, and social and other services.

- ❖ Document low-lying agricultural areas at risk from the effects of natural hazards, including sea-level rise, and implement appropriate land use planning and other measures.

- ❖ Determine impact of climate change on the tuna industry as a result of such effects as changed migration patterns of Pacific tuna stocks, and implement strategies to minimize impacts on this important industry (Office of the President, FSM 2004).

Current Status of the Climate-Proofed National Strategic Development Plan

At the Third FSM Economic Summit, held between 28 March and 2 April 2004, the climate proofed SDP was endorsed by participants. Subsequently the SDP was approved by the National Congress. It has now become the primary national economic planning mechanism of the FSM.

Implementation of the climate proofing called for in the SDP will be guided by the National Guidelines for Mainstreaming Adaptation to Climate Change (see Appendix 3). These Guidelines were approved at the final Tripartite Review Meeting held in the FSM in June, 2004.

I. Case Study Six: Climate Proofing the Cook Islands National Development Strategy

Background

In late 2003, the Cook Islands began preparing a National Development Strategy (NDS) that would outline the county's broad economic strategy and sector development policies. The first major public consultation to set the stage for formulation of the NDS was the First National Development Forum, held in November 2003. As part of preparations for the Forum, five Interim Focus Groups were established by the National Planning Task Force, which had oversight of preparing the NDS. The Focus Groups performed a stocktaking of developments over the past 20 years and identified issues to be addressed in the areas of economic development, education, health care, infrastructure, and law and governance.

Environment was seen as a cross-cutting theme to be considered by all Focus Groups.

The newly established Coordination Unit, based in the Office of the Prime Minister, had responsibility to organize the National Development Forum. The Coordination Unit is jointly staffed by members of the Office of the Prime Minister and the Ministry of Finance and Economic Management. The Unit was assisted by a local consultant and a consultant provided by ADB.

The Forum had two primary objectives:

- review the overall progress of the Cook Islands over the last 20 years and determine its development status; and
- establish a framework for the formulation of the long-term (20 years) NDS.

All sectors of the community, including the Outer Islands, were well represented at the Forum. The major objective of the first day was to identify recent development achievements and also issues facing the nation. Those identified included the following:

- A fourfold increase in visitor arrivals has occurred over the past 20 years.
- Unplanned development places pressure on the environment, infrastructure, and land.
- Environmental themes are now being covered explicitly in the national education curriculum.
- The divide between Rarotonga and the Outer Islands is increasing; Rarotongan students are better equipped to take advantage of opportunities.
- Steady improvement has occcurred in the main health indicators, such as rising life expectancy and very low infant and maternal mortality rates.
- The disparity in health standards between Rarotonga and the Outer Islands needs to be narrowed.
- Water is piped free to most areas, especially in Rarotonga.
- Water shortages on Rarotonga will limit new development.

The primary objective of the second day of the Forum was to identify the common goals for development of the Cook Islands over the next 20 years. The goals included

- balanced and equitable socioeconomic development, with the natural environment very much intact and enhanced;
- service and development efforts that are equally focused on Rarotonga and the Outer Islands;
- greater use of alternative energy sources, both as an environmental enhancement measure and as a means to reducing dependence on imported fuels; and
- significantly reduced numbers of personal transport vehicles and a population that routinely relies on bicycles and public transport for on-island mobility.

Subsequent to the National Development Forum, the National Planning Task Force built on its results and prepared a draft matrix of strategic priority issues. For each strategic priority, the matrix included key challenges, key policy objectives, and key actions required. The seven strategic priority objectives were

- good governance and law and order;
- macroeconomic stability and economic development;
- improved quality of education;
- improved quality of health care services;
- improved standard of infrastructure and provision of utilities, including transport services;
- increased agricultural productivity and self-sufficiency and food security; and
- improved development and management of marine resources.

In subsequent discussions the Task Force acknowledged the need to add environmental quality and tourism as strategic priority objectives. With these additions, the draft matrix developed by the Task Force served as the foundation for climate proofing the Cook Islands NDS.

The Case Study

Climate proofing at the national policy level is one of the major ways to mainstream adaptation. It helps to strengthen the enabling environment for adaptation, while also integrating adaptation planning and implementation into existing and new development policies, plans, and actions.

Climate proofing at the national policy level was assisted by the preparation of Adaptation Mainstreaming Guidelines for the Cook Islands. These Guidelines are presented in Appendix 4. In addition, a general description of the approaches and methods used when mainstreaming adaptation in national development planning and implementation can be found in Chapter VIII.

Climate proofing the NDS was also guided by a number of considerations, including

- advice from the Project Liaison Committee and other stakeholders to ensure that climate-related risks were considered for all the strategic priority objectives;
- the benefits of using the detailed findings from the other case studies;
- the ability to undertake additional studies to evaluate sector-dependent climate risks; and
- the opportunity and ability to establish an effective dialogue with those individuals and groups responsible for preparing the draft materials for the NDS.

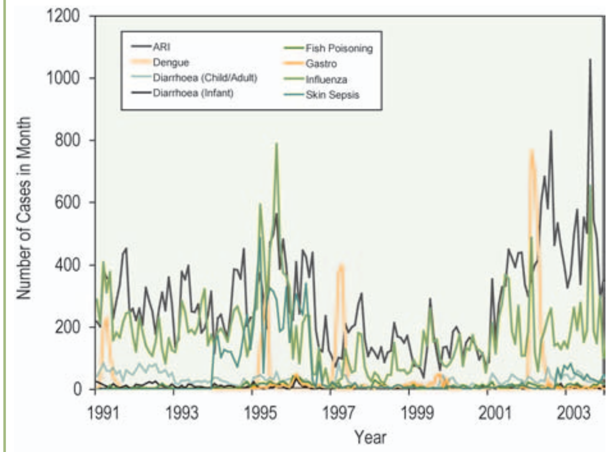
In addition to the detailed findings of the case studies, climate proofing the NDS drew on the results of several studies. These are presented below.

Examples of the Impact of Climate Change on Health

Aggregated monthly nodifiable disease records for Rarotonga were examined to determine whether weather and climatic conditions had an influence. Figure VI.33 shows the variation in admissions numbers for the period 1991–2003.

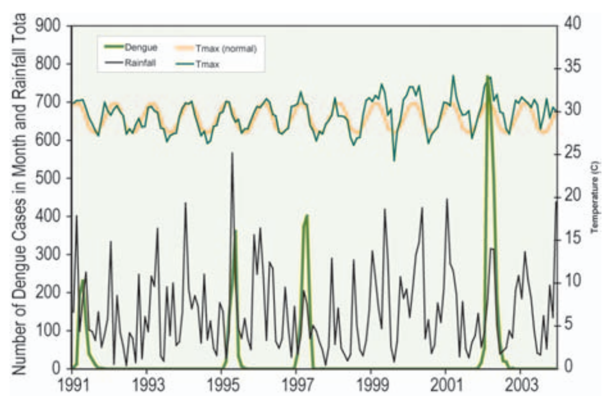
The two diseases with the highest incidence rates, acute respiratory infection (ARI) and dengue, were examined to determine the extent to which the considerable month-to-month variations were linked to climate variability and extremes. The results are presented below. Figure VI.34 shows, for each month from 1991 to 2003, the number of cases of dengue and also the monthly total rainfall, observed mean maximum temperature, and normal mean maximum temperature.

Figure VI.32. Monthly Totals of Notifiable Disease Cases for Rarotonga



Note: ARI = acute respiratory infection.
Source: CCAIRR findings.

Figure VI.33. Number of Cases of Dengue and the Monthly Total Rainfall, Observed Mean Maximum Temperature, and Normal Mean Maximum Temperature for Rarotonga



Source: CCAIRR findings.

Analyses revealed a relationship between dengue cases in a given month and the rainfall total and mean maximum temperature for the previous month, such that

Dengue Cases = -2254 + 77.7 * $Rainfall_{-1}$ + 0.32 * $Tmax_{-1.}$ The R^2 was 0.58 (i.e., explained variance equals 58%) and the standard error equalled 132 cases.

Significantly, the above equation does not provide the ability to predict an outbreak of dengue. Since dengue is not endemic to the Cook Islands, an outbreak results from the arrival in the country of an infected person who is subsequently bitten by a mosquito that is then a vector for spreading the disease. The above relationship does allow some ability to predict whether an existing outbreak will worsen or decline. The latter is more likely to occur if rainfall amounts and maximum temperatures are high. This is shown in Table VI.23.

In addition to showing the potential impact of climate change on dengue cases, the above relationship provides a basis for deciding whether public health interventions are required if an outbreak is already occurring.

The climate risk profile for the Cook Islands (Appendix 2) reveals that both rainfall and maximum temperatures are projected to increase as a consequence of global warming, creating the potential for an increase in the number of cases of dengue in future outbreaks. Interestingly, for the four outbreaks of dengue since 1998, each has seen a steady increase in both the total and maximum number of cases, as shown in Table VI.24. The duration of an outbreak has not changed systematically over the same time period. It is not possible to attribute the observed changes to global warming, but the pattern is consistent with the observed changes in the climate. These, in turn, are consistent with the consequences of global warming.

Table VI.23. Number of Dengue Cases in a Month if an Outbreak is Already Occurring, Based on the Rainfall (mm) and Maximum Temperature (°C) in the Previous Month

Rainfall (mm) - Previous Month	Maximum Temperature–Previous Month (°C)								
	26	**27**	**28**	**28**	**30**	**31**	**32**	**33**	**34**
600	0	36	114	114	270	347	425	503	580
550	0	20	98	98	254	331	409	487	564
500	0	4	82	82	238	315	393	471	548
450	0	0	66	66	22	299	377	455	532
400	0	0	50	50	206	283	361	439	516
350	0	0	34	34	190	267	345	423	500
300	0	0	18	18	174	251	329	407	484
250	0	0	2	2	158	235	313	391	468
200	0	0	0	0	142	219	297	375	452
150	0	0	0	0	126	203	281	359	436
100	0	0	0	0	110	187	265	343	420
50	0	0	0	0	94	171	249	327	404
0	0	0	0	0	78	155	233	311	388

Source: CCAIRR findings.

Table VI.24. Total and Monthly Maximum Number of Cases of Dengue in Rarotonga (1998–2003)

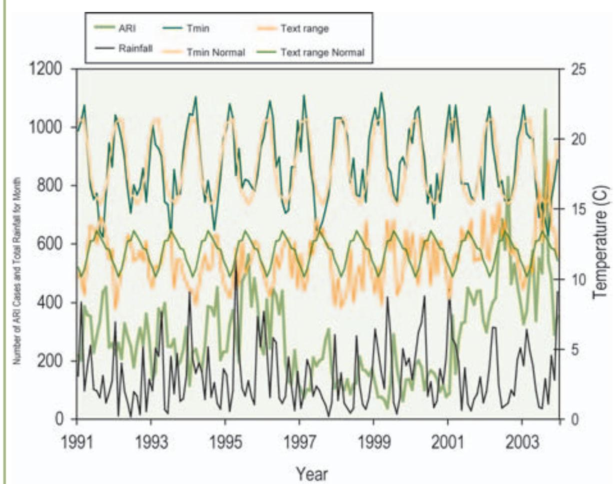
Year of Outbreak	Number of Cases	Maximum Number in Month
1991	644	231
1995	786	361
1997	1,100	401
2001–02	2,330	767

Source: CCAIRR findings.

Figure VI.34 suggests that the number of cases of ARI in a given month in Rarotonga is associated, in part, with lower than normal minimum temperatures and rainfall and with a temperature range that is higher than normal. The relevant correlations with ARI were as follows:

Rainfall	-0.41
Tmin	-0.58
Text range	0.42
All three variables	0.58

Figure VI.34. Number of Cases of ARI, Monthly Total Rainfall, Observed Mean Minimum Temperature and Temperature Range, and Normal Mean Maximum Temperature and Temperature Range for Rarotonga



Source: CCAIRR findings.

The R^2 was 0.34 (i.e., explained variance equals 34%) and the standard error equalled 148 cases.

This relationship provides the ability to estimate the number of ARI cases. An example, for rainfall and extreme temperature range only, is provided in Table VI.25.

Table VI.25. Number of ARI Cases in a Month Based on the Rainfall (mm) and Maximum Temperature (°C) in the Previous Month

Rainfall (mm)	Extreme Temperature Range (°C)						
	6	**8**	**10**	**12**	**14**	**16**	**20**
600	97	145	192	240	288	336	432
550	118	166	214	262	310	357	453
500	139	187	235	283	331	379	474
450	160	208	256	304	352	400	496
400	182	560	277	325	373	421	517
350	203	251	299	347	395	442	538
300	224	272	320	368	416	464	559
250	245	293	341	389	437	485	581
200	267	315	362	410	458	506	602
150	288	336	384	432	480	527	623
100	309	357	405	453	501	549	644
50	330	378	426	474	522	570	666
0	352	400	447	495	543	591	687

Source: CCAIRR findings.

Climate and Infrastructure

Preceding sections of this book, and notably the case studies, provide information on climate-related risks of relevance to the design and implementation of infrastructure development projects in the Cook Islands, including risks related to extreme rainfall, strong wind gusts, drought, extreme high temperatures, and high sea level. All these extreme events are projected to increase in frequency, and hence in magnitude for a given return period, as a consequence of global warming.

These findings, which are presented collectively in Appendix 2, have major implications for ensuring the longevity of existing and new infrastructure. The implications have been acted upon by climate proofing the NDS for the Cook Islands.

Climate Proofing the National Development Strategy

The case studies, as well as the above findings, provided strong reasons for climate proofing the Cook Islands NDS. The task was a cooperative effort involving, in the main, members of the Project Liaison Committee and participants in a National Climate Dialogue.

The process of climate proofing was organized around the seven strategic priorities listed above (plus tourism and the environment). Initial discussions were aided by the use of questions designed to focus the interactions on the climate proofing dimensions of each strategic priority. The questions used are listed in Box VI.4.

The initial responses to the questions were used as a basis for preparing a series of key challenges, objectives, and actions that would help enhance the enabling environment and facilitate the climate proofing of future development in the Cook Islands.

This draft material was shared with members of the Project Liaison Committee for their review and feedback. The revised material was subsequently presented at a National Climate Dialogue. After discussion and some revisions, the Dialogue participants agreed that the key challenges, objectives, and actions should be communicated to the Government, as a practical and tangible contribution to assist with the climate proofing of the NDS.

The approved key challenges, objectives, and actions are shown in Tables VI.31–VI.39.

BOX VI.4

Questions used to Focus Discussions on the Climate Proofing Dimensions of the Cook Islands National Development Strategy

Strategic Priority 1

Good Governance and Law and Order

What requirements do climate variability and change impose on

- institutional arrangements?
- planning?

Strategic Priority 2

Macroeconomic Stability and Economic Development

What are the challenges that climate variability and change pose to

- national economic development?
- economic development of the Outer Islands?

Strategic Priority 3

Improved Quality of Education

What education initiatives are required if the Cook Islands is to

- enhance its sustainability?
- attain a viable economy?
- maintain high environmental quality?
- achieve equitable social and economic development?

Strategic Priority 4

Improved Quality of Health Care Services

What is impeding efforts to reduce the impacts of climate variability and change on public health and well-being?

Strategic Priority 5

Improved Standard of Infrastructure and the Provision of Utilities, Including Transport Services

What can be done to ensure that risks to infrastructure are not increased due to climate variability and change?

Strategic Priority 6

Increase Agricultural Productivity for Self-Sufficiency and Food Security

How can agricultural production be made more sustainable, and food security enhanced, despite climate variability and change?

Strategic Priority 7

Improve Development and Management of Marine Resources

What must be done to ensure the sustainability of the Cook Islands' marine resources despite risks due to climate variability and change?

Strategic Priority 8

Tourism Development

What can be done to reduce the risks that climate variability and change pose to the tourism sector?

Strategic Priority 9

Protection, Conservation, and Sustainable Management of the Environment and Natural Ecosystems[1]

What changes are required to environmental policies, regulations, and procedures (e.g., environmental impact assessment) in order to reduce the risks climate variability and change pose to the Cook Islands?

[1] The National Task Force had not developed a strategic priority for the environment at the time the above questions were prepared. Thus, the wording of strategic priority 9 was designed to assist and guide the Task Force in its work related to the strategic priority on the environment.

Source: CCAIR findings.

Table VI.26. Strategic Priority 1: Good Governance and Law and Order

Key Challenges	Key Objectives	Key Actions Required
All institutional arrangements, policies, and plans foster sustainable development.	Government institutions are structured and strengthened.	• Climate Change Country Team (CCCT) institutionalized. • Technical Working Group established and reporting to CCCT.
Promote information sharing and bottom-up and top-down communication.	Plans developed by all government agencies enhance sustainable development and food security.	• Maritime surveillance and agriculture ministries strengthened. • Disaster Management Unit fully operational. Weather observation and information gathering strengthened.
Promote and provide policy advice with respect to adaptation priorities and practices.		• Promote the development of information technology models to assist with decision making.
	Comply with International Agreements.	• Submit Second National Communication to the UNFCCC.

Note: UNFCCC = United Nations Framework Convention on Climate Change.
Source: CCAIRR findings.

Table VI.27. Strategic Priority 2: Macroeconomic Stability and Economic Development

Key Challenges	Key Objectives	Key Actions Required
Recognize the vulnerability of key economic drivers of the economy, including the challenges that climate variability will pose.	Promote the integration of polices and plans directed at reducing climate-related risks.	• Introduce and strengthen legislation and regulations that facilitate adaptation. • Improve compliance monitoring and enforcement capabilities of relevant regulatory agencies. • Enhance agricultural pest control. • Enhance water resources management on all islands. • Develop strategies to deal with erosion of land, especially on Outer Islands.
Seek alternative and innovative avenues for economic development	Reduce dependency on tourism and black pearl industry.	• Promote research programs in the Cook Islands. • Enhance food security.

Source: CCAIRR findings.

Table VI.28. Strategic Priority 3: Improved Quality of Education

Key Challenges	Key Objectives	Key Actions Required
Develop the skills of Cook Islanders in order to foster sustainable development goals.	Convert awareness into action to deal with variability and extremes in weather and climate—at all levels in society.	• Make HRD strategy reflect the need to develop in-country expertise and understanding in climate change. • Improve training opportunities in science, social studies, and technical areas. • Use technical modelling tools to assist in decision making.
Mainstream climate change issues within the formal and informal education and vocational training curricula.	Raise awareness of climate change-related risks through ongoing media campaigns.	• Identify those responsible for awareness raising. • Ensure that formal education curricula includes climate change issues.

Note: HRD = human resources development

Source: CCAIRR findings.

Table VI.29. Strategic Priority 4: Improved Quality of Health Services

Key Challenges	Key Objectives	Key Actions Required
Establish long-term preventive health care programs that take into account climate variability and change.	Improve the health and well-being of Cook Islanders.	• Strengthen public health programs. • Conduct assessments of climate-related health risks.
Address the impacts of climate variability and change (including extreme events) on the health and welfare of Cook Islanders.	Recognize and strengthen contingency response plans for disease outbreaks.	• Improve the effectiveness of the *tutaka* (annual health department inspection of properties) • Use technical and scientific tools to map and predict disease outbreaks. • Strengthen border control.

Source: CCAIRR findings.

Table VI.30. Strategic Priority 5: Improve the Standard of Infrastructure and the Provision of Utilities, including Transport Services

Key Challenges	Key Objectives	Key Actions Required
Ensure that the risks to infrastructure are not increased due to climate variability and change.	Ensure compliance and enforcement of building, EIA and related regulations.	• Establish computer models and technical expertise to make informed decisions (e.g., use of GIS). • Revise EIA regulations and codes to reflect new information and practices. • Provide guidance on how to make current land use practices (buildings, etc.) more resilient and more sustainable.
Promote sound and sustainable land use practices.	Provide information on risks to buildings and other structures.	• Strengthen advisory capacity of Ministry of Works. • Promote rainwater harvesting.
Increase the security of water and energy supplies in both Rarotonga and the Outer Islands, in order to reduce vulnerability of people and industries to droughts and other extreme events.	Promote renewable energy use.	• Promote research programs in the Cook Islands. • Promote use of alternative sources of water supply.

Note: EIA = environmental impact assessment; GIS = geographical information system.

Source: CCAIRR findings.

Table VI.31. Strategic Priority 6: Increase Agricultural Productivity for Self-Sufficiency and Food Security

Key Challenges	Key Objectives	Key Actions Required
Ensure that agricultural production is environmentally sound and sustainable.	Recognize the need to promote alternative production systems. Minimize risks to agricultural production and food security as a result of environmental and related changes, including climate variability and change.	• Foster alternative production systems such as hydroponics. • Identify the interactions between agricultural activities and the environment. • Promote research programs such as appropriate crop strains, including those tolerant to drought and saline conditions. • Strengthen the Pesticide Board and implementation of the Pesticide Act. · Improve controls and management of domestic animals, e.g., pigs.
Establish good transport and marketing systems for agricultural produce from the Outer Islands	Improve the system for inter-island transfer of food, e.g., marketing centers and better transport.	• Devise mechanisms to move produce from the farm gate to the market.

Source: CCAIRR findings.

Table VI.32. Strategic Priority 7: Improve Development and Management of Marine Resources

Key Challenges	Key Objectives	Key Actions Required
Preserve marine resources for the benefit of current and future generations.	Improve institutional arrangements to minimize risks to the sustainability of living marine resources and ecosystems.	• Identify the risks arising from interactions between marine resources and the environment. • Strengthen maritime surveillance. • Identify and manage the links between climate variability and coral bleaching, crown of thorns, and fish poisoning, and develop appropriate management strategies (e.g., traditional management/*raui* measures). • Identify and manage climate-related risks for aquaculture (e.g., pearl industry in the Northern Group).
Minimize risks to the sustainability of living marine resources and ecosystems as a result of environmental and related changes, including climate variability and change.	Implement plans and polices that reduce adverse impacts of climate change and variability.	• Establish research programs to improve information sharing. • Strengthen the monitoring of migratory fish species. • Implement policies and plans that reduce adverse impacts and exploit beneficial relationships (e.g., adaptive management of the tuna fishery in light of the impact of ENSO on migratory fish species).

Note: ENSO = El Niño Southern Oscillation.
Source: CCAIRR findings.

Table VI.33. Strategic Priority 8: Tourism Development

Key Challenges	Key Objectives	Key Actions Required
Recognize that high quality environment is the key to a viable tourism business.	Ensure that all tourism businesses are committed and use environmentally friendly practices.	• Implement PATA guidelines for tourist businesses. • Establish stringent performance standards for tourism. • Recognize the impacts of over-water resorts and their high vulnerability to extreme weather and climate events.
Reduce the vulnerability of the tourism sector to climate variability and change, including extreme events.	Implement risk management strategies that reduce the impact of extreme climate events on tourism to acceptable levels.	• Identify and prioritize the climate-related risks facing the tourism industry.·Strengthen disaster management. • Develop in-house risk management strategies.

PATA = Pacific Asia Travel Association.
Source: CCAIRR findings.

Table VI.34. Strategic Priority 9: Protection, Conservation, and Sustainable Management of the Environment and Natural Ecosystems

Key Challenges	Key Objectives	Key Actions Required
Maintain the quality of the environment and of natural ecosystems.	Develop robust regulations and guidelines that protect the environment.	• Strengthen EIA procedures in ways that reduce political interference in environmental management. • Ensure that Outer Islands opt into the Environment Act. • Strengthen national and island Environmental Councils.
Minimize the adverse consequences of climate change on the economy, society, and environment.	Develop climate change adaptation strategies and address unacceptable risks arising from natural hazards, including climate change. Integrate climate change and sea-level rise in strategic and operational impact assessments and other regulatory procedures.	• Develop simple and easy-to-follow procedures. • Improve technical expertise and decision-making processes. • Strengthen national institutional arrangements for the effective implementation of climate change policies and plans.
Harmonize responses to climate change with other sustainable development initiatives.	Increase efficiency of energy use and convert to renewable energy sources to minimize greenhouse gas emissions.	• Formulate a National Energy Sector Policy. • Decrease the use of imported petroleum fuels through conservation, efficiency, use of renewable energy, and other measures.

EIA = environmental impact assessment.
Source: CCAIRR findings.

Participants in the National Climate Dialogue also endorsed the National Guidelines for Mainstreaming Adaptation to Climate Change (NGMACCs) (see Appendix 4) that had been previously developed in partnership with, and approved by, the Project Liaison Committee.

Both the Guidelines and the proposals for climate proofing the NDS were subsequently presented to the Cabinet of the Government of the Cook Islands, for its approval and adoption. The Acting Prime Minister had attended the National Climate Dialogue in her capacity as Minister for the Environment.

The Adaptation Mainstreaming Guidelines and the Climate Proofing Proposals are submitted to the Cook Islands Cabinet. The Acting Prime Minister is seated at the end of the table.

The Cabinet resolved to

- approve adoption and implementation of the NGMACC; and
- approve the recommendations for climate proofing the National Sustainable Development Strategy that is currently in preparation.

Some of the Participants in the National Climate Dialogue Held in Rarotonga in August, 2004

CHAPTER VII

Key Findings and Recommendations

BOX VII.1

Key Points for Policy and Decision Makers

- Follow-up to the case studies has already occurred, including plans to seek funding from the Global Environment Facility and other sources to cover the incremental costs of climate proofing the completion of the circumferential road in Kosrae and the protection of assets on the north coast of Rarotonga.
- Project sustainability (e.g., lifetime) can be threatened by climate change, but climate proofing a project at the design stage will normally require an investment that is small relative to the additional maintenance and repair costs incurred over the lifetime of the project.
- Many adaptation options qualify as "no regrets" adaptation initiatives, including being cost effective.
- Retroactive climate proofing is likely to be considerably more expensive than that undertaken at the design stage of a project.
- Governments should reflect these findings by ensuring that all projects are climate proofed at the design stage, making this part of good professional practice.
- Governments should also determine the incremental costs and benefits of all major development projects and request that developed country aid providers and other agencies fund these incremental costs; the number of funding options is growing.
- National- and subnational-level regulations should be climate proofed, as this will allow enforcement of policies and plans that should, themselves, be climate proofed in accordance with the National Guidelines for Mainstreaming Adaptation to Climate Change (NGMACCs);
- ADB should show leadership with respect to adaptation to climate change by
  - ➢ enhancing enabling environments at national levels, consistent with the NGMACCs;
  - ➢ maximizing the synergies between ADB's sustainable development initiatives (e.g., poverty reduction) and its climate change initiatives; and
  - ➢ ensuring that all development projects with which it is associated comply with best professional practices, including climate proofing, in order to reduce to acceptable levels the risks that should be described in national climate risk profiles.
- ADB is encouraged to prepare climate risk profiles for all its developing member countries, using as examples those already prepared for the Cook Islands and the Federated States of Micronesia.
- Many lessons have been learned and demonstrated in preparing the case studies, including showing that
  - ➢ a risk-based approach to adaptation is both desirable and practicable;
  - ➢ adaptation is a process and has many dimensions;
  - ➢ because of this, a framework and associated methodologies are essential;
  - ➢ Climate Change Adaptation through Integrated Risk Reduction provides such a framework, as well as relevant methodologies; and
  - ➢ decision support tools such as SimClim facilitate prioritization of adaptation options.
- Most barriers to the successful application of a risk-based approach to adaptation relate to the existence of, and access to, information.
- Numerous recommendations arose from in-country discussions; arguably the most significant relate to advocating the use of the risk-based approach to adaptation, both within the region and internationally.
- A deficiency of the current project- and community-focused case studies is that they all relate to high islands and, with one exception, to islands on which the national capital is located; additional case studies, both in Asia and the Pacific, are required.

Source: CCAIRR findings.

A. Follow-Up to the Case Studies

Updates on the status and subsequent key steps are provided for each of the six case studies.

Climate Proofing a Portion of the Circumferential Road, Kosrae, the Federated States of Micronesia

Before proceeding to build the road, the government of the state of Kosrae is seeking funding from bilateral or multilateral aid providers, to cover the incremental costs of the climate proofing. Serious consideration is being given to seeking funds from the Global Environment Facility (GEF) to cover the incremental costs of climate proofing the design and construction of the entire unbuilt section of RS4. Funding would also be requested to cover the incremental costs of maintaining and protecting the biodiversity of the areas the road would traverse, including the *Terminalia* forest. Protecting biodiversity, and ensuring that the road could withstand both present and anticipated climate-related risks, would help ensure that the roadbuilding project received all environmental and other approvals from the state. These must be received before construction commences.

Climate Proofing the Western Basin Breakwater, Avatiu Harbour, Rarotonga, Cook Islands

The Government of the Cook Islands is, with the cooperation and assistance of the South Pacific Applied Geosciences Commission and Australian Assistance for International Development, proceeding with the feasibility study for coastal protection systems, including the breakwater. The study will use the design parameters generated in the case study.

In part as a result of the quantification of current and anticipated risks to economic and social assets on the north coast of Rarotonga, consideration is being given to seeking funding from GEF to cover the incremental costs of providing enhanced protection to those assets.

Walung, a community at the southwest corner of Kosrae, would be one of the many beneficiaries of the Circumferential Road's Completion.

Stakeholders discuss the findings of the Breakwater Case Study.

Climate Proofing the Community of Avatiu-Ruatonga, Rarotonga, Cook Islands

At a meeting of the Cabinet of the Government of the Cook Islands held on August 10, 2004, the Cabinet

- instructed the Ministry of Works and Environment Services to develop and implement an acceptable plan for regular excavation of gravel and other materials that have accumulated in the beds of streams in Rarotonga, as an urgent measure to reduce the risk of flooding, now and in the future; and
- approved submission of a proposal to New Zealand Assistance for International Development for funding the Cook Islands National Sustainable Land Development and Resource Management Project.

The latter project builds on the approach taken, and methods used, in the Avatiu-Ruatonga Case Study. Significantly, the proposed decision support system and land use management tools will consider many factors in addition to climate-related risks, in order to promote sustainable land management plans and practices.

Climate Proofing the Community of Sapwohn, Sokehs Island, Pohnpei, the Federated States of Micronesia

A meeting held to update members of the community regarding the findings of the case study resulted in the following recommendations:

- If funding assistance can be realized to put into action the findings of the case study, then priority should be accorded those who will be affected most by climatic conditions, such as flooding from surface runoff or high sea levels.
- Make the road going up to the upper portion of the village an all-weather road, so that people who have land in the upper portion of the village can relocate to this area.
- Negotiate with the Nanmarki of Sokehs (the paramount traditional chief of Sokehs), the state governor, and whoever is responsible for public lands, to make land available for the relocation of those who are staying with families in the village but do not have land in the village.
- Discourage more dredging of the reef in front of the village.
- Have the Pohnpei state government relocate the sewage outfall situated on the leeward side of the

The Acting Prime Minister of the Cook Islands is briefed on the case study findings.

At a Sapwohn Community Meeting, local residents discuss the findings of the case study.

village to a safe distance from the village or any village that is currently affected by this sewage outfall.
- Provide an engineer who can understand the situation in the village and can advise as to where future structures can or cannot be built, when drainage works can or cannot be built, and where sewer systems can or cannot be built.
- Build a road outside the ring of mangrove to be the main road; such a road would also act as a sea wall.

The Pohnpei state government is undertaking another case study, this time on one of the Outer Islands of Pohnpei (Nukuoro); a deficiency of the current project- and community-focused case studies is that they all relate to high islands and, with one exception, to islands on which the national capital is located.

Climate Proofing the Federated States of Micronesia Sustainable Development Plan

The Government of the Federated States of Micronesia (FSM) has requested the Asian Development Bank (ADB) to assist with the climate proofing of the Infrastructure Development Plan (IDP). ADB is currently developing a methodology to determine the costs of climate proofing an infrastructure development project at the stage of project preparation technical assistance (PPTA) (Appendix 5).

Climate Proofing the Cook Islands National Development Strategy

At a meeting of the Cabinet of the Cook Islands held on August 10, 2004, the Cabinet

- approved the recommendations for climate proofing the National Sustainable Development Strategy that is currently in preparation; and
- approved adoption and implementation of the National Guidelines from Mainstreaming Adaptation to Climate Change (NGMACC).

Participants in this meeting in Rarotonga recommended that the Government seek assistance from ADB to climate proof the IDP.

The Acting Prime Minister of the Cook Islands is briefed before the Cabinet approves the adaptation mainstreaming guidelines and the climate proofing recommendations.

B. Implications for ADB Project Processing and Operations

The implications of the case study findings for ADB project processing and operations are discussed as responses to a series of questions that arose during preparation of the case studies.

Is Climate Change a Reality?

Normally such a question is answered by showing graphs of past observations and future projections of such variables as global temperature, precipitation, and sea level. But the most compelling and appropriate evidence is to assess the recent and projected changes in relevant variables for a location or area of interest. The climate risk profiles (CRPs) for the FSM and the Cook Islands (Appendixes 1 and 2, respectively) present the results of just such assessments. They contain persuasive evidence that significant changes in climate (notably in both extreme events and interannual variability) will take place in the coming decades. Moreover, these changes are consistent with changes observed over the past few decades, and in some cases even longer.

The variables considered in the risk profiles are:

- heavy rainfall events;
- drought;
- high sea levels and storm waves;
- strong winds; and
- extreme high air temperatures.

How will Climate Change Reduce Project Sustainability (e.g., Lifetime)?

The increases in extreme events that form part of climate change will place increasing stresses on structures, infrastructure, communities, and other assets and entities. Take, for example, the portion of Kosrae's circumferential road that is scheduled for construction this year or next. It will have a design life of 50 years, and the design rainfall is the hourly rainfall with a return period of 25 years. Prior to the case study activities, the road had been designed based on an hourly rainfall of 177 mm. But more accurate estimates of hourly rainfall for Kosrae (no observed data were available) suggested that the design rainfall should have been 190 mm and that this may increase to 254 mm by 2050.

Maintenance and repair costs for the 6.6 km of road were estimated for present conditions and for the conditions projected to prevail under climate change. The accumulated costs over the 50-year life of the road were $16 million and $5 million, respectively. These costs must be compared to the original construction costs: $2 million if built to the original design and $2.5 million if built to a climate proofed design. Clearly, the escalating repair and maintenance costs will threaten the long-term viability of the road if it is not built to a climate-proofed design.

This example is used to underpin a general response to the question. Project viability will be threatened as a result of climate change unless measures to address the increases in climate-related risks are incorporated into the initial design of the project.

How can Project Sustainability be Maintained Despite Climate Change?

The short answer is by climate proofing the project at the design stage.

Again, using the Kosrae road as an example, net present values for the 50-year life of the road were estimated to be as follows:

Current design

- no climate change — $4.4 million
- with climate change — $7.8 million

Climate-proofed design

- with climate change — $5.0 million

The climate-proofed design yields an internal rate of return of 11%.

In Kosrae a similar section of road has already been built. It is instructive to compare the incremental costs of climate proofing the two sections of road. The incremental cost to climate proof the as yet unbuilt section is $77,000 per km, while the cost of retroactively climate proofing the completed portion is $243,000 per km—a much more expensive option.

The key message is that project viability is best assured by ensuring that measures to address the increasing climate-related risks are incorporated into the project design. Retroactive climate proofing adds significantly to project costs and may lead to a failed project.

Will Addressing Climate Change Increase Project Costs and/or Reduce Project Viability?

Climate proofing may increase the capital costs of a project, but normally immediate gains will be realized, due to reduced maintenance and repair costs.

A key question is when will the savings offset the higher initial costs? For the as yet unbuilt section of the Kosrae road, the answer is about 15 years. This emphasizes the need to assess costs over the design life of the project (including decommissioning, if appropriate), rather than simply focusing on minimizing the initial capital costs.

What are the Implications for Governments?

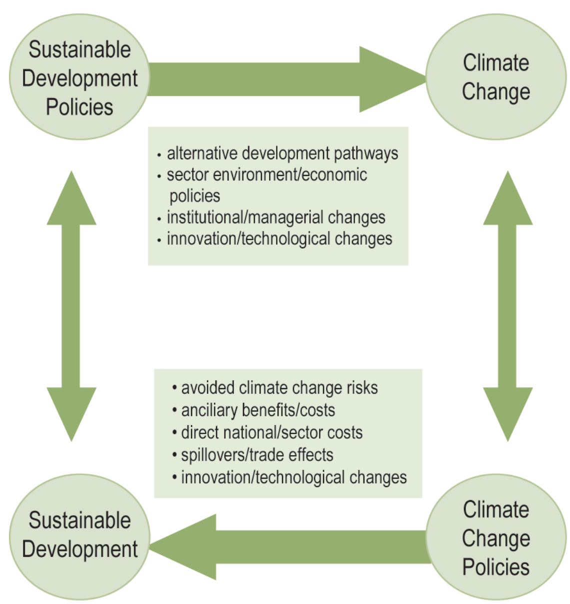
Governments will have to cope with significant implications, but they can be summarized as follows:

- The likelihood of adverse weather and climate conditions has been shown to be already high and projected to increase in the future.
- The likelihood of adverse consequences of these weather and climate events is also already very high, and is likely to increase markedly as a result of climate change.
- Most climate-related risks can be reduced in a cost-effective manner.
- Care should be exercised to ensure that future development does not exacerbate climate-related risks.
- Governments should ensure that all proposed, new, and upgraded development projects are climate proofed at the design stage:
  - ❑ This should be part of good professional practice.
  - ❑ National and state CRPs should be used as the basis for "climate proofing".
  - ❑ Compliance with this requirement should be assessed as part of enhanced (climate proofed) environmental impact assessment (EIA) procedures.
- Governments should undertake cost-benefit analyses of all major development projects, including determining the incremental costs and benefits. If it is a developing country, and the incremental costs are large, the Government should request developed country aid providers and other relevant agencies to fund those incremental costs.
- Governments should ensure that all regulations (e.g., building codes, public health regulations) are also climate proofed, as this will allow enforcement of policies and plans that should, themselves, be climate proofed.
- Governments should consider developing and implementing NGMACCs, similar to those in Appendixes 3 and 4, for the Federated States of Micronesia and the Cook Islands, respectively.

What are the Implications for ADB Operations?

Climate change poses a threat to important development issues such as poverty reduction, water and energy supply, waste management, wastewater treatment, food security, human health, natural resources, and protection against natural

Figure VII.1. Linkages Between Sustainable Development, Climate Change, and the Policies in these Areas



Source: CCAIRR findings.

hazards. Development also impacts on climate change.

Linkages between climate change and development are increasingly recognized (Figure VII.1). Climate change is largely the result of human-induced greenhouse gas emissions that are driven by socioeconomic development patterns characterized by economic growth, technology, population growth, and patterns of governance. These socioeconomic development patterns, in turn, determine vulnerability to climate change and the human capacity for greenhouse gas mitigation and for adaptation to climate change. The impacts of climate change on human and natural systems in turn influence socioeconomic development patterns and, hence, greenhouse gas emissions.

Increasingly, it is recognized that the artificial separation of these activities results in missed opportunities for synergies, unrecognized and undesirable trade-offs, and mutual interference in ensuring successful outcomes. The effect of climate policy integrated into wider development policies can be greater than the sum of concurrent, unrelated policies.

As noted by the GEF (2004), the linkages between adaptation and sustainable development can be made at several different scales or levels:

Local level. The most severely impacted communities in the developing countries will be those communities living in regions most exposed to climatic impacts (e.g., flood- and drought-prone areas within countries). As these people are often poorer than the rest of the population within the country, they are in special need of targeting to provide support for adaptation to climate change.

Sector level. Within countries, the most adversely impacted sectors would include agriculture, water resource management, and coastal zone management, as well as disaster management (e.g., floods, cyclones, and droughts). Policy makers, planners, and managers in those sectors need to consider the future impacts of climate change in their sector planning;

National level. At the national level, policy makers need to take into account the potential adverse impacts of climate change in planning their development strategies within and across sectors. An important feature of national policymaking is the need to strengthen existing policies and actions that enhance a country's ability to respond to its vulnerabilities to climate change, while seeking to cease policies and actions that may lead to "maladaptation" to climate change.

Regional and subregional level. Many climate change impacts will be felt acutely at the regional and subregional level in a number of key parts of the world; thus regional and subregional planning and coordinated actions may be called for.

Global level. The global nature of the challenge will require the global community to act together under the United Nations Framework Convention on Climate Change (UNFCCC) as well as to respond collectively to the impacts of climate change within other development efforts: for example, many of the Millennium Development Goals may be in danger of not being achieved due to the adverse impacts of climate change.

By way of example, the expected greatly increased frequency of extreme climate events has significant implications for energy supply, transformation, distribution, use, and demand. Examples include

- increased difficulty in supplying fuel for transport and power generation from the high seas, making marine transport to islands problematic at times;
- damage to roads and bridges by high winds that restricts fuel deliveries by truck or tanker;
- physical storm impacts from winds and flying debris on photovoltaic energy supply systems;
- changes in rainfall quantities and patterns for hydro total energy generation and vulnerability to droughts, and thus the need to consider increased storage in new and renovated hydro schemes;
- increased maximum wind speeds impacting on turbine and tower survivability risks for wind power;
- increased risks of damage to generation plant buildings, infrastructure, distribution lines, and transformers; and

- increased demand for climate control to counter more frequent extreme high temperatures, such as by the tourism sector.

For ADB to show leadership with respect to adaptation to climate change, it must ensure that both its internal policies and procedures, and the national implementation activities with which it is associated, recognize the importance of

- enhancing enabling environments at the national level, in the manner indicated in the NGMACCs (Annexes 3 and 4);
- maximizing the synergies between ADB's sustainable development initiatives (e.g., poverty reduction) and its climate change initiatives;
- ensuring that all development projects with which it is associated comply with best professional practices, including climate proofing projects, policies, and plans in ways that reduce, to an acceptable level, the risks identified in national CRPs; and
- preparing CRPs for all of ADB's Pacific developing member countries.

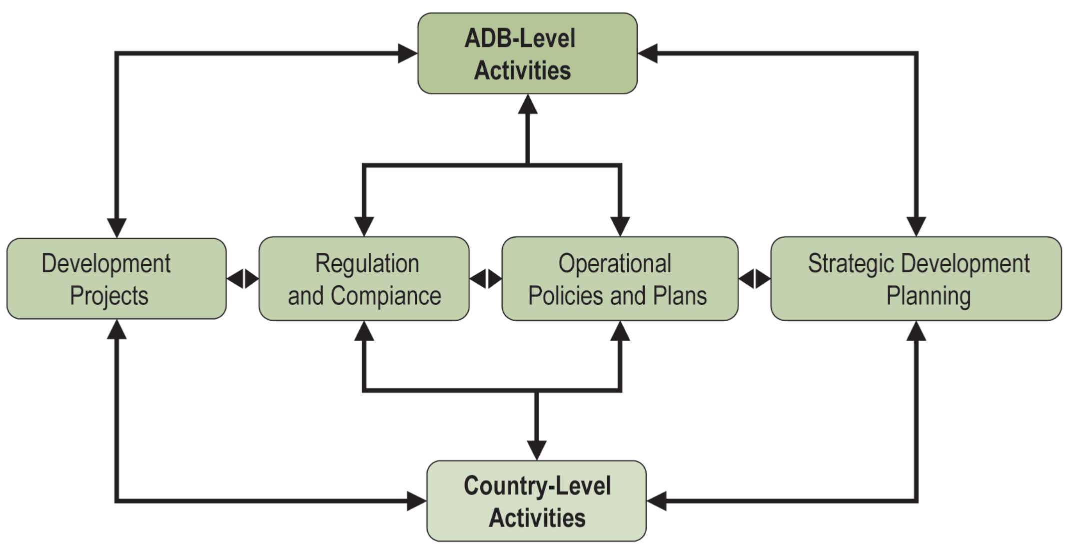
Experience in both the Cook Islands and the FSM is highlighting the importance of the enabling environment for successful adaptation, across all the many dimensions of adaptation (see Figure IV.2).

Experience in both the Cook Islands and FSM is also highlighting the opportunities to exploit synergies between ADB's sustainable development initiatives and climate change adaptation initiatives. Examples include ADB's technical assistance in preparing national and sector strategic development plans and in strengthening the regulatory environment and environmental management in the Outer Islands of both countries.

Thus, we are seeing the benefits of the very strong and intentional complementarities between the adaptation mainstreaming initiatives being undertaken within ADB and those developed and demonstrated at the country level via the six case studies prepared under TA 6064-REG Climate Change Adaptation Program for the Pacific (Second Phase, Country Level Activities), 2003.

Figure VII.2 highlights areas where efforts can be made to maximize the synergies. Table VII.1 indicates ways in which ADB might modify its

Figure VII.2. Nexus of ADB and Country-Level Adaptation Mainstreaming Activities



ADB = Asian Development Bank.
Source: CCAIRR findings.

Table VII.1. Tools and Timing for Mainstreaming Adaptation in ADB Procedures

Procedure	Entry Point	Timing	Tools
Country Strategy and Program (CSP) CSP Update (CSPU)	Country Environmental Analysis	CSP/CSPU	[Strategic Environmental Assessment] **Climate Risk Profile** Management Status and Gap Analysis
Project Preparation Technical Assistance	Technical Assistance Paper Environmental Assessment, incl. Environmental Management Plan Report and Recommendation of the President	Pre-Design Project Design	**Project Adaptation Brief** Terms of Reference Rapid Environmental Assessment Environmental Impact Assessment
Implementation	Project Performance Report	Project Implementation	Environmental Management Plan
Project Completion and Evaluation	Project Completion Report Project Audit Report	Project Completion	Performance Audit

Source: CCAIRR findings.

policies and procedures to ensure that the design and funding implications associated with climate proofing its infrastructure, community, and other development projects are addressed early in the project cycle. Such initiatives mean that climate proofing will become an integral part of best practice, rather than a later add-on.

It would require that ADB continue to develop methods to identify, early in the project cycle, the incremental costs of this climate proofing (see Appendix 5), so that these costs can be met from sources other than loans, etc., to the developing country. Sources could include the GEF and other funding sources managed by ADB. Such moves would allow ADB to set and demonstrate a standard of good practice among multilateral lending institutions, with the hope that others will follow.

The following principles were used to guide the specific suggestions as to how the ADB might mainstream climate change adaptation in its policies and procedures:

- additions to policies and procedures must be consistent with and add value to existing policies and procedures;
- they must expedite project preparation and implementation rather than add further requirements and place additional work demands on staff; and
- they must not only reflect best practice, but in fact lead it.

At a strategic level, CRPs (see Appendixes 1 and 2 for examples) can help ensure that the Country Environmental Analysis gives adequate recognition to climate-related risks. In turn, such risks should be reflected in the Country Strategy and Program (CSP). Climate risks would be featured in the CSP in at least two ways: i) highlighting the need for projects and other initiatives to be climate proofed, in order to address the risks identified in the CRP; and ii) identifying projects and other initiatives that could reduce the level of risk and at the same time contribute to sustainable development. The CSP Update (CSPU) would be an ideal instrument to ensure that the new understanding regarding climate-related risks, and how they might best be addressed, is reflected and acted upon without undue delay.

At the operational (project) level, the CRP would provide guidance to ADB staff who are preparing the project preparatory technical assistance (PPTA). Specifically, the CRP would be used to ensure that the terms of reference for the technical assistance include the requirement that climate risks be reflected in both pre-design work and the actual project design. Under normal circumstances, best practice would automatically result in this occurring. But experience shows that many professionals are unaware of the need to take into account current, let alone future, climate-related risks. At best, they may be aware of the need, but lack the information and tools to meet such a standard. The CRP meets these needs, aided where necessary by a Project Adaptation Brief—in effect, a CRP tailored to a specific project.

If the process works as intended, reflecting climate-related risks in project design will become standard practice. Any lapses in the quality of the work will be detected in peer reviews of reports presenting the results of the Initial Environmental Examination and/or the EIA.

Further quality control on the process will come via Project Performance Reports on the effectiveness of the Environmental Management Plan. The plan should include contingencies if the measures to address climate-related risks prove inadequate. Another, but similar, level of quality control would occur after project completion, via the Project Performance Audit.

At a higher level, these procedures would need to be recognized and formalized within ADB's policies.

C. The Global Environment Facility as One Mechanism for Financing Adaptation[2]

The GEF is one source of financing for climate proofing development projects, communities, and other vulnerable entities.

In response to the urgent needs of vulnerable countries, in the last few years the Conference of the Parties (COP) to the UNFCCC has given increasing recognition to the issues of climate change vulnerability and adaptation. The COP has requested the GEF to manage three new climate change funds. Only the first of the three funds described below is operational. The Strategic Priority on Adaptation and the Small Grants Program are also operational. Both are also described below.

Least Developed Countries Fund

One specifically defined role for the Least Developed Countries Fund is support of preparation and implementation of national adaptation programs of action (NAPAs) in Least Developed Countries. NAPAs are aimed at identifying the most at-risk areas and sectors in those countries and prioritizing urgent adaptation measures that they should implement. The COP has thus requested the GEF to support implementation of NAPAs as soon as possible after their completion and to develop draft operational guidelines for this Fund.

Other activities supported through the Fund include

- strengthening national focal points to enable implementation,
- training in negotiating skills and language,
- promotion of public awareness programs,
- development of adaptive technology, and
- strengthening of the capacity of meteorological and hydrological services to collect and disseminate information.

Contributions to the Fund are voluntary.

[2] Information in this section is based primarily on "GEF Assistance to Address Adaptation", GEF/C.23/Inf.8, 28 April 2004.

Special Climate Change Fund

The Special Climate Change Fund finances activities in four areas, all of which are complementary to those funded by the GEF climate change focal area. The four areas are:

- adaptation to climate change;
- transfer of technologies;
- measures related to several defined sectors including energy, transport, industry, agriculture, forestry, and waste management; and
- steps to diversify economies in developing counties under Article 4, paragraph 8(h) of the UNFCCC.

COP guidance for the operation of this Fund includes giving priority to support for activities related to adaptation and technology transfer. The guidance identifies priority sectors such as water resources, land management, agriculture, health care, infrastructure development, fragile ecosystems, and integrated coastal zone management. The guidance also calls for activities to improve monitoring of diseases and vectors affected by climate change and related forecasting and early warning systems, and also in this context improvements in disease control and prevention. The Special Climate Change Fund also supports capacity building for preventive measures, planning, preparedness, and management of disasters relating to climate change, including contingency planning, in particular for droughts and floods in areas prone to extreme weather events. The Fund also assists in strengthening existing national and regional centers and information networks for rapid response to extreme weather events and, where needed, establishing new ones.

Contributions to the Special Climate Change Fund are also voluntary.

Adaptation Fund

The Adaptation Fund will receive revenues from a share (2%) of the proceeds from Clean Development Mechanism projects under the Kyoto Protocol and will be used to finance concrete adaptation projects and programs. Additional voluntary contributions to this fund are also being encouraged.

Strategic Priority on Adaptation—Piloting an Operational Approach to Adaptation

Recent guidance from the COP called for the GEF to establish pilot or demonstration projects to show how adaptation planning and assessment can be practically translated into projects that will provide real benefits, and can be integrated into national policy and sustainable development planning. This would be on the basis of information provided in the national communications, or of in-depth national studies, including NAPAs. The GEF has allocated $50 million during the fiscal years 2005–2007 to support adaptation projects through a strategic priority in the climate change focal areas. This is called "Piloting an Operational Approach to Adaptation".

The Strategic Priority on Adaptation is designed to support a portfolio of projects that will maximize the opportunity for learning and capacity building, and that will be representative of particularly vulnerable regions, sectors, geographic areas, ecosystems, and communities. The approach is intended to provide the GEF and its partners with the opportunity to implement and learn about adaptation within a wide scope, thereby providing valuable lessons and guidance for the international community as it moves forward in assisting developing countries to adapt to the impacts of climate change. Under the pilot, the GEF will fund the incremental cost of those adaptation activities that generate global environmental benefits, as well as the incremental cost of selected adaptation activities that are identified as high priorities by national communications. Baseline activities will be funded by the governments, nongovernment organizations, bilateral and other sources of financing.

Box VII.2 provides the operational guidelines that will be followed in developing projects for the Strategic Priority. Several points merit highlighting:

- Projects under the pilot will address adaptation in the context of countries meeting their national development objectives; adaptation activities must be country-driven and integrated into national sustainable development planning and poverty reduction strategies.

- The pilot will offer the opportunity to test selected adaptation measures in key vulnerable sectors; the experience and lessons from the pilot should assist the global community as it seeks to address the issue of adaptation to climate change.
- Selection of particularly vulnerable sectors will be based on information contained in the national communications to the UNFCCC, NAPAs, and other major national or regional studies.
- The pilot will include a mixture of large and medium-sized projects; financing will also be provided through the Small Grants Program.
- The level of GEF financing will be determined on the basis of incremental cost reasoning; GEF resources will be related to the generation of global environmental benefits and will be determined on the basis of the incremental cost principle. In addition, the GEF, when appropriate, will finance the incremental cost of additional activities that a country must include within its development planning in order to address climate change impacts.
- It is expected that the incremental cost approach and cofinancing will be consistent with the GEF overall portfolio experience. Cofinancing for each project will depend on the delivery of global environmental benefits, additional costs associated with actions necessitated by climate change, and the degree of capacity building; the larger the project, the greater the expected cost sharing.

BOX VII.2

Operational Guidelines for the Strategic Priority "Piloting an Operational Approach to Adaptation"

The following operational guidelines apply to the pilot:

- The guidance from the United Nations Framework Convention on Climate Change requests the Global Environment Facility (GEF) to establish "pilot or demonstration projects to show how adaptation planning and assessment can be practically translated into national policy and sustainable development planning."
- "Activities to be funded should be country-driven, cost-effective, and integrated into national sustainable development and poverty-reduction strategies." The adaptation measures will be guided by such preparatory work as the first and second national communications, National Adaptation Programs of Action (NAPAs), and other relevant country studies.
- The portfolio is designed to maximize the opportunity for learning and capacity building and will be representative of particularly vulnerable regions, sectors, geographic areas, ecosystems, and communities.
- The experiences and lessons from the projects should be applicable in a wide context: the GEF will use experience from the strategic priority to develop good practices and estimates of the costs of adaptation to better mainstream adaptation into the full range of GEF activities;
- The pilot or demonstration projects must include (i) activities within a natural resources management context that generate global environmental benefits, and (ii) adaptation measures that provide other major development benefits (e.g., water, energy, healthcare, agriculture, biodiversity).
- The existing eligibility criteria for GEF funding, such as country drivenness, ecological and financial sustainability, replicability, stakeholder involvement, etc., will be applied to the projects submitted under the Strategic Priority;
- The Strategic Priority is funded to $50 million over 3 years and will require a mixture of 20 to 30 large and medium-sized projects to construct an appropriate portfolio. It is envisaged that about $5 million will be set aside for the Small Grants Program.
- It is expected that the incremental cost approach and cofinancing will be consistent with GEF practices and overall portfolio experience; cofinancing for each project will depend on the delivery of global environmental benefits, additional costs associated with actions necessitated by climate change, and the degree of capacity building. The larger the project, the greater the expected cost sharing;
- A monitoring and learning program to achieve active learning and dissemination during the development and implementation of the whole portfolio will be considered.

The pilot on adaptation became operational on July 1, 2004.

Source: Information in this section is based primarily on "GEF Assistance to Address Adaptation", GEF/C.23/Inf.8, 28 April 2004.

Small Grants Program

Recognizing that small communities are often the most severely affected, yet the least equipped to deal with the impacts of climate change, up to 10% of the resources under the Strategic Priority on Adaptation will be allocated to the GEF Small Grants Program. It will work with the GEF Secretariat and the implementing agencies to pilot community adaptation initiatives through its existing small grants program. The Program will

- develop community-based capacity and tools to respond to adaptation;
- finance diverse community-based adaptation projects in a number of selected countries; and
- capture and disseminate lessons learned at the community level.

In order to be eligible for GEF funding, community adaptation projects must also satisfy the criteria of adaptation incrementally (Box VII.2). Interventions will include both activities that generate global environmental benefits and activities that generate broader development and local benefits (e.g., in the water, health care, and agriculture sectors).

Pilot activities under the Small Grants Program will be implemented in three overlapping phases:

- Phase I. Program-wide capacity development on adaptation and developing effective management procedures for the use of grants: capacity development will be at the global level, country program level, and local level.
- Phase II. Funding for a portfolio of community-based adaptation projects in a number of selected countries: this phase will also focus on capacity development, primarily at the local level.
- Phase III. The final phase is meant for effective capturing of lessons; it will involve continuous monitoring and evaluation of the country programs to assess lessons, and disseminate the overall results of the pilot program.

The Small Grants Program strategy will facilitate interlinkage of the pilot community adaptation measures with other GEF and non-GEF national adaptation activities. It is envisaged that communities living in countries representing different ecosystems and natural resource management practices will be selected for funding of adaptation initiatives. For example, the portfolio will include some Least Developed Countries and Small Island Developing States, as well as countries with mountainous ecosystems, coastal ecosystems, flood plains, and dry lands.

Mainstreaming Adaptation into Other GEF Focal Areas

Projects funded under the Strategic Priority for Adaptation will build on and expand the scope of the existing adaptation experience of the GEF portfolio, which generates global environmental benefits and emphasizes linkages among all focal areas.

Vulnerability and adaptation to climate change are becoming increasingly relevant components in projects across all GEF focal areas. The GEF portfolio in biodiversity, international waters, and land degradation includes selected examples of activities that build capacity or support measures that help countries respond to the consequences of climate change. However, this support is typically indirect and rarely if ever undertaken specifically because of ongoing or expected climate risks. Untapped opportunities to integrate adaptation concerns into these focal areas appear to exist, thereby strengthening within GEF-financed projects the linkages between climate change and the attainment of other global environmental objectives.

At the end of the pilot, in addition to the lessons that are learned from projects directly financed under the Strategic Priority, the GEF should also be able to point to a strengthened portfolio of activities in all areas that serve to enhance the capabilities of countries to adapt to climate change impacts in all focal areas. At the end of the pilot, adaptation should thus be fully mainstreamed in the GEF portfolio.

D. Lessons Learned and Demonstrated

Numerous lessons were learned during the preparation of the case studies, and from associated activities. Those demonstrated by the case studies are summarized in Box VII.3.

BOX VII.3

Key Lessons Learned and Demonstrated

Climate change will manifest itself largely as changes in the frequency and consequences of extreme events and interannual variations (e.g., the El Niño Southern Oscillation), rather than as long-term trends in average conditions.

The climate risk profiles for both the Cook Islands and the Federated States of Micronesia reveal high current levels of risk related to extreme rainfall, drought, strong winds, high sea levels, and extremely high temperatures, with most of these risks projected to increase substantially in the near term as a consequence of global warming.

While uncertainties abound in projections of greenhouse gas emissions, and of the response of the global climate as estimated by models and other methods, confidence in estimates of future changes in climate-related risks are improving, due to the consistency in i) model-based projections of changes in the likelihoods of extreme events and climate variability, and ii) between these projections and the observed changes in these likelihoods over recent decades.

While inconsistent with international conventions, at a practical level adaptation should thus focus on reducing both present and future risks related to climate variability and extremes. In many instances current levels of climate risk are already high, due to increases in risk over the past few decades. Adapting to current climate extremes and variability prevents precious financial and other resources from being squandered on disaster recovery and rehabilitation, and is an essential step to being able to withstand the pending changes in climate.

A risk-based approach to adaptation is both desirable and practicable:

- It combines both the likelihood and consequence components of climate-related impacts.
- It assesses risks for both current and anticipated conditions, with the option of examining either specific events or an integration of those events over time.
- Risk assessment and management are common to many sectors—e.g., health care, financial, transport, agriculture, energy, and water resources.
- Familiarity of planners and decision makers with risk management facilitates mainstreaming of risk-based adaptation.
- It facilitates an objective and more quantitative approach, including cost-benefit analyses that result in evaluation of the incremental costs and benefits of adaptation and assist in prioritizing adaptation options.
- It involves many players but also provides a framework that facilitates coordination and cooperation, including the sharing of information that might otherwise be retained by information "gate keepers".
- It is linked to sustainable development by identifying those risks to future generations that present generations would find unacceptable.

Adaptation has many dimensions and must be viewed as a process. This means that a framework and associated methodology are essential:

- Adaptation takes place at many levels, and these need to be linked across the full ranges of time frames, spatial scales, and sectors.
- The success of adaptation is enhanced by integration of bottom-up and top-down approaches.
- Top-down activities should focus on creating a favorable enabling environment, such as by climate proofing policies, plans, and regulations. This is a prerequisite to successful adaptation and should be the major emphasis and benefit of adaptation mainstreaming.
- Bottom-up approaches reflect the fact that adaptation typically takes place at the local level—in communities, households, businesses, etc.
- Climate Change Adaptation through Integrated Risk Reduction (CCAIRR) operationalizes the framework and provides relevant methodologies.
- Decision support tools, such as SimClim, that facilitate intercomparison of adaptation measures, are fundamental to ensuring the effectiveness of adaptation.

Typically, adaptation is a cost-effective intervention, especially when implemented at the concept and design stages of a project. Retrospective adaptation normally incurs far greater costs.

Climate change, especially through changes in extreme events and variability, has the potential to reduce project sustainability, such as the effective lifetime of infrastructure, community, and other development projects.

Project sustainability can be maintained, however, despite climate change, through timely identification of the climate-related risks and implementation of measures to reduce those risks to an acceptable level.

Addressing climate change is unlikely to increase project costs, and hence reduce project viability, but this requires that costs and benefits be evaluated over somewhat longer timeframes than is common practice today.

The case studies give rise to messages that must be listened to and acted upon by governments, multilateral financial institutions, and the other players who have key roles in enhancing the enabling environment for adaptation.

Source: CCAIRR findings

E. Barriers to Successful Application of the CCAIRR Framework and Methods

Before generalized findings and lessons can be drawn from case studies prepared using a risk-based approach to adaptation, many more examples will need to be developed. As noted above, all the current project- and community-focused case studies presented in this book relate to high islands in the Pacific and, with only one exception, to islands on which the national capital is located.

Experience gained in using the Climate Change Adaptation through Integrated Risk Reduction (CCAIRR) framework and methods has resulted in the recognition of a number of impediments to its more widespread application. None of these is critical, and advance knowledge of the challenges and limitations will help ensure that planning for the preparation of additional case studies, as well as for the practical application of adaptation measures, can take these limitations into consideration and thus reduce their impact appreciably.

It is desirable to have internationally consistent assessment methodologies. International agencies, such as the IPCC, play major roles in establishing best practices. They would need to formally endorse and encourage a risk-based approach to adaptation before widespread uptake occurs. Present best practice favors the more traditional assessments of vulnerability and of adaptation options. The limitations of such approaches have traditionally included

- a lack of formal assessment of the likelihood of future extreme events or variations in climate or of baseline conditions;
- a focus on individual events (e.g., an extreme rainstorm or a cyclone) or on a future date, rather than on an aggregation of the anticipated climatic conditions over a specified time period in the future;
- the inability to differentiate between the costs of current climate extremes and variability and the future costs of those events, plus any systematic trend (i.e., inability to evaluate the incremental costs of climate change);
- the difficulty of incorporating economic, social, and wider environmental scenarios into the assessment procedures;
- lack of a functional link between the vulnerability and adaptation assessments; and
- lack of formal procedures for prioritizing adaptation options on the basis of cost and other measures of efficiency and effectiveness.

Until a risk-based approach to adaptation is formally endorsed and encouraged, documentation and training opportunities will be lacking. While a risk-based approach requires no greater skills and experience than are called for in the traditional assessments, building a cadre of in-country expertise is necessary. While parallel frameworks and methodologies are being advocated, confusion and arguments for maintaining the status quo will occur.

Once these initial barriers have been overcome, and a commitment has been reached to undertake a specific risk-based assessment, operational barriers may occur. Most of these exist even with the more traditional vulnerability and adaptation assessments, but some barriers may be increased, at least in the initial implementation of a risk-based approach. Many barriers also relate to information access, but additional barriers include the need for

- formal specification of risk-based targets that define future levels of acceptable risk, requiring consultation with, and consensus among, key stakeholders;
- specification of relationships between magnitude and consequence of risk events of relevance, which are usually presented in the form of stage-damage curves (see Chapter VIII);
- "rules" that specify future social, economic, and wider environmental changes; and
- appropriate discount rates to be applied to future costs and benefits: in SimClim the discount rate is set by the user and can be adjusted without needing to rerun each simulation.

For the current case studies, all these barriers were overcome. Future efforts to develop additional case studies, as well as to support the practical application of adaptation measures, can build on both the methodologies and experience gained in preparing the current case studies. Thus, the barriers are unlikely to be as imposing as for the initial work reported in this book.

The barriers to information access may prove to be more intractable, though again, experience in preparing the current case studies provides some grounds for optimism. A risk-based approach to adaptation is also an "information-based" approach. This is both a demonstrated strength and a potential weakness.

Information is required to define current return periods (and hence likelihoods) for the risk events of interest (e.g., extreme high sea levels). In some cases, data may not be available for the study region, or only a short period of record is available. Such problems are not specific to the risk-based approach. Thus, regardless of the approach, innovative solutions must be found. For example, as noted in the Kosrae road case study, no *in situ* measurements of sea level have been made in Kosrae. However, satellite-based measurements of sea level were shown to be consistent with more conventional observations (see Appendix 1) and therefore provide a way to overcome the absence of *in situ* measurements. Another example relates to the unavailability of long-term rainfall data for the specific catchment that contributes to the flooding of Avatiu-Ruatonga. Fortunately, short-term rainfall and runoff measurements were available for that catchment. These were used to scale the long-term rainfall records available for a site that was not as representative of the catchment conditions. But some data were missing from the long-term daily rainfall records for Rarotonga. A relationship between rainfall observations for that and a nearby station was used to fill in the missing data.

Significantly, the available information usually requires additional processing in order to estimate current return periods for the risk events. A simple tabulation of descriptive statistics such as the mean, or even percentiles, is insufficient. Moreover, the data must have an appropriate time resolution: hourly, daily, monthly, annual. For example, if the risk events are extreme rainfall and associated flooding, and the catchments are of a size similar to those in Kosrae, Pohnpei, and Rarotonga, an hourly or 2-hourly time resolution will be required. On the other hand, drought studies can use monthly rainfall totals.

The preceding requirements mean that the original data must be accessible, in order to allow for these customized analyses. The main challenge is often gaining access to the original data, rather than issues related to data format or the subsequent analyses. Decision support tools, such as SimClim, support the importing of data in various formats and enable return periods and related statistics to be determined with ease.

The case study experience also provides some optimism regarding access to original observed data. First, requests were made by local members of the CCAIRR team. These individuals were also trained in undertaking the subsequent analyses. Both these approaches were also consistent with the philosophy of enhancing local capacity. Secondly, information providers saw the planned analyses as adding importance and value to the data in their possession. They were also given the opportunity to undertake the necessary analyses, increase their own expertise, and thus be able to respond to future requests from any parties.

A similar situation exists regarding the information required to determine risk event return periods for times in the future. Scenarios of climate-related risk events are normally based on the output of GCMs, but the standard GCM output must be processed in order to derive the return periods and related statistics. An alternative approach is to use a decision support tool such as SimClim, which uses inbuilt routines, including GCM results, to scale the observed data and subsequently determine the required statistics for a specified time in the future (see Chapter VIII).

Other data requirements include the information necessary to characterize the topography of the study area (for flooding due to rain and/or high sea levels) as well as the socioeconomic conditions. As is evident from the Avatiu-Ruatonga and Sapwohn case studies, available elevation data seldom have the spatial and elevation resolutions required to estimate flood depths and extent. The former case study showed that it is possible to generate the required information relatively quickly, at low cost, and with adequate spatial and height resolutions, provided the necessary Global Positioning Satellite (GPS) equipment and suitably qualified operators are available. For Sapwohn, it was necessary to use

Total Station Survey equipment, in part because the overhead vegetation made GPS equipment inoperable. That approach was more time-consuming, but did demonstrate alternative ways to meet the need for such information.

The area and location of structures can be obtained from diverse sources or by a variety of methods. For the Sapwohn and Avatiu-Raratonga case studies, these included use of aerial photographs, census records, and direct observation.

For the Sapwohn case study, other socioeconomic information was obtained from the census records, or by way of simple and rapid on-the-ground observations. Normally, census data is only available in aggregated form, and not for individual structures. To overcome this constraint, a local member of the CCAIRR team was sworn in as a census officer. He subsequently processed the data into the aggregated form required for analysis, using SimClim.

In the case of the Avatiu-Ruatonga case study, the necessary socioeconomic information was acquired from census data in the public domain or by direct observation.

Finally, another important item of information is the cost of the adaptation measures being evaluated in the cost-benefit and other analyses. Appropriately qualified and experienced professionals were asked to estimate the costs, with a representative value being chosen for the analyses. In SimClim, these costs are set by the user, who can subsequently assess the extent to which uncertainties in these cost estimates impact on the prioritization of the adaptation options.

F. Recommendations

Several recommendations evolved from preparing the case studies and from associated activities. Many were prepared, reviewed, and endorsed at the concluding Tripartite Review Meetings held in the FSM and the Cook Islands.

Recommendations Arising from the Final Tripartite Review Meeting—Cook Islands

The four Cabinet decisions related to the Climate Change Adaptation Program for the Pacific (CLIMAP) should be followed up and implemented in a timely manner:

- NGMACCs: implementation will strengthen the enabling environment for adaptation and integrate adaptation with other development initiatives.
- Climate proofing the National Sustainable Development Strategy: implementation will enhance the sustainability of development initiatives, in a cost-effective manner.
- Developing a plan for excavating gravel and other materials from stream beds in Rarotonga: implementation will reduce current and future risks of flooding from heavy rainfall events.
- Securing funding and implementing the activities proposed in the Cook Islands National Sustainable Land Development and Resource Management Project: this is a vehicle for applying the risk-based approach to adaptation and extending it to the Outer Islands as well as to the remainder of Rarotonga.

The Government of the Cook Islands should be assisted to secure financing to cover at least the incremental costs of climate proofing communities and other assets on the north coast of Rarotonga, and in other vulnerable areas.

The Ministry of Works should continue to act as the focal point for facilitating implementation of the risk-based approach to adaptation.

The Disaster Management Unit should be made fully resourced and functional, and its work harmonized with adaptation initiatives in Rarotonga and the Outer Islands.

The Climate Change Country Team of key players and stakeholders should be strengthened and institutionalized, so as to have oversight of a programmatic approach to climate change responses in the Cook Islands, with emphasis on empowering and delegating responsibilities to communities.

The Climate Change Adaptation Program for the Pacific (CLIMAP) results should be used in the Cook Islands Second National Communication to the UNFCCC.

The use of the risk-based approach should be promoted regionally and internationally, in part by including sessions on the CLIMAP case studies in regional and international workshops being convened to address climate, development, and related issues.

Existing information should be made accessible to those undertaking future assessments of climate risk and adaptation.

The case study findings should be made widely available, including being used in preparing materials for the media and in other awareness-raising initiatives.

Follow-up on the case studies should be coordinated and integrated with initiatives undertaken as part of the Comprehensive Hazard Assessment and Risk Management program.

Roles and priorities should be assessed in climate change work, awareness raising, and action, especially at the community level, including

- developing and highlighting viable adaptive responses to climate change —"action, not gloom and doom";
- identifying ways for awareness of climate change to initiate action in multiple target groups, including grassroots;
- using Cook Islands Maori in consultations and in preparation and delivery of materials, and in the gathering of anecdotal and other information on community examples; and
- assessing the effectiveness of consultation, awareness raising, education, and related programs undertaken at community level (possibly by a research student).

Climate change should be incorporated into the NDS and actions should be discussed at the upcoming National Environment Forum, including assessments of climate-related risks.

Integration of science and social science in primary school should be encouraged, where appropriate, and climate change should be promoted as a context for learning in science and social science.

The World Wide Fund for Nature initiative in environmental education should be supported.

Local resources (e.g., funding, teacher training) should be provided for the schools to promote climate change.

Recommendations Arising from the Final Tripartite Review Meeting—Federated States of Micronesia

State governments should strengthen existing and pending regulations in ways that reflect projected increases in climate-related risks.

National and state governments should adopt the NGMACCs.

The national and state governments should climate proof relevant policies and plans in order to strengthen the enabling environment for adaptation, thereby ensuring that future infrastructure and other development projects are themselves climate proofed.

ADB should facilitate the climate proofing of all future infrastructure and other development projects in the FSM; the first few projects to be climate proofed should be documented and disseminated as case studies.

ADB should assist participating countries to secure external funding of the incremental costs of adaptation for the case study projects.

Given that the case studies were developed as part of a regional project, ADB should convene a special regional workshop, or add sessions to already scheduled workshops, to enhance the uptake of the case study findings and methods by other Pacific Island Countries.

The management and administrative arrangements that contributed to the successful preparation of the case studies should be highlighted, specifically in the FSM, as well as the lessons learned that would facilitate improved implementation of similar ADB activities in the future.

Recommendations Based on the Lessons Learned and Demonstrated and on Barriers to Successful Application

Given the results of the case studies, ADB may wish to continue to demonstrate and advocate a risk-based approach to adaptation, both within the region and internationally, noting that it combines both the likelihood and consequence components of climate-related impacts, assesses risks for both current and anticipated conditions, and has the option of examining either specific events or an integration of those events over time.

Other reasons for advocating a risk-based approach include the familiarity of planners and decision makers with risk management, which is common to many sectors including health care, finance, transport, agriculture, energy and water resources, thus facilitating the mainstreaming of risk-based adaptation. The approach also facilitates an objective and more quantitative approach, including cost-benefit analyses that result in evaluation of the incremental costs and benefits of adaptation and assist in prioritizing adaptation options. The risk-based approach involves many players, but also provides a framework that facilitates coordination and cooperation, including the sharing of information that might otherwise be retained by information "gate keepers".

Significantly, a risk-based approach can be linked to sustainable development by identifying those risks to future generations that present generations would find unacceptable.

Advocacy of the risk-based approach to adaptation could extend to encouraging international agencies, such as the IPCC, to formally endorse and encourage a risk-based approach to adaptation, including provision of documentation and training opportunities. A need exists to build a cadre of in-country expertise.

ADB may also wish to give consideration to developing and disseminating additional case studies, especially in countries that are part of continental land masses, but also for atolls and raised coralline islands in the Pacific Ocean and elsewhere. The preparation of generalized findings and lessons is needed, based on new as well as existing case studies that demonstrate a risk-based approach to adaptation.

ADB has the opportunity to show leadership with respect to adaptation to climate change by

- helping to enhance enabling environments at the national level, consistent with the NGMACCs;
- maximizing the synergies between ADB's sustainable development initiatives (e.g. poverty reduction) and its climate change initiatives; and
- ensuring that all development projects with which it is associated comply with best professional practices, including climate proofing, to reduce to acceptable levels the risks that should be described in national CRPs.

ADB is encouraged to prepare CRPs for all its developing member countries, using as examples those already prepared for the Cook Islands and the FSM.

ADB may wish to identify, maximize, and take advantage of the many synergies between its sustainable development initiatives and climate change adaptation initiatives. Examples include ADB's technical assistance in preparing national and sector strategic development plans and in strengthening the regulatory environment and environmental management in the Outer Islands of both the Cook Islands and FSM.

ADB may wish to consider some of the following measures:

- Modify its policies and procedures to ensure that the design and funding implications of climate proofing its infrastructure, community, and other development projects are addressed early in the project cycle.
- Undertake to develop methods to identify, early in the project cycle, the incremental costs of this climate proofing, allowing these costs to be met from sources other than loans, etc., to the developing country.
- Strengthen the Country Environmental Analysis so that it gives adequate recognition to climate related risks. In turn, such risks should be reflected in the CSP.
- Use the CSPU as a mechanism to ensure that new understanding regarding climate-related risks, and how they might best be addressed, are reflected and acted upon without undue delay;

- Use national CRPs to provide guidance to ADB staff preparing PPTAs, thus ensuring that the terms of reference for the technical assistance include the requirement that climate risks be reflected in both pre-design work and the actual project design.
- Adopt the Project Adaptation Brief as a way to tailor the CRP to a specific project.

The results of the present case studies should be used to highlight the following observations:

- It is possible to enhance the sustainability (e.g., lifetime) of projects at risk to climate change by climate proofing such projects at the design stage, noting that this will normally require a small investment relative to the additional maintenance and repair costs otherwise incurred over the lifetime of the project.
- Many adaptation options qualify as "no regrets" adaptation initiatives, including being cost effective.
- Retroactive climate proofing is likely to be considerably more expensive than that undertaken at the design stage of a project.
- Governments should reflect these findings by ensuring that all projects are climate proofed at the design stage, making this part of good professional practice.
- Governments of developing countries should determine the incremental costs and benefits of all major development projects and request that developed country aid providers and other agencies fund these incremental costs.
- National- and subnational-level regulations should be climate proofed, as this will allow enforcement of policies and plans that should themselves be climate proofed in accordance with the NGMACCs.

If a risk-based approach to adaptation is to gain full acceptance, further attention needs to be given to methods that support

- formal specification of risk-based targets that define future levels of acceptable risk;
- determination of the damage costs of flooding from heavy rainfall and sea surges, in combination;
- specification of relationships between the likelihood and consequence of risk events of relevance, and especially the refinement of stage-damage curves;
- quantification of the social, environmental, and wider economic costs of climate variability and change, including extreme events;
- "rules" specifying future social, economic and wider environmental changes; and
- selection of appropriate discount rates to be applied to future costs and benefits.

CHAPTER VIII

Elaboration of the Approach, Methods, and Tools

A. Introduction

As indicated in Figure VIII.1, this chapter provides additional information on the approach, methods, and tools used during preparation of the case studies. It also elaborates the methods that might be used to incorporate climate change adaptation into policy development, planning, and decision-making processes at the national level.

BOX VIII.1

Key Points for Policy and Decision Makers

Additional information is provided on

- an integrated risk-based approach to adaptation, and specifically the Climate Change Adaptation through Integrated Risk Reduction framework and methodology;
- application of risk characterization and management methods to adaptation;
- characterizing baseline conditions;
- building and characterizing scenarios, including scenarios for climate change, sea-level rise, and socioeconomic conditions;
- cost-benefit analysis for evaluating adaptation;
- mainstreaming adaptation in national development planning and implementation;
- adaptation mainstreaming guidelines; and
- SimClim, a decision support tool for a risk-based approach to adaptation.

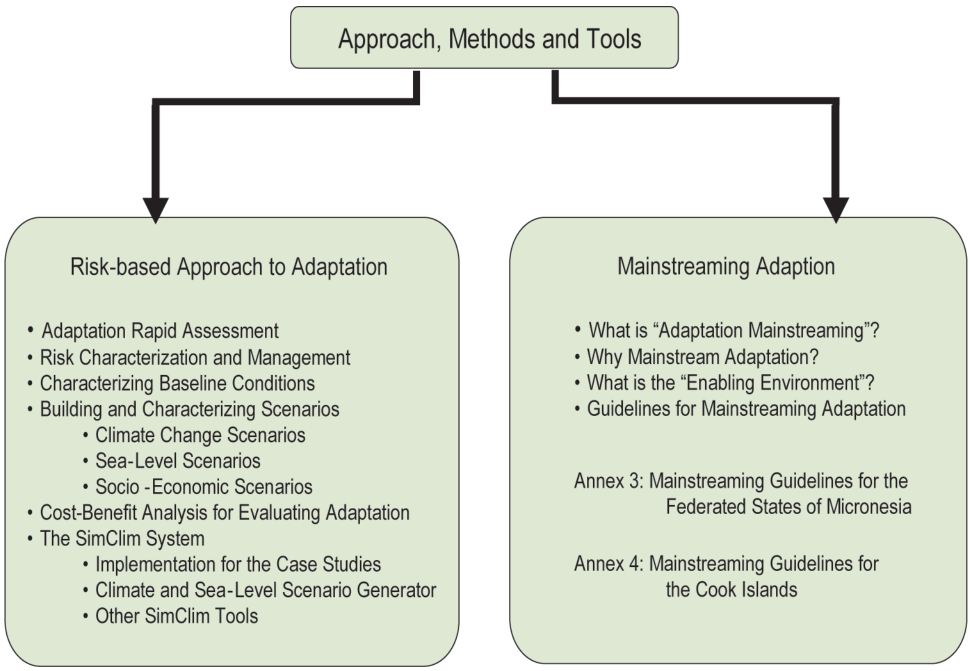
Source: CCAIRR findings.

B. Approach, Methods, and Tools for an Integrated, Risk-Based Approach to Adaptation

Consistent with the idea of adaptation as an ongoing, flexible process, a comprehensive, integrated approach is required. It must address the capacity to adapt, as well as facilitate implementation of specific adaptation measures. Consequently, and as illustrated in Figure IV.1, the approach developed and applied in the case studies included the following linked initiatives and activities:

- capacity building, including awareness raising, empowerment, advocacy, and institutional strengthening;
- provision, enhancement, and application of data, tools, and knowledge;
- identification, characterization, and management of risks related to climate variability and change, including extreme events;
- mainstreaming climate change and adaptation into policies, plans, and development strategies; and
- monitoring and evaluation so that the management of risks and response capabilities are assessed and improved over time.

Figure VIII.1. Structure and Content of the Chapter



Source: CCAIRR findings.

Consultation with stakeholders is an ongoing process, and is one way in which the necessarily strong linkages between these components can be assured.

It is important that, over time, economic and social development should proceed with due regard for the need to implement specific adaptation measures. These include avoidance of development in highly hazardous areas; soft and hard coastal protection; safe building practices and infrastructure designs; and strengthened policies, plans, and regulations that address climate-related risks. In this manner, development becomes climate-proofed to acceptable levels of risk associated with future changes in climate and sea level.

Since the approach is both risk-based and integrated, it is referred to as "climate change adaptation through integrated risk assessment," or CCAIRR (pronounced "care"). The collection of activities makes up the "CCAIRR package". It is important to note that the application of CCAIRR is iterative, involving a number of repetitions of the process. CCAIRR can be used in both a rapid assessment mode or in a more comprehensive risk-based approach to adaptation. Both were used in the preparation of the case studies presented in this book. The rapid assessment mode was employed as part of the initial consultation process to identify potential case studies (see Figures VI.1 and V1.2), including the nature of the climate-related risks, current capacities to address the risks, shortfalls in this capacity, and availability of relevant information. The framework and methods that constitute the full CCAIRR package were used in the preparation of the case studies selected for presentation in this book.

Adaptation Rapid Assessment Methodology

The first iteration of the CCAIRR approach, the Adaptation Rapid Assessment (ARA) mode, is used to provide a situation analysis for a risk-based adaptation study, including documenting the baseline conditions for subsequent implementation of more comprehensive initiatives leading to adaptation. The procedures for a first-order ARA are consistent with the five components of the CCAIRR package spelled out below. It is important to bear in mind that, in practice, the components are best addressed in parallel activities, rather than as linear and sequential steps.

a. Component 1: Capacity Assessment and Strengthening

The rapid assessment begins with an assessment of the extent to which climate change and climate-related risks are part of the current management of resources, assets, and development. A consultative and interactive approach is used to develop the broad picture of the study area and types of risks faced in the local situation. It also involves an initial appraisal of the level of skills and technical capacity for characterizing and managing such risks.

b. Component 2: Knowledge, Data, and Tools

This component involves a first-order identification and assessment of sources of existing knowledge, data, and tools that are applicable to high-priority risks, areas, and development projects.

c. Component 3: Rapid Risk Assessment

The third component is based around a first-order assessment of the current risks posed by climate variability and extreme events, as well as an estimation of the extent to which future changes in the climate and sea level could exacerbate these risks.

d. Component 4: Mainstreaming

As noted earlier, mainstreaming requires actions intended to result in the reflection of all dimensions of adaptation to climate variability and change in development policies, plans, strategies, regulations, and practices—potentially from local, regional, and state through to national (and even international) levels. The intention is to create an enabling environment that will encourage and promote, in a routine and sustained manner, both the capacity to adapt and the incorporation of specific adaptation measures into evolving patterns of socioeconomic development and change.

e. Component 5: Monitoring and Evaluation

Ultimately, the success of the adaptation initiatives depends on the degree to which the process is self-sustaining. If adaptation is viewed correctly as a dynamic, evolving process that can adjust to changing information and circumstances over time, procedures for monitoring and evaluating any changes in risk, and the success and failures of adaptation initiatives, must be in place in order to provide the necessary feedback. Such feedback will lead to modification of policies, plans, and implementation measures. Thus, Component 5 includes a first-order appraisal of the existing capacity for such monitoring and evaluation, and identifies the requirements and mechanisms for any strengthening that might be needed.

Collectively, the components of the CCAIRR ARA mode provide a solid foundation and blueprint for the next iterations of the comprehensive CCAIRR approach, as demonstrated here using the case studies. In combination, the five components of the ARA will paint an initial, integrated picture of

- the types and relative importance of climate and sea-level extremes and the nature and relative magnitude of the risks they pose to communities and other groupings, including priority foci for subsequent detailed assessments;
- the extent to which such risks and management options are currently perceived and incorporated into policy, planning, and decision making at various levels, from local practices and regulations to national policy, and the windows of opportunity for improvement; and
- the existing capacity to adapt to present and future risks in the context of sustainable development and management, and the ways in which the adaptive capacity could be enhanced

by strengthening individual skills, technical and institutional capabilities, and the enabling environment for decision making.

In short, because it is largely a consultative rather than a highly technical process, the CCAIRR ARA sketches the baseline situation and lays the foundation upon which subsequent activities and actions can build in order to promote climate change adaptation through integrated risk reduction.

The following sections describe the main elements of the CAAIRR framework and methods. Each element corresponds to a component of the Adaptation Rapid Assessment methodology discussed above, but involves more detailed and comprehensive assessments and analyses.

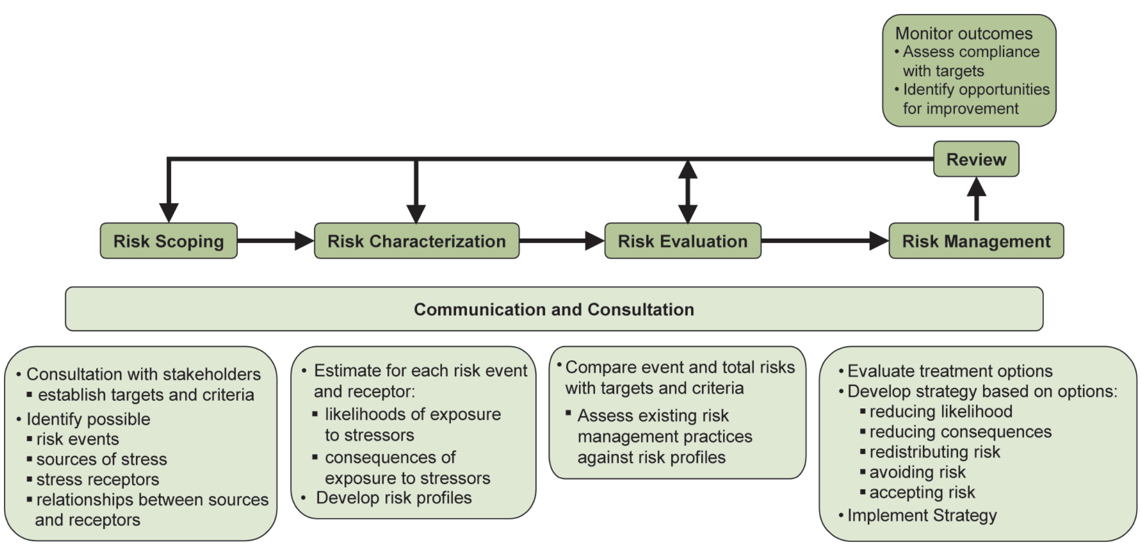
Using Risk Characterization and Management Methods in Support of Adaptation

Risk characterization and management are the basis of Component 3 of the CCAIRR Methodology. As shown in Figure VIII.2, the approach to characterizing and managing risk is well established.

When its is used within the CCAIRR framework, the risk-based methodology makes explicit the link between climate-related risks and the actions (i.e., adaptation measures) required to reduce them to acceptable levels. In this way a major shortcoming of the widely used approach of vulnerability and adaptation assessments is overcome. In that approach, no mechanism directly links the findings of the vulnerability assessment with the process of identifying and prioritizing appropriate adaptation strategies.

As noted in the previous chapter, a risk-based approach also avoids other limitations in the more conventional vulnerability and adaptation assessments. These include the absence of a formal assessment of the likelihood of future extreme events or variations in climate or baseline conditions; emphasis on individual events or on a future date, rather than on an aggregation of the anticipated climatic conditions over a specified time period into the future; the inability to evaluate the incremental costs of climate change; the difficulty of incorporating economic, social, and wider environmental scenarios into the assessment procedures; and the absence of formal procedures

Figure VIII.2. Generic Steps and Activities for Characterizing and Managing Risk



Source: CCAIRR findings.

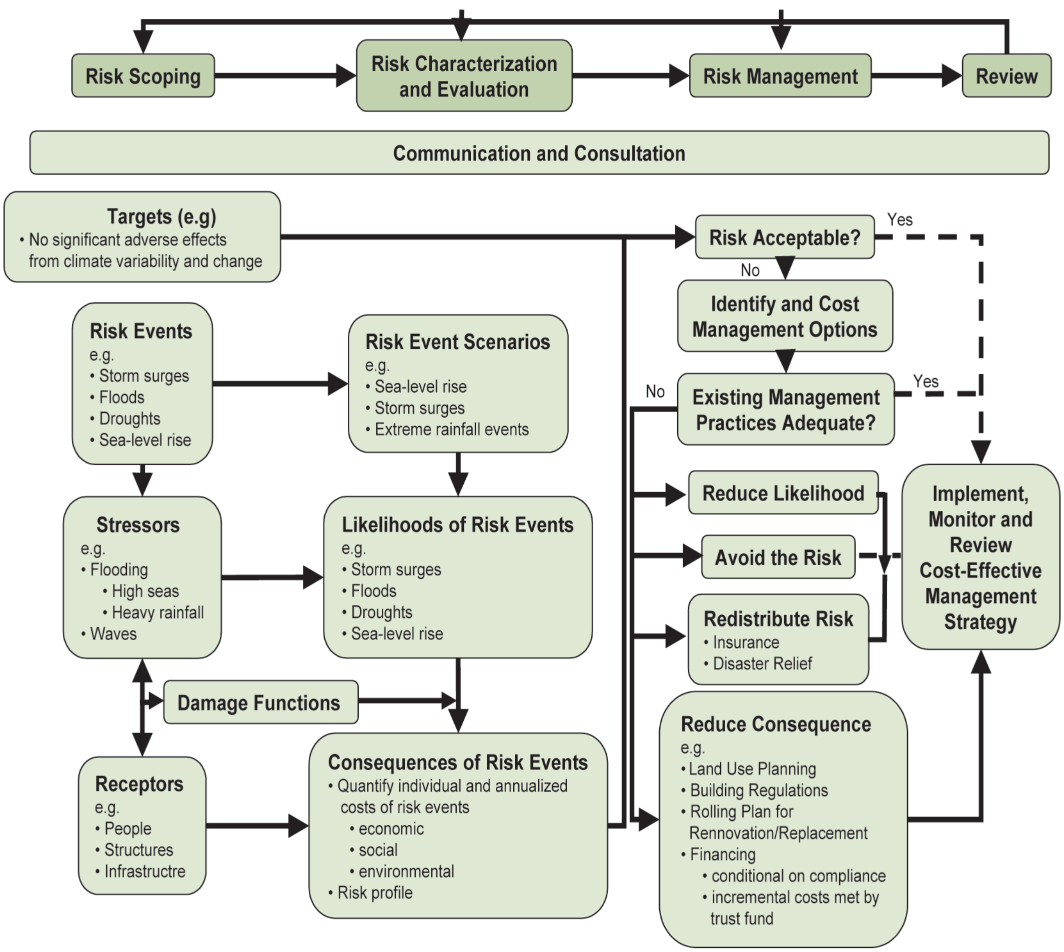
for prioritizing adaptation options on the basis of cost and other measures of efficiency and effectiveness.

The widely-used procedures for characterizing and managing risk provide the basis for the following procedures, which relate specifically to climate risks (Figure VIII.3).

a. Step A: Risk Scoping

Through a consultative process involving stakeholders and in-country experts, risk reduction targets and criteria are established. These are based on identifying levels of risk that are acceptable to stakeholders. Existing information sources and expert judgment are used to identify possible climate-related risk events, and the associated

Figure VIII.3. Procedures Used in the Characterization and Management of Climate-related Risks



Source: CCAIRR findings.

sources of stress and components ("receptors") of the natural and human systems on which the stresses act. The pathways for these interactions are also identified.

b. Step B: Risk Characterization and Evaluation

For each of the risk events identified in Step A, scenarios are developed to provide a basis for estimating the change in the likelihood of each risk event as a result of climate change. The extent to which the climate is likely to change into the future will influence the probability of the risk event occurring. The consequences of a given risk event are quantified in terms of individual and annualized costs. The findings are compiled into a risk profile.

c. Step C: Risk Management

In this step a number of questions are asked, all with reference to the target agreed in Step A. Actions to be taken depend on the responses to the questions.

Is the risk acceptable? If "yes," it is appropriate to continue with current strategies. This should include monitoring and reviewing, as the acceptability of the risk may change over time. If "no," risk management options are identified and assessed in terms of costs and benefits.

Are the current risk management options adequate? If "yes", it is appropriate to continue with the current strategy. Again, this includes monitoring and reviewing due to the possibility that the acceptability of the risk may change over time. If "no", one or more of the following risk management strategies should be implemented:

- Take actions to reduce the likelihood of the risk event occurring. For example, design and construct a breakwater to the standards required to minimize the frequency of wave overtopping, with associated damages to the breakwater and to other infrastructure.
- Avoid the risk. For example, prohibit development in areas that are exposed to risk events of concern.
- Redistribute the risk. For example, ensure provision of insurance cover or the availability of disaster relief programs.
- Reduce the consequences. For example, plant drought-tolerant crops if drought is a risk event of concern.

d. Step D: Monitoring and Review

The next step is to implement the risk management program, and monitor and review the risk management outcomes in relation to the agreed target. If the target is not met, it will be necessary to repeat one or more of the following steps: i) identify the problem and formulate a response plan; ii) enhance the quality of the risk characterization procedures and findings; and iii) enhance the quality of the risk management procedures and outcomes.

The process of risk characterization and management is iterative, to ensure that the quality of the outcomes are always consistent with the risk reduction targets that are established, reviewed, revised, and reaffirmed through a consultative process.

Characterizing Baseline Conditions

Characterization of baseline conditions is an important part of Component 2 of the CCAIRR methodology. This information provides the foundation for risk characterization and evaluation, and for costing and prioritizing the risk management (i.e., adaptation) options.

Following is a list of the information that, depending on specific circumstances, may be used to characterize the baseline conditions:

- precipitation data (daily and hourly) to estimate drought and heavy rainfall risks;
- air temperature data (daily maximum and minimum), to assess risks to human health;
- wind gust data, to assess risks related to structure damage, erosion, and food supply;
- sea-level data (tide gauge and satellite), to assess risks related to erosion and structure damage;
- ocean temperature data, to assess risks to reef and lagoon ecosystems and to fish stocks;
- tropical cyclone tracks and intensity, to assess risks associated with severe weather and storm surges;

- maps (current and historical);
- aerial photographs (current and historical);
- satellite imagery (current and historical);
- descriptions (written, oral) of adverse weather and climate events affecting the study areas in the past;
- inventories of land and marine resources;
- population and dwelling data (past, present, and projected);
- health data (past, present, and projected);
- employment data (past, present, and projected);
- history of, and plans for, infrastructure and other major investments; and
- income and expenditures (family, study areas, and national).

Building and Characterizing Scenarios

Scenarios of future climate, sea-level, and socioeconomic changes are required. These must

- meet given sector requirements (e.g., coastal flooding, health care) and provide "time slices" in the future (e.g., 2040, 2080);
- satisfy the requirements of risk assessments (e.g., be applied to extreme events; daily, monthly or seasonal temporal resolutions; or spatial patterns or site-specific time-series data);
- take account of the scientific uncertainties in modeling;
- take account of different scenarios of future greenhouse gas emissions; and
- be updated as knowledge and information change.

In short, CCAIRR requires a degree of flexibility and customization in scenario construction. This requirement is not always met by the conventional, top-down approach involving the provision of externally prepared, fixed scenarios. Such scenarios do not always match the needs of risk assessments and cannot be easily modified.

For this reason, CCAIRR uses flexible scenario-generating tools that can be applied and maintained by in-country users. These tools are designed to build in-country technical capacity for generating customized scenarios in support of sustainable adaptation.

The scenario-generating tools themselves are imbedded within an integrated model system called SimClim (see Section 9). Customized versions of SimClim have been developed for the FSM and the Cook Islands, including tools for generating climate, sea-level, and socioeconomic scenarios. The flexible scenario-generating tools allow the user to develop customized scenarios applicable to the FSM or Cook Islands, choosing between future time horizons, emission scenarios, GCM patterns, and levels of model sensitivity.

a. Climate Change Scenarios

Scenarios of local climate change are generated within SimClim using a "pattern-scaling" technique. Three categories of data are required in order to apply this technique.

Category 1: year-by-year projections (from 1990 to 2100) of global mean temperature change for various greenhouse-gas emission scenarios. These include the set of global projections produced by the IPCC (IPCC 2001). The projections were obtained through the IPCC Data Distribution Centre and through personal communication with the modelers responsible for developing the IPCC's projections.

Category 2: regional patterns of monthly mean temperature and precipitation changes due to the buildup of greenhouse gases in the atmosphere, as simulated by very complex global climate models (GCMs). These data were also obtained from Intergovernmental Panel on Climate Change (IPCC) Data Distribution Centre and "down-scaled" to areas of interest in the Federated States of Micronesia (FSM) and Cook Islands using simple interpolation techniques. Significantly, the patterns were expressed per degree of global warming. This is a "normalizing" procedure that extracts the differences between GCMs regarding their overall sensitivity to greenhouse gas increases. It allows the temperature change estimates to be comparable across the various GCMs.

Category 3: observed, historical climate data for the FSM and Cook Islands. These datasets included time-series climate data (e.g., hourly, daily and monthly) for specific sites on the islands as well as spatially interpolated monthly climatologies for temperature and precipitation.

Locally relevant scenarios of climate change are generated within SimClim in the following manner: Using the pattern-scaling technique, the normalized patterns (from Category 2) are scaled by the projections of global mean temperature change (from Category 1) in order to produce time-dependent (i.e., applicable to specific future dates) changes in climate for areas of interest in the FSM or Cook Islands. These projected changes in climate are then used to perturb the baseline climatology (from Category 3), thus producing a "new" climate (or scenario) that reflects changes in atmospheric concentrations of greenhouse gases.

b. Sea-Level Scenarios

For scenarios of future sea-level changes, pattern-scaling techniques similar to those used for climate scenarios were employed. These techniques have been developed and recently incorporated into the SimClim system in order to make them accessible to in-country users. The key components of the method include global-mean sea-level projections, regional GCM patterns of sea-level changes, and local historical sea-level data. Projections of global mean-sea-level changes, from 1990 to 2100, as developed by the IPCC (IPCC 2001), were incorporated into SimClim.

As for climate, sea level is not expected to change uniformly around the world. Due to differences in the rates of thermal expansion of the oceans and in ocean circulation and wind patterns, sea-level changes vary from one region to another. These regional patterns are simulated by the coupled ocean-atmosphere GCMs. Four GCM patterns were obtained from the Hadley Centre (UK) and the spatially dependent changes over time were again expressed as a function of global temperature change.

Finally, at the local scale, long-term trends in relative sea level due to local factors, usually vertical land movements, were taken into account, using tide gauge data.

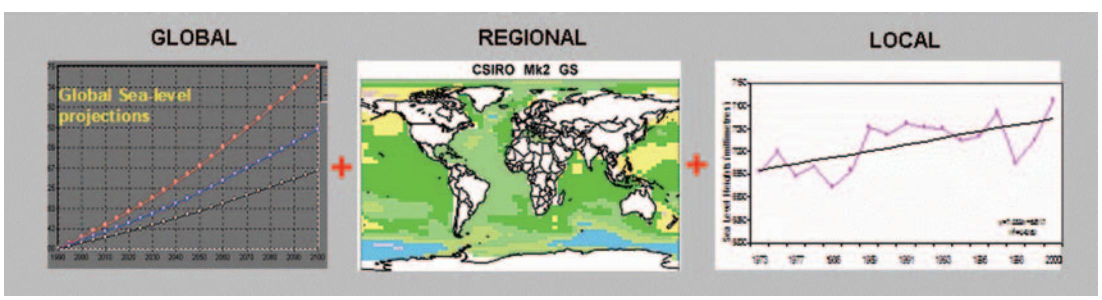
Development of sea-level scenarios was based on all three components—global, regional and local (Figure VIII.4). Again, SimClim facilitates the generation of sea-level projections for user-defined future time horizons, emission scenarios, modeling assumptions (high, best-judgment and low sensitivity), and GCM patterns.

c. Socioeconomic Scenarios

Socioeconomic data and relationships are incorporated into a "land use scenario generator" in SimClim, in order to provide the capacity for generating future patterns of coastal settlement for the purpose of simulating future risks related to extreme events.

While climate change takes effect, other changes are taking place as well. Economic and demographic pressures cause changes in the way

Figure VIII.4. Generating Future Sea-level Scenarios: Combining Global, Regional, and Local Information on Sea-Level Changes



Source: CCAIRR findings.

land is used. The land use change model simulates these changes.

Generically defined to cope with changes in "land use", the model is also capable of dealing with a very specific type of land use: structures, that is buildings or properties. Structures can be built, demolished, or renovated, and they can (and will) change over time. Structures have properties such as value, floor height, and age.

These properties are important in assessing the effects of flooding, with the flooding characteristics changing over time because of climate change. Floor height is used to determine the percentage damage caused by flooding (given the flood level). Subsequently, the property (and contents) value is used to calculate the actual flood damage. Properties age, and when they become too old they are renovated or rebuilt. Another reason for renovation or rebuilding, or even relocation, is the risk of flooding. If this becomes too high, the occupants may decide to make *in situ* changes to their building, or relocate.

The sequence for the land use change model is as follows:

1. What is the current land use? Determine where all the structures are, their value, their age, their floor height.
2. What changes will take place for each of the structure types? How many new houses are necessary, how many shops and community buildings? This is driven by economic and demographic changes that are user defined. The changes are specified as percentage increase (or decrease) in total occupied area for each land use type. Thus the total number of new buildings necessary is known, but not their (spatial) location.
3. Each building is assessed. Is it reaching an age when rebuilding, renovation, or relocation is imminent?
4. If the (expected) flood damage to a building is exceeding a threshold, again a decision can be made to rebuild, renovate, or relocate.
5. Rebuilding/renovation can change the floor level of a property (possibly depending on adaptation), while relocation can "move" a building to a different (probably safer or more suitable) location.
6. The model "loops" over the whole study area, determining the likelihood for all possible land use transitions.
7. These likelihoods depend on the current land use type, but also on the types in the neighboring cells (near and far), as well as on other factors determining the suitability of a location, including roads, proximity to water, and the slope.
8. Given the likelihood of all possible transitions, the model makes a selection consistent with the total area for each land use type, as specified in Point 2.
9. The model repeats these steps for each time interval of the simulation, allocating, aging and renovating buildings.

For every simulated year, the land use change model prepares an updated collection of structures. Flood exposure is assessed, to estimate the expected damages.

Adaptation options aimed at lowering flood damage to structures control the way buildings are aging, rebuilt, renovated, or relocated, e.g., by raising the floor level or decreasing the suitability for structures at a location with a high risk of flooding. By keeping track of both the damage costs and the costs of implementing the adaptation options, a cost-benefit analysis can be undertaken. Further details are provided in Appendix 6.

Cost-Benefit Analysis for Evaluating Adaptation

For the current case studies, evaluation of adaptation options focused on their comparative cost and their effectiveness in reducing damage costs. As noted later in this chapter, adaptation options also need to be subjected to an assessment of their environmental and social impacts and overall contribution to sustainable development. Such assessments will be facilitated if adaptation is mainstreamed, including the climate proofing of relevant legislation, regulations, and other development and planning instruments.

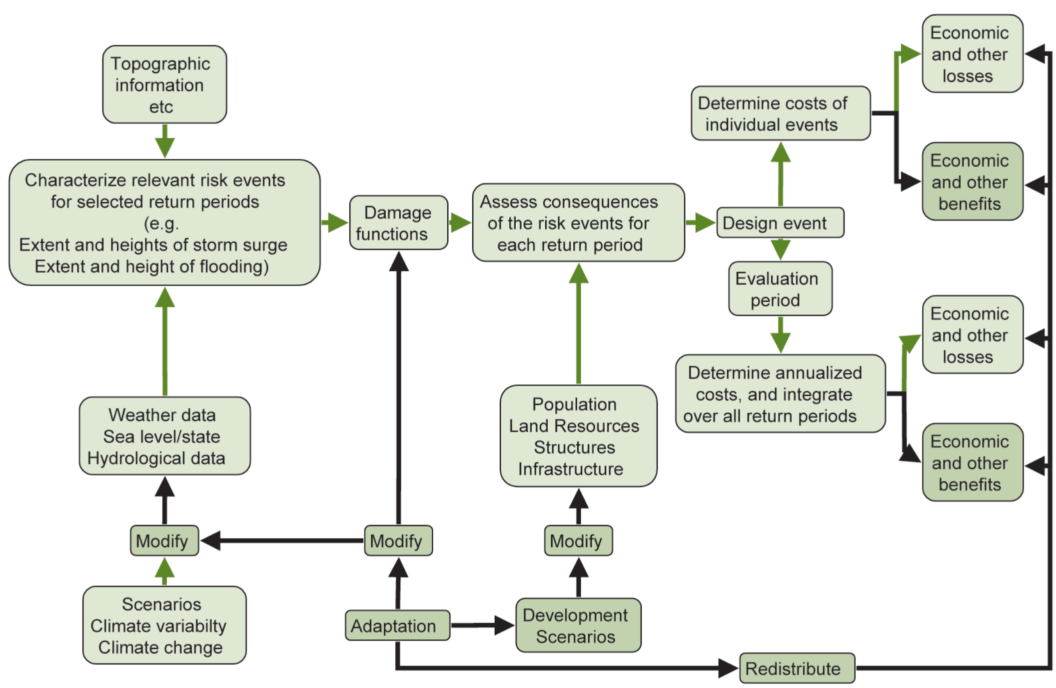
Once the expected risks from climate change at a specific location are understood, decisions need to be made about how much, if any, of today's resources should be invested to reduce the risks to an acceptable level. "Adaptation option" is the term used to describe a proposed investment of this type. Different adaptation options may have different degrees of effectiveness at reducing climate-induced risks, and each will come at a different cost. The purpose of cost-benefit analysis is to compare all feasible adaptation options at a particular location and select those with the greatest economic value.

Economic analysis in this context is necessarily a long-run analysis (see Figure VIII.5), as it must capture the effects of changes in the physical environment (climate change itself) over decades, and express them in terms of value in the present. As noted in the previous section, a long time horizon means that fundamental changes will also occur in the human environment, e.g., in infrastructure, demographics, and growth and mix of economic activity; these need to be taken into account. Changes in vulnerability and risk are the product of the changing frequency of extreme events and the changing value on the ground of the assets that might be damaged (or the productive activities that might be curtailed).

The first step is to determine the economic value of the expected risks from climate change for the location being analyzed, which for present purposes is the "project site." The project site might be a coastal residential community, a port facility, a power plant, a road, or any other definable asset. The discussion and examples below refer to a coastal residential community, but the concepts apply equally to other categories of sites.

The stock of buildings and important infrastructure is surveyed and valued at replacement cost to reflect the cost of repairing or, in the extreme,

Figure VIII.5. The Approach used in Assessing Economic and Other Losses, Costs, and Benefits*



Note: Adaptation Initiatives are shown in orange.
* These can be determined for an Individual risk event, or for all occurrences of the risk event within a specified time period.
Source: CCAIRR findings.

replacing assets damaged by extreme events. In practice, in most communities, the housing stock can be categorized in three or four different types, based on the main building materials used, e.g., concrete block, all timber, plywood/corrugated metal, etc. Local building contractors provide all-inclusive estimates for replacing buildings of each type, per square meter. The total replacement value of the housing stock can then be calculated for the area dimensions of each structure in the project site, as determined by site survey or from census data.

Climate change is a process in which potentially damaging events occur with greater frequency, i.e., with an increasing probability of occurring in a given year, and with greater severity. As only the frequency and severity of events over time can be projected, rather than the occurrence of any discrete event, it is necessary to analyze average "expected" damage values in each year as a function of climate change.

Damage to any particular structure within the project site will depend on the severity of the event and will cover the range from no damage (minor events) to total demolition. As the severity of events increases, the damage effect takes an "S" shape, i.e., the extent of damage rises slowly with storm severity at first, and begins to rise steeply once a given "threshold" severity is exceeded. At the high end of the curve, near-total demolition occurs across a broad range of severe events.

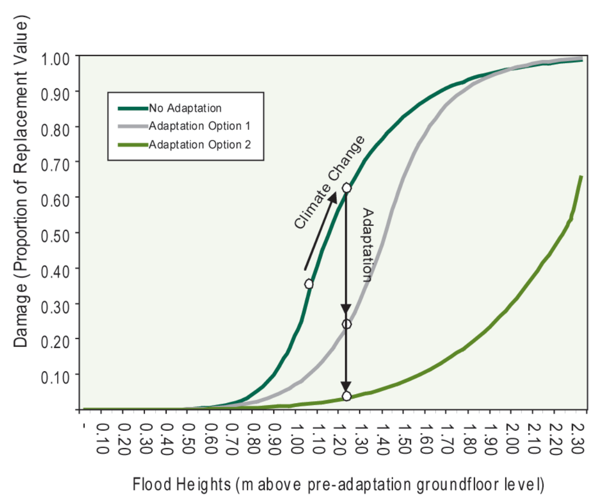
The curve just described is known as a stage-damage curve. In the present example, the damaging event to buildings is floodwater, either in the form of rainfall runoff (freshwater) or storm surges from the sea (saltwater), with severity measured in meters of flood height above the ground-floor level. A set of typical stage-damage curves is shown in Figure VIII.6.

A stage-damage curve is a picture of the vulnerability of a structure to damage from (in this case) floods, which is rooted in the building's design characteristics and materials of construction. A specific stage-damage curve can be constructed for each building, depending on the materials used in its construction. In Figure VIII.6, the green curve shows the initial situation of a particular building (e.g., a residential, one-story concrete/block house with a slab ground floor and metal roof, near the shore) as found by hypothetical survey of the project site. For that building in its present location and configuration, a flood of about 0.9 meters causes damage equivalent to about 10% of the replacement value of the building; a flood of 1.1 meters causes damage equivalent to about 40% of replacement value; the building is more than 90% destroyed if the flood height reaches 1.7 meters.

Altering a building's design characteristics will affect its vulnerability to flood damage. For example, any of several hypothetical adaptation options—building a floodwater diversion wall around a house, raising the ground floor level of the house, or moving the house to a new location—will reduce its exposure to flood damage and result in a new (shifted) stage-damage curve. This is seen in lower levels of damage inflicted at every flood height after adaptation is implemented. Thus the benefit of a given adaptation option can be depicted in a new stage-damage curve drawn next to the initial one. Two stage-damage curves relevant to hypothetical adaptation "option 1" and "option 2" are shown in Figure VIII.6.

The process of climate change results, in the present example, in higher and more damaging flood heights. Combined with the increasing frequency and severity of events measured and predicted by GCMs, the initial stage-damage curve

Figure VIII.6. Hypothetical Stage-Damage Curves



Source: CCAIRR findings.

for each structure can be used to calculate the damage expected to occur each year as time passes. When these are summarized across all structures, and the calculations are repeated for each year in the planning period, a stream of expected annual damage values results. These are expressed in a present value (PV), representing the total incremental damage expected in the project site due to climate change.

Adaptation options are analyzed within the same framework. As mentioned, adaptation for a given structure results in a shifted stage-damage curve showing, for each flood event, a lesser degree of damage than without adaptation. For a particular adaptation option, the above procedures are repeated to calculate the present value of expected damage after the adaptation option is implemented. The difference between the PV of expected damage in the no-adaptation case and the PV of the adaptation option measures the gross benefit of implementing the adaptation option. The procedures are repeated again for all feasible adaptation options. Table VIII.1 illustrates the results that might be obtained from such analysis for a coastal community.

The PV of savings due to adaptation option 1 in this example—that is, the PV of the damage *avoided* by implementing option 1—is about $3.55 million. If the initial cost of adaptation option 1 is no greater than $3.55 million, then investment in the option will save the community resources in the long run. Similarly, if the initial cost of option 2 is not greater than $5.53 million, investment in option 2 will save resources in the long run. Once the analysis of the benefits of potential adaptation options has been carried through to this stage, selection between the two options (and others that may also be feasible) will depend upon the initial cost and, hence, the economic return available to each.

Table VIII.1. Comparison of Hypothetical Present Values of Expected Damages Under Climate Change

	Present Values of Expected Damage ($)	Total Savings Due To Adaptation ($)
No Adaptation	6,163,000	
Adaptation Option 1	2,609,000	3,553,000
Adaptation Option 2	634,000	5,529,000
etc		

Source: CCAIRR findings.

A discount rate is used to calculate the present value of a stream of future costs, in recognition that a given cost incurred in the future is worth less than the same cost incurred today. The actual discount rate chosen reflects a subjective valuation of now versus the future: a lower discount rate reflects a higher concern about future costs, and vice versa for a higher discount rate. In particular, use of a lower discount rate reflects a higher valuation of future cost savings from adaptation relative to the present or initial costs of adaptation, leading to greater investment in adaptation.

The choice of an "appropriate" discount rate to use in cost-benefit analysis depends on the nature of the economic problem. As climate change is a long-term process that coincides with major demographic changes, economic development, and intergenerational transfers of assets, a national and international concern over climate change itself is indicative of a relatively high concern to avoid future costs that may affect the well-being of the next generation of the country's long-term growth potential. It would therefore seem anomalous to apply a "high" discount rate to the expected future costs of climate change, given a high level of confidence in projections of the future costs. A rate as high as, say, that normally used to evaluate shorter-term financial investments (e.g., 10%) will almost certainly result in a misallocation of resources away from adaptation. Nevertheless it is certainly possible that the "international" discount rate for future costs from climate change is consistently lower than the discount rate implicitly used by many countries and perhaps most individuals. A lower "international" discount rate (e.g., 3%) may reflect a higher awareness among world bodies of the dynamics of climate change and consequently greater confidence in the predictions of the rate and the degree by which the climate will change; or it may reflect a heightened appreciation of the threat that climate change poses to the world economy and the pace of development. Whatever the case, international resources are and will be available to assist small and vulnerable countries to invest in adaptation and to contain risk.

For most of the cost-benefit analyses related to the case studies presented in this book, results are presented for discount rates of zero and 3%, reflecting the above discussion.

SimClim: a Software Tool for Simulating Climate Risks and Evaluating Adaptation Options

Preparation of the case studies was assisted by having access to both a method for integrating complex arrays of data and to compute models to produce assessments of risks and adaptation. This need was motivated by a desire to demonstrate the benefits of adaptation in relation to the costs, with a clear demarcation between those costs arising from natural variability and those associated with future climate change. Given the complexity involved, such assessments could only be conducted efficiently through model simulations. For this purpose, the SimClim system was used.

a. Overview of the SimClim system

SimClim is a generic, "open-framework" software modeling tool for examining impacts and adaptations to climate variability and future change, including extreme events. The system contains tools for spatial analyses (like a geographic information system) as well as tools for temporal analyses at specific sites (for example, for examining climate time-series data or estimating return periods of extreme events). As a flexible, open-framework system, SimClim can be implemented for any country, region, or area for which the required input data exist.

At its core, SimClim contains a climate change scenario generator. This component allows the user to produce customized, regionally specific scenarios, drawing upon a range of IPCC projections of global warming and regional patterns of change from GCM results. The specific method of "pattern scaling" used by SimClim (which combines results of simple GCMs with those of complex ones) is widely accepted both in concept (as described by IPCC 2001 and Houghton et al. 2001) and in practice (for example, through the model SCENGEN as disseminated by the United Nations Development Programme [Hulme et al. 2000]). The climate data, whether current baseline climate or scenarios of future climates, can be analyzed in their own right or used to drive sector impact models in a seamless manner within SimClim.

Sector models are attached to the system in order to examine the impacts of climate variability and change, for example, on agriculture, coasts, or water resources. Such models are forced, either solely or in part, by climate variables. Importantly, SimClim has the capacity to provide hourly, daily, monthly, or seasonal climate data to these models, either as spatially interpolated averages or time-series, depending on their specific input requirements. With these tools, SimClim provides a system to help answer the key questions regarding risks and adaptation—when, where, and how much?

b. Implementation of SimClim for the Case Studies

For the Cook Islands and FSM case studies, a set of "second generation" features of SimClim was implemented. These features have been the subject of model developments carried out concurrently in the Pacific island region under the Assessment of Impacts and Adaptation to Climate Change (AIACC) program (funded by the United Nations Environmental Programme-GEF and executed by System for Analysis, Research and Training (START) and in New Zealand (funded by the New Zealand Foundation for Research, Science and Technology). These underscore the synergistic relationship between development partner-sponsored activities in the Pacific region. These features include

- fine spatial resolution modeling capacity, to provide capacity for risk analyses at the local scale, where adaptation options are typically implemented;
- explicit components for assessing adaptation options, to provide capacity for systematic comparative analyses of adaptive responses;
- incorporation of "human dimension" layers into the model (e.g., roads, infrastructure, people, and property), to provide a basis for quantifying risks to society and the economy;

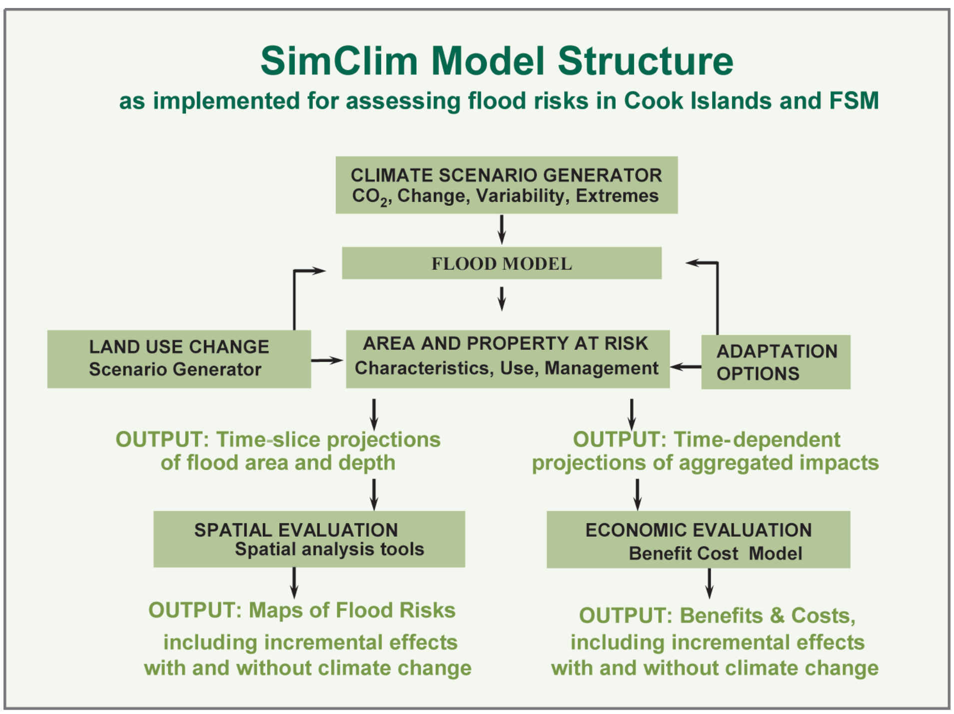
- land use scenario generator, to examine the implications of development pathways as factors in increasing or reducing risks;
- capacity to run simulations in transient (time-dependent) mode, in order to capture the full effects of climate and land use that are *changing* (not just changed) over time; and
- tools for economic evaluation of risk damage and adaptation, in order to provide a basis for decision making for investments to reduce the risks of climate variability and change.

Figure VIII.7 shows how these new features were implemented structurally within the core SimClim system, for the flood-related (both inland and sea flooding) case studies in both the Cook Islands and FSM. A brief description of each component follows.

c. Climate and Sea-Level Scenario Generator

The local case study areas in the Cook Islands and FSM were relatively small. Flooding in these areas, whether from inland runoff or storm-generated elevated sea levels, is sensitive to extreme events occurring on small time-scales. For this reason, hourly rainfall and sea-level (from tide gauges) time-series data were acquired to implement the various flood models. Of particular concern were the extremes in the time-series that contribute to unacceptable risk. The scenario generator made it possible to perturb these baseline time-series with combinations of IPCC emission scenarios and GCM patterns of rainfall or sea-level change (as well as possible changes in tropical cyclone intensity), and thereby rerun the flood models under different future climates over selected time horizons (e.g., to the year 2050).

Figure VIII.7. Implementation of SimClim for Assessing Flood Risks and Adaptation and their Changes due to Climate Change



Source: CCAIRR findings.

Flood Models. Relatively simple rainfall-discharge and sea-flooding models were developed for the case study areas in each country. In terms of inland flooding, variations of the Rational Method, commonly used in water engineering, were used, in which Discharge (Q) = CiA, where C is the runoff coefficient, i is the rainfall intensity, and A is the catchment area. Extreme discharges were related to channel capacity and surface flooding in order to simulate the spatial patterns of flooding. For sea flooding at Avatiu-Ruatonga in the Cook Islands, the methods used in SimClim were built on estimates of the components of storm surge, wave run-up, and dune overtopping and their return periods, as made in previous engineering reports commissioned by the Government. In SimClim, these values were perturbed by changes in sea-level and cyclone intensity, as derived from the scenario generator, in order to simulate future conditions. For sea flooding at Sapwohn Village in the FSM, the only available data were hourly tide-gauge data and reports from residents regarding previous sea-flood events. Using the extreme-event tools and sea-level scenario generator in SimClim, extreme high-water events and their elevations above mean sea level were simulated.

Property and Area at Risk. This component contains geo-referenced data on building types and their individual characteristics pertinent to flooding (floor heights, construction materials, age, etc) and other land uses at risk from flooding. Underlying these data was a digital elevation model (DEM). This was used to relate properties to ground elevation and thus to flood risk. For each case study, these data were obtained via field surveys.

Land Use Scenario Generator. This component provides the capacity to "evolve" the patterns of settlement in the case study sites. Rules can be specified, for example, to discourage building in high-risk zones or to reflect high or low population pressures as they could affect risk.

Adaptation Options. Specific adaptation measures were chosen for each site to reflect a certain category of response to risk, for example, channelization or water diversion (modifying the extreme event); elevation of minimum floor heights (modifying susceptibility to flooding); avoidance of building in high-risk zones (modifying damage potential). For each adaptation measure, the user specified the extent of application (e.g., minimum floor height) and the unit cost of implementation.

Spatial evaluator. This component contains tools for examining, in "time-slice" mode (e.g., for the year 2040, 2080), the spatial patterns of flood effects (see Figure VIII.5). For example, the user could choose to examine the flood extent and depth for the 100-year return period flood under current climate, and then investigate how those flood characteristics would change under a future scenario of climate or sea-level change. Both 2-D maps and 3-D flyover tools were available for visualization.

Economic evaluator. The economic evaluator, in calling on the flood model, requires simulations of floods in "transient" (e.g., year-by-year) mode and for the range of flood frequencies at each time step (see Figure VIII.5). The flood heights were related to stage-damage curves, which were developed for each building type in order to estimate damages to buildings in dollar values. For any given flood, the total damages were calculated for the area flooded. At each time step, the expected damages were summarized over the range of return period floods. For each simulation run over a specified time period, the expected damages for each year were discounted and aggregated to give an annualized expected damage, in present value. This provided a basis for cost-benefit comparisons of adaptation options. Multiple simulations with and without climate change, and with and without adaptation, provided a basis for identifying the incremental benefits and costs associated specifically with climate change (as opposed to natural climate variability). The outputs are presented in nonspatial graphical and tabular format.

d. Other SimClim tools used in Preparation of the Case Studies

SimClim also provided tools in support of analyses for other case study applications of climate risks. The Site Data Importer allowed the user to easily import time-series climate and sea-level data into the system. Once the data were in the system, the Extreme Event Analyzer proved to be especially useful for extracting extreme events and estimating their return periods, including changes in magnitude and/or frequency, with scenarios of climate change generated by the system. As shown in Figure VIII.8, the user has flexibility in selecting the climate variable, the time period during the year from which extreme events are selected, and the number of consecutive hours or days upon which the extreme event is defined. Significantly, the Extreme Event Analyzer is linked directly to the Scenario Generator, which is used to perturb the time-series with a user-selected scenario of climate change in order to assess future changes in risk.

In the preparation of the case studies, the Extreme Event tools were used, for example, to estimate

- changes in return periods of rainfall events that could damage the proposed new road in Kosrae,
- changes in significant wave heights and their return periods for engineering the design of the western breakwater at Avatiu, and
- changes in extreme sea-level events in Pohnpei.

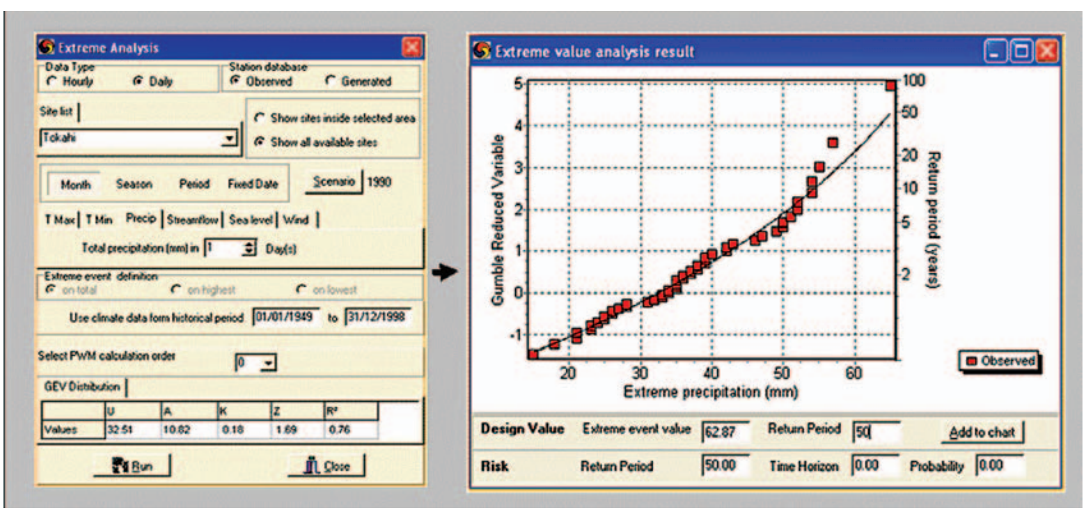
C. Mainstreaming Adaptation in National Development Planning and Implementation

Climate proofing at the national policy level is achieved largely through mainstreaming adaptation in national development policies and plans.

What is meant by "Mainstreaming Adaptation"?

In the context of addressing climate change and related issues, the term "mainstreaming" is used to describe the integration of policies and measures to address climate change into ongoing and new development policies, plans, and actions of policies and measures to address climate change. Mainstreaming aims to enhance the effectiveness, efficiency and longevity of initiatives directed at reducing climate-related risks while at the same time contributing to sustainable development and improved quality of life.

Figure VIII.8. The Extreme Event Analyzer in SimClim



Source: CCAIRR findings.

Mainstreaming also endeavors to address the complex tensions between development policies aimed at immediate issues and the aspects of climate policy aimed at longer-term concerns. The tensions often become most apparent when choices have to be made about the disbursement of limited government funds—for example, choices between supporting education and health care programs on the one hand, and funding climate change adaptation initiatives on the other. Indeed, mainstreaming is largely about reducing tensions and conflicts, and avoiding the need to make choices, by identifying synergistic, win-win situations. Thus mainstreaming focuses on "no regrets" measures for adaptation.[3]

Why Mainstream Adaptation?

Even in the near future, climate change is likely to impose untenable social, environmental, and economic costs. Most Pacific island countries are already experiencing disruptive conditions that are consistent with many of the anticipated adverse consequences of climate change, including but not limited to extensive coastal erosion, drought, flooding, coral bleaching, and higher sea levels.

The risks associated with the full spectrum of climate-related hazards, from extreme events to the consequences of long-term changes in the climate, should be managed in a holistic manner as an integral part of national development planning and management. Most countries already have policies and plans to manage financial risks, human health risks, biosecurity risks, agricultural risks, risks to the transport sector, and energy supply risks. Climate-induced disasters and climate change and variability should also be included in the national risk management portfolio.

National and local development plans and sector plans should include harmonized disaster risk management strategies and climate change adaptation measures that will ensure that risks are reduced to acceptable levels. These measures, and the related strategies, will help strengthen decision-making processes by requiring that specific programs and projects include plans and measures to manage risks associated with extreme events, as well as with climate change and variability. The overall goal should be to manage, in a holistic manner and as an integral part of national and subnational development planning, the risks associated with the full spectrum of weather, climate, and oceanic hazards, from extreme events to the consequences of long-term climate change.

What is the "Enabling Environment" for Adaptation?

The "enabling environment" for adaptation comprises the high-level and robust systems and capabilities that foster the adaptation process, including innovation, revitalization of traditional knowledge and practices, application of human knowledge and skills, policies, financing, legislation and regulations, information, markets, and decision support tools. It encourages and supports the climate proofing of development projects and related initiatives, as well as being supportive of the wider sustainable development process. This is shown in Table VIII.2. It highlights the multiple dimensions of the enabling environment. Longer-term interventions at national and subnational levels, often with support from the international community, are required to create and strengthen the enabling environment.

The Adaptation Mainstreaming Guidelines

The Guidelines are grouped into three categories, namely those related to

- the principles underlying the mainstreaming of adaptation,
- enhancement of the enabling environment for adaptation, and
- the process of mainstreaming adaptation.

The Guidelines approved for the Cook Islands and FSM include examples of their national application. These are provided in Appendixes 3 and 4.

[3] "No regrets" measures for adaptation are consistent with sound environmental management and wise resource use, and are thus appropriate responses to natural hazards and climate variability, including extreme events; they are therefore beneficial and cost effective, even in the absence of climate change.

Table VIII.2. The Multiple Dimensions of the Enabling Environment

Enabling Environment for Sustainable Development		Enabling Environment for Climate-Proofed Development		Climate-Proofed Development
Favorable macroeconomic conditions Available and affordable financing Robust and responsive legal and regulatory regimes				
Climate-proofed national development strategy	→	Climate-Proofed • Development plans • Resource use plans • Regulations • Codes • Permitting procedures	→	Economic and social development programs and projects that are compliant with climate-proofed policies and plans
Empowered and equitably involved stakeholders Equitable allocation of rights, responsibilities, and benefits Needs-driven and targeted information Relevant and applicable standards, codes, methodologies, and tools Functional, sustainable technologies (hard and soft) Supportive human and institutional capacities				

Note: The dimensions related to climate proofing are shown in red.

a. Guidelines Relating to the Principles Underpinning the Mainstreaming of Adaptation

Guideline 1: Manage climate risks as an integral part of sustainable development.

Climate change is largely the result of greenhouse gas emissions associated with human activities. The latter are driven by socioeconomic development patterns characterized by economic growth, technology uptake and application, population growth and migration, and adjustments in governance. In turn, these socioeconomic development patterns influence vulnerability to climate change as well as the human capacity for mitigation and adaptation. The cycle is completed as a result of climate change impacting on human and natural systems, to influence socioeconomic development patterns and, hence, greenhouse gas emissions.

The artificial separation of these activities results in missed opportunities for synergies, unrecognized and undesirable trade-offs, and mutual interference in ensuring successful outcomes. The benefits arising from integrating climate policy into wider development policies can be greater than the sum of concurrent but independent policy initiatives. Effective management of the risks to natural and human systems that arise from climate variability and change, and their integration into planning for sustainable development, gives rise to additional guidelines.

Policymaking, planning practices, and development activities should ensure that all future generations will be able to enjoy every important aspect of life, including peace and security, a healthy environment, a small risk of preventable catastrophe (including those related to climate variability and change), conservation of knowledge, stable governance, a good life for children, and opportunities for living.

Guideline 2: Ensure intergenerational equity with regard to climate risks.

Any climate-related risks that present generations may find unacceptable must not be imposed onto future generations.

Guideline 3: Adopt a coordinated, integrated, and long-term approach to adaptation.

Successful adaptation to climate variability and change requires a programmatic approach that provides institutional and operational support for individual projects. This will help minimize the limitations resulting from the short-term and narrow nature of projects, thus reducing administrative and related burdens and giving much more control over the direction taken by individual projects. Such an approach also increases the possibility of sustaining benefits of a project, even after funding has ceased, and expedites the proposal development, approval, and implementation processes.

Guideline 4: Achieve the full potential of partnerships.

Adaptation activities should be based on cooperation to bring about desired changes, from the bottom up as well as from the top down. This calls for enduring partnerships at all stages of the adaptation process, ensuring active and equitable participation of private and public stakeholders, including business, legal, financial, NGO, and other stakeholders.

Guideline 5: Adaptation should exploit the potential of sustainable technologies.

Transfer and use of inadequate, unsustainable, or unsafe technologies for adaptation must be avoided. Technology recipients should be able to identify and select technologies that are appropriate to their actual needs, circumstances and capacities and are classed as "sustainable technologies"—i.e., environmentally sound, economically viable, and socially acceptable. For example, some approaches to coastal protection have proven to be inadequate (e.g., weight of rocks making up a breakwater, relative to energy of the significant wave), unsustainable (e.g., sea walls often accelerate erosion for adjacent, unprotected areas of the coast) or unsafe (e.g., seawalls and revetments may, in some instances, exacerbate the volume and impacts of seawater overtopping the foreshore area).

Guideline 6: Base decisions on credible, comparable, and objective information.

Ideally, the measurements and assessments required to provide this information will be made using internationally recognized, but locally adapted, methodologies and tools, thereby helping to ensure comparability between information collected by different assessors.

Guideline 7: Maximize the use of existing information and management systems.

Wherever possible and practical, make use of existing information and information management systems. This may well require additional initial effort to source and harmonize dispersed and disparate sets of information, but will likely result in a strengthening of existing information management systems as opposed to their marginalization.

Guideline 8: Strengthen and utilize in-country expertise.

Enhance and employ in-country expertise in the technical and policy dimensions of adaptation to climate change.

Guideline 9: Strengthen and maximize use of existing regulations, codes, and tools.

Wherever possible and practical, make use of existing decision support tools and regulatory instruments to guide selection, and facilitate implementation, of adaptation measures. Examples include environmental impact assessments and building codes. This is likely to result in strengthening existing tools and regulations, rather than weakening them through confusion and inadequate enforcement.

b. Guidelines Relating to Enhancing the Enabling Environment for Adaptation

Guideline 10: Climate proof relevant legislation and regulations.

The enabling environment for adaptation is enhanced when legislation and regulations that facilitate adaptation are introduced and strengthened, and also when the compliance monitoring and enforcement capabilities of relevant regulatory agencies are improved.

Guideline 11: Strengthen institutions to support the climate proofing of development.

Organize and strengthen institutions in ways that i) enhance communication between climate risk assessors and adaptation policy makers and implementers; ii) reduce the likelihood of conflict and duplication of effort when managing climate-related risks; iii) lessen the chances of mistrust and misunderstanding between policy and decision makers and other stakeholders in adaptation activities; and iv) overall, help to provide consistent, defensible, and useful advice to policy and decision makers with respect to adaptation priorities and practices.

Guideline 12: Ensure that macroeconomic policies and conditions favor climate proofing.

Macroeconomic conditions that favor successful adaptation activities include those that foster economic transparency. Such conditions are needed in order to ensure that climate-related risks are not masked or compensated by hidden subsidies and thereby transferred to the wrong parties. Involvement of the private sector in adaptation (e.g., investors and other players in the finance sector) will be encouraged by macroeconomic conditions that will deliver low inflation; stable and realistic exchange and interest rates; pricing that reflects the true (marginal and fully internalized) costs of materials, energy, labor, and other inputs; deregulation; free movement of capital; operation of competitive markets; open trade policies; and transparent foreign investment policies.

Guideline 13: Ensure favorable access to affordable financing of climate-proofed development initiatives.

Address the current reluctance of banks and other lending institutions to finance adaptation activities, due to the perception that they involve longer-term projects that have high levels of risk. Help address this barrier by promoting institutions, arrangements, and mechanisms that can provide innovative financing, including microfinance, green finance, concessionary loans, leasing arrangements, and public-private partnerships, thereby allowing adaptation to increase, without government intervention.

c. Guidelines Relating to the Process of Mainstreaming Adaptation

Guideline 14: Characterize climate-related risks that require sustained attention.

Document the relevant major risks to the economy, environment, and society resulting from climate variability and change (including extreme events), characterizing these in terms of their probabilities of occurrence and associated economic and social consequences.

Guideline 15: Replicate the knowledge, motivation, and skills that facilitate successful adaptation.

Identify the motivations that drive various stakeholders to engage in the adaptation process, and replicate these motivations in other players, through education, training, and other initiatives that empower people.

Guideline 16: Enhance the capacity for continuous adaptation.

Adaptive capacity is a complex and dynamic mix of social, economic, technological, biophysical, and political conditions that determine the capacity of a system to adapt. These factors vary over time, location, and sector. The main features of communities, countries, and regions that determine their adaptive capacity include economic wealth, technology, information and skills, infrastructure, institutions, and equity. Addressing these factors makes it possible to enhance adaptive capacity.

Guideline 17: Ensure that climate proofing activities complement other development initiatives.

Emphasis must be placed on coordinating activities, taking advantage of synergies, minimizing duplication, and avoiding redundancies. This will help ensure that climate-proofing activities complement other development efforts. Priority should be given to adaptation activities that deliver tangible and visible benefits, rather than to exploratory studies, i.e., emphasis should be on activities that deliver outputs and outcomes that are of at least equal relevance and value to those provided by mainline government ministries; this can help offset the fact that climate change is often perceived as a longer-term issue, while other challenges, including food security, water supply, sanitation, education, and health care, require more immediate attention.

Guideline 18: Initiate a process of continual improvement in adaptation outcomes.

A commitment should be made to initiate and practice monitoring, reviewing, and strengthening adaptation activities. Methods used should emphasize transparency, consistency, and accountability, as well as fostering continued improvement in the efficiency with which outcomes are delivered, and in their contributions to sustainable national development.

CHAPTER IX

Summary and Conclusions

The case studies presented here have demonstrated the climate proofing of infrastructure and community development projects and the mainstreaming of climate change considerations into national strategic development plans. The field studies and other activities to develop the six case studies were undertaken in the Cook Islands and the Federated States of Micronesia. However, the innovative methodologies and tools, as well as the findings, are applicable to all Small Island Developing States, and even to larger developing and developed countries.

The ultimate aim of the case studies was to show *why* and demonstrate *how* reducing climate-related risks is an integral part of sustainable development. The results highlight the fact that many adaptation measures meet the criteria of no regrets adaptation initiatives, including being cost effective. Implementation of specific risk-reduction measures at project and local levels can be facilitated if land use planning and associated regulations and permitting procedures for structure, infrastructure, and community development projects incorporate requirements that are designed to reduce risks related to current and future climate extremes and variations.

The overall goal of a risk-based approach to climate change adaptation is to manage both the current and future risks associated with the full spectrum of atmospheric and oceanic hazards. The case studies were chosen to highlight the range of levels at which adaptation takes place and the linkages between them. The levels are i) project, ii) regulation and compliance, iii) short- and mid-term policy making and planning at the subnational level, and iv) national strategic development planning. The studies demonstrated the importance of mainstreaming adaptation, including strengthening the enabling environment for adaptation in order to increase the likelihood of successful adaptation at project and community levels.

The work undertaken included assessments of both the risks arising from current climate variability and extremes and from the future, incremental changes in those risks as a result of longer-term changes in climate extremes and variability. Significantly, the case studies demonstrated methods for prioritizing adaptation strategies and specific measures in terms of both their costs and benefits. A major goal—and challenge—was to determine, in a rigorous and quantitative manner, the incremental costs of adaptation to climate change.

For both the Cook Islands and the Federated States of Micronesia (FSM), climate risk profiles were prepared. Extreme climate events that are relatively rare at present (likelihood in one year less than 0.05), as a result of global warming are projected to become relatively common (in many cases likelihoods are projected to increase to over 0.20 by 2050).

In order to ensure stakeholder buy-in and sustained uptake, five principles underscored preparation of the case studies:

- all activities were to be undertaken in an inclusive, transparent and participatory manner;
- wherever possible, existing information and other resources were to be used;
- local experts should work alongside and at times lead their international counterparts;
- all outcomes should have high relevance to key stakeholders, add value to current and planned initiatives, and be sustainable; and

- selection of the case studies was to be in accordance with criteria established by the Asian Development Bank (ADB) and expanded through consultation with stakeholders in each country (governments, nongovernment organizations (NGOs), private sector, and communities).

In addition to the technical and policy-oriented work, considerable effort was devoted to a key dimension of adaptation, namely capacity building, including awareness raising, empowerment and action, and institutional strengthening.

Climate-related risks facing both the infrastructure projects and the communities are already considerable, but in all cases are projected to increase substantially as a result of increases in climate extremes and variability. For infrastructure projects, it is possible to avoid most of the damage costs attributable to climate change, and to do this in a cost-effective manner, if climate proofing is undertaken at the design stage of the project. Cost effectiveness can be further enhanced if environmental impact assessment (EIA) and related procedures require that all development be climate proofed. Climate proofing communities can also be cost effective if planning and regulatory measures take into account both current and future climate-related risks.

Climate proofing national strategic development plans enhances the enabling environment for adaptation; establishes the requirement for climate proofing sector and subnational (e.g., state, island and community) development plans as well as individual development projects; and helps to ensure that actions to reduce climate-related risks are an integral part of, and harmonized with, sustainable development initiatives. Such initiatives will be facilitated through the use of national Adaptation Mainstreaming Guidelines, such as those prepared and approved for the FSM and the Cook Islands.

Many key lessons have been learned and demonstrated. Climate change will manifest itself largely as changes in the frequency and consequences of extreme events and interannual variations, rather than as long-term trends in average conditions. While uncertainties inhere in projections of greenhouse gas emissions and of the response of the global climate as estimated by models, confidence in estimates of future changes in climate-related risks are high. This is due to the consistency in model-based projections of changes in the likelihood of extreme events and climate variability as well as between these projections and the observed changes in these likelihoods over recent decades.

While inconsistent with international conventions, at a practical level adaptation should thus focus on reducing both the present and future risks of climate variability and extremes. In many instances, current levels of climate risk are already high, because risks have increased over the past few decades. Moreover, adapting to current climate extremes and variability prevents precious financial and other resources from being squandered on disaster recovery and rehabilitation and is an essential step toward being able to withstand the pending climate changes.

A risk-based approach to adaptation is both desirable and practicable. It combines both the likelihood and consequence components of climate-related impacts and can assess risks for both current and anticipated conditions, with the option of examining either specific events or an integration of those events over time. Furthermore, risk assessment and management are common to many sectors—e.g., health care, financial, transport, agriculture, energy, and water resources—and the familiarity of planners and decision makers with risk management facilitates mainstreaming of risk-based adaptation. Compared to the more conventional approaches used in vulnerability and adaptation assessments, a risk-based approach also facilitates an objective and more quantitative approach, including cost benefit analyses that result in evaluation of the incremental costs and benefits of adaptation and assist in prioritizing adaptation options. Many players are usually involved in the risk- and cost-benefit-based assessments, but the approach provides a framework that facilitates coordination and cooperation, including the sharing of information that might otherwise be retained by information "gate keepers".

The risk-based approach is also linked to sustainable development because it identifies those risks to future generations that present generations would find unacceptable. The case studies have highlighted the need to ensure that future development does not exacerbate climate-related risks.

Adaptation has many dimensions and must also be viewed as a process. This means a framework and associated methodology are essential. Climate Change Adaptation through Integrated Risk Reduction (CCAIRR) provides an operational framework as well as relevant methodologies. The success of adaptation has enhanced CCAIRR's bottom-up and top-down approach: top-down activities should focus on creating a favorable enabling environment, for instance, by climate proofing policies, plans and regulations. This is a prerequisite to successful adaptation and should be the major emphasis and benefit of adaptation mainstreaming. Bottom-up activities should be founded on meaningful consultation and widespread empowerment of key players. Decision support tools, such as SimClim, that facilitate intercomparison of adaptation measures, are fundamental to ensuring the effectiveness of adaptation.

Most barriers to the successful application of a risk-based approach to adaptation relate to the existence of, and access to, information. The barriers to information are somewhat intractable, though again, experience in preparing the current case studies provides some grounds for optimism.

Before generalized findings and lessons can be drawn from case studies prepared using a risk-based approach to adaptation, many more examples will need to be developed. It is desirable to have internationally consistent assessment methodologies. International agencies, such as the IPCC, play major roles in establishing best practices. These agencies would need to formally endorse and encourage a risk-based approach to adaptation before their widespread uptake occurs. At present, best practice favors the more traditional assessments of vulnerability and of adaptation options. These have many limitations compared to a risk-based approach.

Until a risk-based approach to adaptation is formally endorsed and encouraged, documentation and training opportunities will also be lacking. While a risk-based approach requires no greater skills and experience than are called on in the traditional assessments, a cadre of in-country expertise will need to be built. While parallel frameworks and methodologies are being advocated, confusion and arguments for maintaining the status quo will occur.

Additional barriers include the need for formal specification of risk-based targets that define future levels of acceptable risk. This requires consultation with, and consensus among, key stakeholders; specification of relationships between magnitude and consequence of risk events of relevance; "rules" that specify future social, economic, and wider environmental changes; and appropriate discount rates to be applied to future costs and benefits. In SimClim, the discount rate is set by the user and can be adjusted without needing to rerun the simulation.

For the present case studies, all these barriers were overcome. Future efforts to develop additional case studies, as well as to support the practical application of adaptation measures, can build on both the methodologies and the experience gained in preparing the current case studies. Thus the barriers are unlikely to be as imposing as for the initial work.

References

Australian Bureau of Meteorology, no date. Available: http://www.bom/gov.au/ climate/averages/ climatology/tropical_cyclones/ tropical_cycl.shtml.

Campbell, J. R., and K. McGregor. 1993. *Cllimate Change Adaptation: Incorporating Climate Change Adaptation into Development Activities in Pacific Island Countries: A Set of Guidelines for Policy Makers and Planners*. Apia, Samoa: South Pacific Regional Environment Programme.

Cook Island News. 2004. Proofing for Climate Change. 5 February.

D'Aubert, A.-M., and P. D. Nunn. 1994. Catalogue of Tropical cyclones and Droughts in the Tropical Pacific, 1800–Present. Unpublished Report. Suva, Fiji Islands: University of the South Pacific.

Dorrell, Don E. Owner and Managing Director, Coastal Environmental International Ltd., Rarotonga, Cook Islands.

Fiji Meteorological Service. 1994. *List of Tropical Cyclones in the South West Pacific 1969/70–Present*. Information Sheet No. 21. Nadi, Fiji Islands.

Giorgi, F. and B. Hewitson. 2001. Regional climate information - evaluation and projections. Chapter 10. In: IPCC (2001). Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press. pp. 583–638.

Global Environment Facility. 2004. *GEF Assistance to Address Adaptation*. GEF/C.23/Inf.8, April 28, 2004. Available: http://thegef.org/ Documents/Council_ Documents/GEF C23/C.2.Inf.8.Rev.1_Adaptation Council paper FINAL.doc.

Government of the FSM (Federated States of Micronesia). 1999. *FSM Climate Change Program*. Prepared under the United Nations Framework Convention on Climate Change. Palikir.

Hay, J. D., and R. Kay. 1993. Possible future Directions for Integrated Coastal Zone Management in the Eastern Hemisphere: A Discussion Paper. In *Eastern Hemisphere workshop on the Vulnerability Assessment of Sea Level Rise and Coastal Zone Management*, edited by N. Mimura and R. McLean. Tsukuba, Japan: Intergovernmental Panel on Climate Change Regional Workshop.

________, and K. McGregor. 1993. Climate Change and Sea Level Rise Issues in the Federated States of Micronesia. Apia, Western Samoa: South Pacific Regional Environment Programme.

Hay, J. E., N. Mimura, J. Campbell, S. Fifita, K. Koshy, R. F. McLean, T. Nakalevu, P. Nunn, and N. de Wet. 2003. *Climate Variability and Change and Sea-level Rise in the Pacific Islands Region: A Resource Book for Policy and Decision Makers, Educators and Other Stakeholders*. Apia, Samoa: South Pacific Regional Environment Programme.

Henderson-Sellers, A., H. Zhang, G. Berz, K. Emanuel, W. Gray, C. Landsea, G. Holland, J. Lighthill, S.-L. Shieh, P. Webster, and K. McGuffie. 1998. Tropical cyclones and global climate change: a post-IPCC assessment. Bulletin of the American Meteorological Society 79: 19-38.

Hulme, M., T. Wigley, E. Barrow, S. Raper, A. Centella, S. Smith, and A. Chipanshi. 2000. *Using a Climate Scenario Generator for Vulnerability and Adaptation Assessments*: MAGICC and SCENGEN Version 2.4 Workbook, Norwich, UK: Climatic Research Unit.

IPCC (Intergovernmental Panel on Climate Change). 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press.

JPL (Jet Propulsion Laboratory). No Date. Available: www. Podaac-esip.jpl.nasa.gov.

JICA (Japan International Cooperation Agency). 1994. The Additional Study on Coastal Protection and Port Improvement in the Cook Islands. Draft Final Report for Ministry of Planning and Economic Development—The Cook Islands. Pacific Consultants International and The Overseas Coastal Area Development Institute of Japan.

Kerr, I. S. 1976. Tropical Storms and Hurricanes in the Southwest Pacific, November 1939 to April 1969. Misc. Pub. 148. Wellington, NZ: New Zealand Meteorological Service, Ministry of Transport.

Kirk, R. and D. E. Dorrell. 1992. Analysis and Numerical Modelling of Cyclone Sea-states Avarua and Nike Areas. Report commissioned by Government of the Cook Islands.

Office of the President, FSM (Federated States of Micronesia). 2004. Proceedings, Third FSM Economic Summit. Plaice, Pohnpei, Federation States of Micronesia. 28 March–2 April.

Ready, Steve. Meteorologist, New Zealand Meteorological Service.

Revell, C. G. 1981. Tropical Cyclones in the Southwest Pacific, November 1969 to April 1979. Misc. Pub. 170. Wellington, NZ: New Zealand Meteorological Service, Ministry of Transport.

Swart, R., J. Robinson and S. Cohen. 2003. Climate Change and Sustainable Development: Expanding the Options. *Climate Policy* 3S1: S19–S40.

UNDP-GEF (United Nations Development Programme-Global Environment Facility). 2003. UNDP-GEF Capacity Development and Adaptation Cluster. Adaptation Policy Framework. New York.

Appendix 1

Federated States of Micronesia—Climate Risk Profile

Summary

The likelihood (i.e., probability) components of climate-related risks in the Federated States of Micronesia (FSM) are evaluated, for both present-day and future conditions. Changes over time reflect the influence of global warming.

The risks evaluated are extreme rainfall events (both hourly and daily), drought, high sea levels, strong winds, and extreme high air temperatures.

Projections of future climate-related risk are based on the output of global climate models, for given emission scenarios and model sensitivity.

With the exception of maximum wind speed, projections of all the likelihood components of climate-related risk show marked increases as a result of global warming.

A. Introduction

Formally, risk is the product of the consequence of an event or happening and the likelihood (i.e., probability) of that event taking place.

While the consequence component of a climate-related risk will be site or sector specific, in general the likelihood component of a climate-related risk will be applicable over a larger geographical area and to many sectors. This is due to the spatial scale and pervasive nature of weather and climate. Thus the likelihood of, say, an extreme event or climate anomaly is often evaluated for a country, state, small island, or similar geographical unit. While the likelihood may well be within a given unit, information is often insufficient to assess this spatial variability, or the variations are judged to be of low practical significance.

The following climate conditions are considered to be among the potential sources of risk:

- extreme rainfall events,
- drought,
- high sea levels,
- strong winds, and
- extreme high air temperatures.

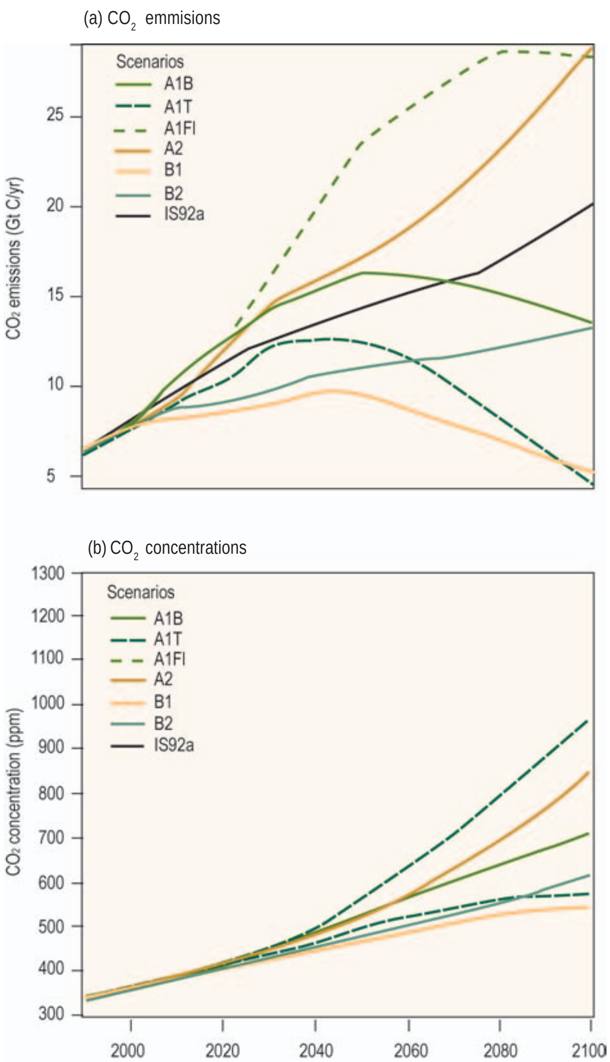
B. Methods

Preparation of a climate risk profile for a given geographical unit involves an evaluation of current likelihoods of all relevant climate-related risks, based on observed and other pertinent data.

Climate change scenarios are used to develop projections of how the likelihoods might change in the future. For rainfall and temperature projections, the Hadley Centre (United Kingdom) global climate model (GCM) was used, as it gave results intermediate between those provided by three other GCMs, namely those developed by the Australian Commonwealth Scientific and Industrial Research Organisation, Japan's National Institute for Environmental Science, and the Canadian Climate Centre. For drought, strong winds, and sea level, the Canadian GCM was used to develop projections.

Similarly, the SRES A1B greenhouse gas emission scenario was used when preparing rainfall, temperature, and sea level projections. Figure A1.1 shows that this scenario is close to the middle of the envelope of projected emissions and greenhouse gas concentrations. For drought both the A2 and B2 emission scenarios were used, while for strong winds only the A2 scenario was used.

Figure A1.1. Scenarios of CO_2 Gas Emissions and Consequent Atmospheric Concentrations of CO_2



Notes: CO_2 = carbon dioxide; Gt C/yr = gigatonnes of carbon per year.
Source: IPCC 2001.

C. Information Sources

Daily and hourly rainfall, daily temperatures, and hourly wind data were obtained through the Pohnpei Weather Service Office and with the assistance of Mr. Chip Guard, National Oceanic and Atmospheric Administration, Guam. Sea-level data for Pohnpei were supplied by the National Tidal Facility, The Flinders University of South Australia, and are copyright reserved. The sea-level data derived from Topex-Poisidon satellite observations were obtained from www.//podaac-esip.jpl.nasa.gov.

D. Data Specifications

While much of the original data was reported in Imperial units, all data are presented using System International units.

E. Uncertainties

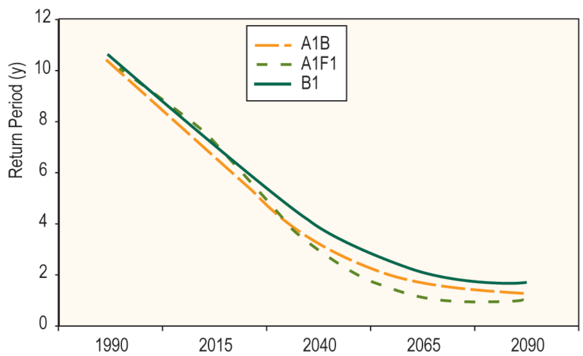
The sources of uncertainty in projections of the likelihood components of climate-related risks are numerous. They include uncertainties in greenhouse gas emissions and those arising from modeling the complex interactions and responses of the atmospheric and ocean systems. Figure A1.2 shows how uncertainties in greenhouse gas emissions impact on estimates of the return periods of a daily precipitation of at least 250 mm for Pohnpei.

Similar graphs can be prepared for other GCMs and extreme events, but are not shown here. Policy and decision makers need to be cognizant of uncertainties in projections of the likelihood components of extreme events.

F. Graphical Presentations

Many of the graphs that follow portray the likelihood of a given extreme event as a function of a time horizon. This is the most appropriate and useful way in which to depict risk since design life (i.e., time horizon) varies depending on the nature of the infrastructure or other development project.

Figure A1.2. Return Periods for Daily Rainfall of 250 mm in Pohnpei for Given Greenhouse Gas Emission Scenarios



Note: Calculations used Hadley Center GCM with Best Judgment of Sensitivity.
Source: CCAIRR findings.

G. Extreme Rainfall Events

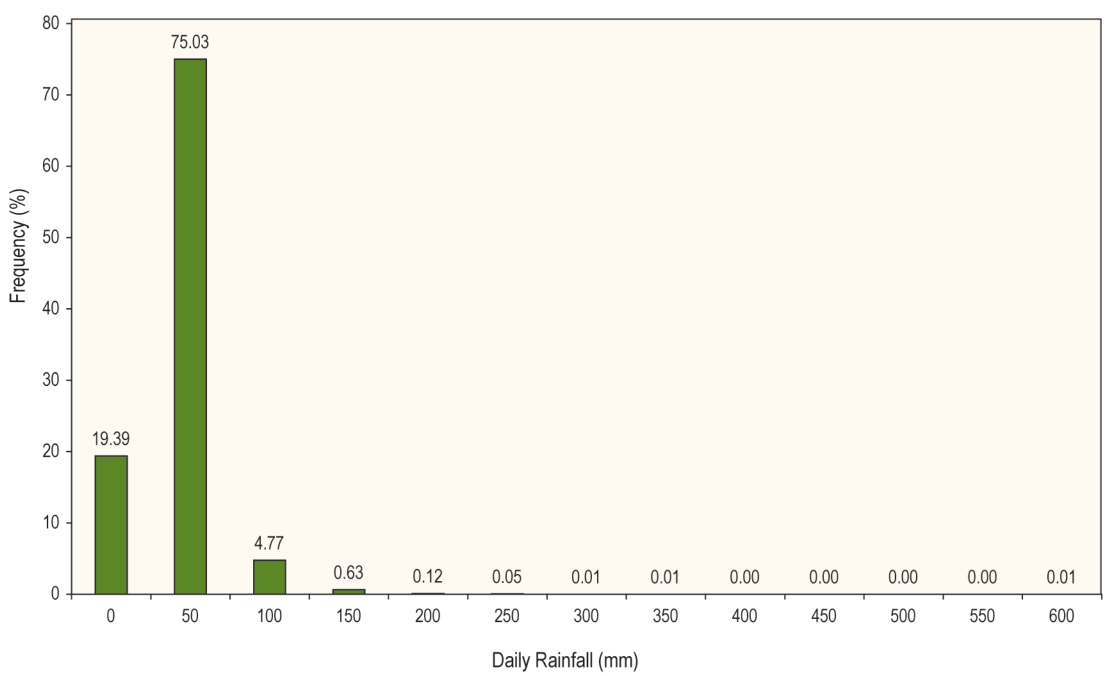
Daily Rainfall

Figure A1.3 shows the frequency distribution of daily precipitation for Pohnpei. A daily total above 250 mm is a relatively rare event, with a return period (i.e., recurrence interval) of 10 years.

Figure A1.4 shows the likelihood of such an extreme rainfall event occurring in Pohnpei and Kosrae, within a given time horizon ranging from 1 to 50 years.

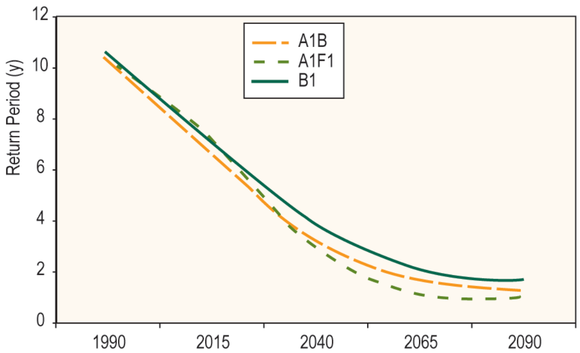
As shown in Table A1.1, global warming will significantly alter the return periods, and hence the likelihoods, of the extreme rainfall events. For example, Figure A1.5 illustrates how the likelihood of a daily rainfall of 250 mm will increase over the remainder of the present century.

Figure A1.3. Frequency Distribution of Daily Precipitation for Pohnpei
(1953–2003)



mm = millimeters.
Note: The numbers above the bars represent the frequency of occurrence, in percentages, for the given data interval.
Source: CCAIRR findings.

Figure A1.4. Return Periods for a Daily Rainfall of 250 mm Occurring Within the Indicated Time Horizon
(years)

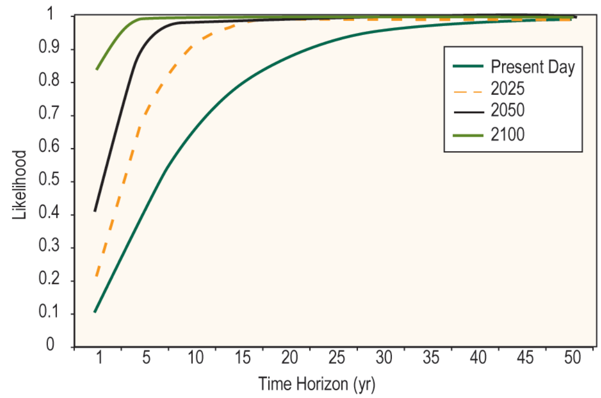


Note: 0 = zero chance; 1 = statistical certainty.

Data are for Pohnpei (1953–2003) and Kosrae (1953–2001, with gaps). A daily rainfall of 250 mm has a return period of 10 and 16 years, respectively.

Source: CCAIRR findings.

Figure A1.5. Likelihood of a Daily Rainfall of 250 mm Occurring Within the Indicated Time Horizon
(years)



Note: 0 = zero chance; 1 = statistical certainty.
Data are for Pohnpei.

Source: CCAIRR findings.

Table A1.1: Return Periods for Daily Rainfall, Pohnpei and Kosrae
(years)

Rainfall (mm)	Present	2025	2050	2100
Pohnpei				
100	1	1	1	1
150	2	1	1	1
200	5	2	1	1
250	10	5	2	1
300	21	9	4	2
350	40	17	8	2
400	71	28	13	3
450	118	45	20	5
500	188	68	30	7
Kosrae				
100	1	1	1	1
150	3	2	1	1
200	6	4	2	2
250	16	9	5	2
300	38	21	12	4
350	83	50	31	9
400	174	119	83	22
450	344	278	237	64
00	652	632	410	230

Source: CCAIRR findings.

Hourly Rainfall

Figure A1.6 shows the frequency distribution of hourly precipitation for Pohnpei. An hourly total above 100 mm (3.9 in) is a relatively rare event. Table A1.2 shows that such a rainfall has a return period of 6 years. The table also shows, for both Pohnpei and Kosrae, that global warming will have a significant impact on the return periods of extreme rainfall events.

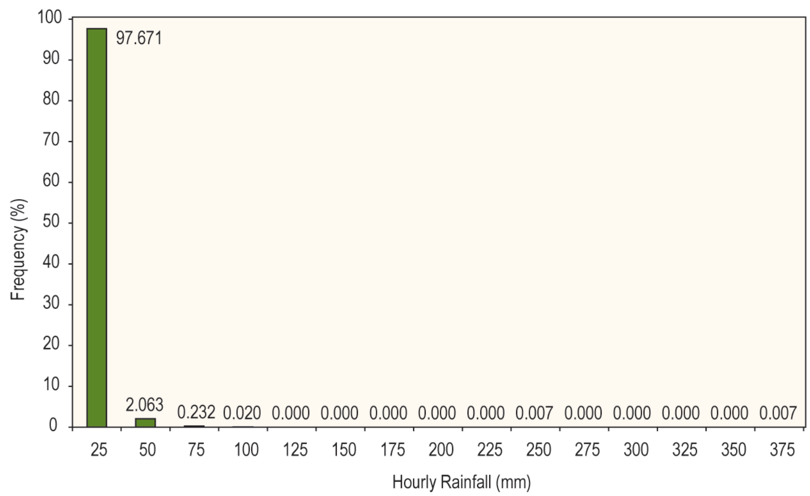
Figure A1.7 depicts the impact of global warming on the likelihood of an hourly rainfall of 200 mm for Pohnpei.

H. Drought

Figure A1.8 presents, for Pohnpei, the number of months in each year (1953–2003) and each decade for which the observed precipitation was below the fifth percentile. Monthly rainfall below the fifth percentile is used here as an indicator of drought.

Most of the low rainfall months are concentrated in the latter part of the period of observation, indicating that the frequency of drought has increased since the 1950s. The years with a high

Figure A1.6. Frequency Distribution of Hourly Precipitation for Pohnpei



Notes: Data are for 1980 to 2002, with gaps. The numbers above the bars represent the frequency of occurrence for the given data interval, in percent of hours of observed rainfall.

Source: CCAIRR findings.

Table A1.2: Return Periods for Hourly Rainfall, Pohnpei and Kosrae

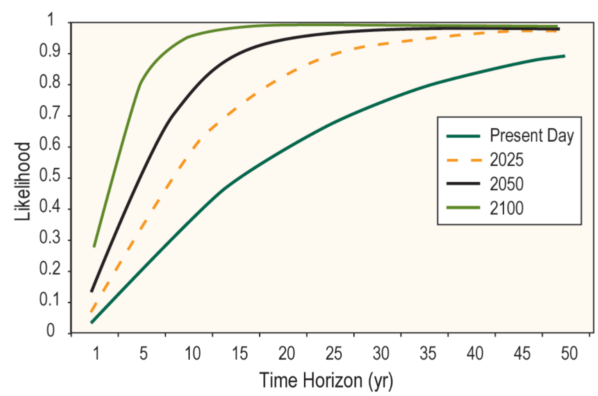
(years)

Rainfall (mm)	Present	2025	2050	2100
Pohnpei				
50	2	1	1	1
100	6	3	2	1
150	14	7	4	2
200	23	12	7	4
250	34	18	11	5
300	47	25	15	8
350	61	32	20	10
400	77	40	26	13
Kosrae				
50	2	2	1	1
100	8	6	5	3
150	16	13	10	6
200	28	21	16	11
250	41	31	24	16
300	56	42	33	22
350	73	55	43	29
400	91	68	54	37

Source: CCAIRR findings.

Figure A1.7. Likelihood of an Hourly Rainfall of 200 mm Occurring in Pohnpei Within the Indicated Time Horizon

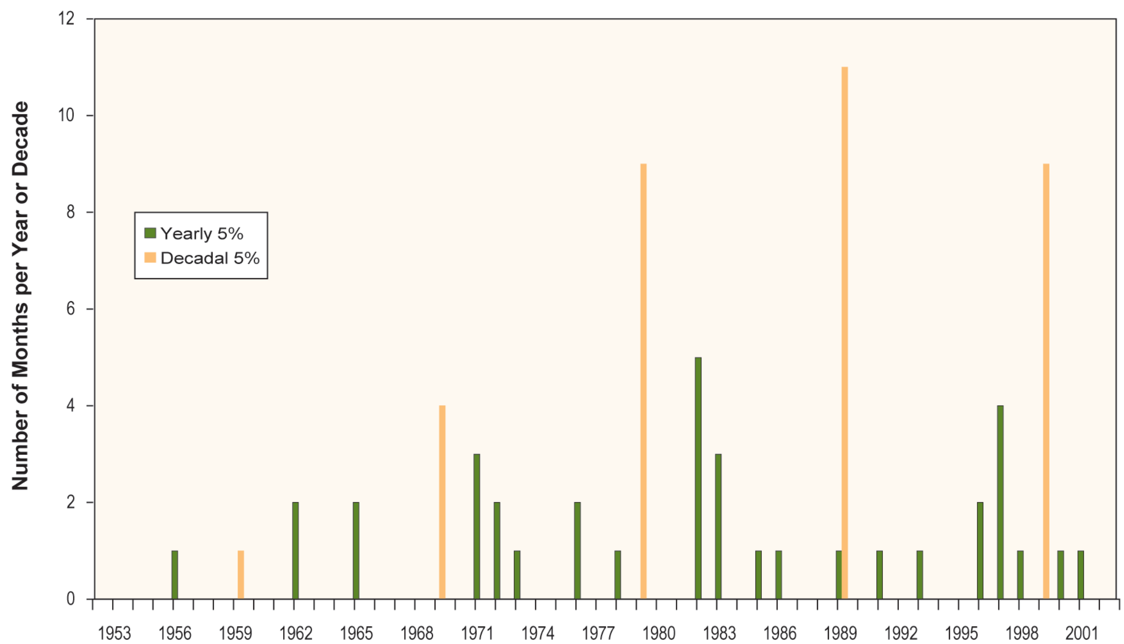
(years)



Notes: 0 = zero chance; 1 – statistical certainty. Values for present day based on observed data for 1980–2002, with gaps.

Source: CCAIRR findings.

Figure A1.8. Number of Months in Each Year or Decade for Which the Precipitation Was Below the Fifth Percentile



Note: Data are for Pohnpei.
Source: CCAIRR findings.

number of months below the fifth percentile coincide with El Niño Southern Oscillation (ENSO) events.

A similar analysis could not be undertaken for Kosrae, because its rainfall records are incomplete.

Figure A1.9 shows the results of a similar analysis, but for rainfall estimates (1961–1990) and projections (1991–2100) by the Canadian GCM. The results are presented for both the A2 and B2 emission scenarios.

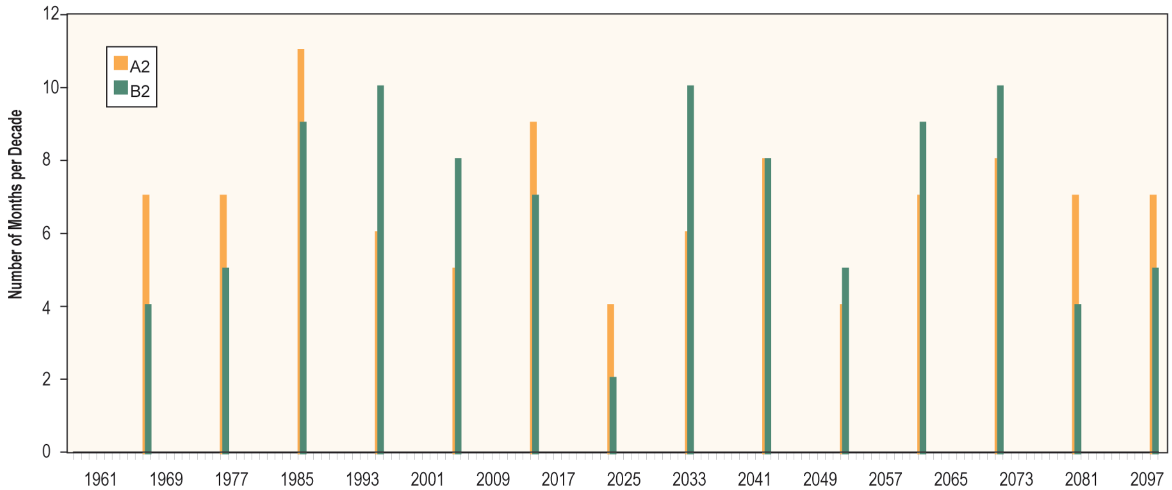
Figure A1.9 also shows that the GCM replicates the increased frequency of months with extreme low rainfall during the latter part of the last century. The results also indicate that, regardless of which emission scenario is used, the frequency of low rainfall months will generally remain high relative to the latter part of the last century.

I. High Sea Levels

Figure A1.10 shows daily mean values of sea level for Pohnpei, relative to mean sea level. Large interannual variability occurs in sea level. Low sea levels are associated with El Niño events, while exceptionally high sea levels occurred in October 1988.

Even more extreme high sea levels occur over time scales of less than a day. Table A1.3 provides return periods for given sea level elevations for Pohnpei, for the present day and projected future. The latter projections are based on the Canadian GCM 1 GS and the A1B emission scenario.

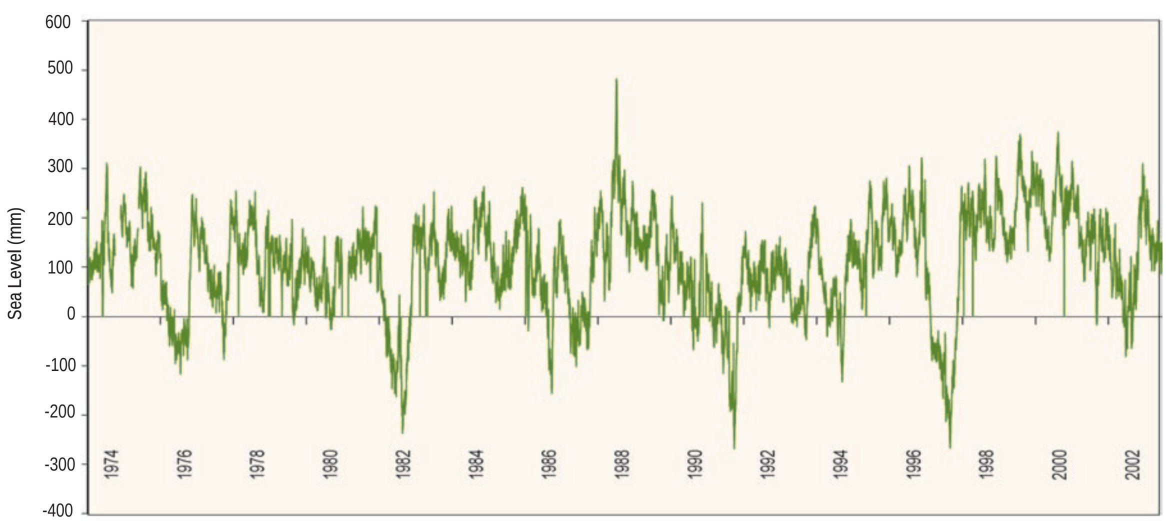
Figure A1.9. Number of Months per Decade for Which Pecipitation for Pohnpei is Projected to be Below the Fifth Percentile



Note: data from the Canadian Global Climate Model, with A2 and B2 emission scenarios and best estimate for GCM sensitivity.

Source: CCAIRR findings.

Figure A1.10: Daily Mean Values of Sea Level for Pohnpei
(1974–2003)



Note: The sea level elevations are relative to surveyed mean sea level.

Source: CCAIRR findings.

Table A1.3. Return Periods for Extreme High Sea Levels, Pohnpei
(years)

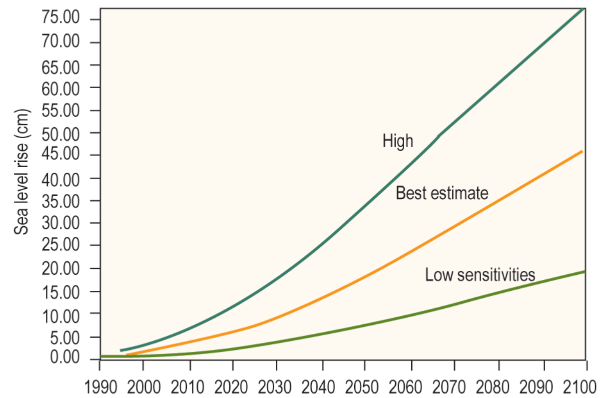
Sea Level (mm)	Present Day	2025	2050	2100
80	1	1	1	1
90	1	1	1	1
100	4	2	1	1
110	14	5	2	1
120	61	21	5	1
130	262	93	20	1
140	1,149	403	86	2

Note: cm = centimeters.
Source: CCAIRR findings.

The indicated increases in sea level over the next century are driven by global and regional changes in mean sea level as a consequence of global warming. Figure A1.11 illustrates the magnitude of this contribution.

Sea level elevations are not recorded *in situ* for Kosrae. However, satellite observations of sea levels are available and can add some understanding to both historic and anticipated changes in sea levels.

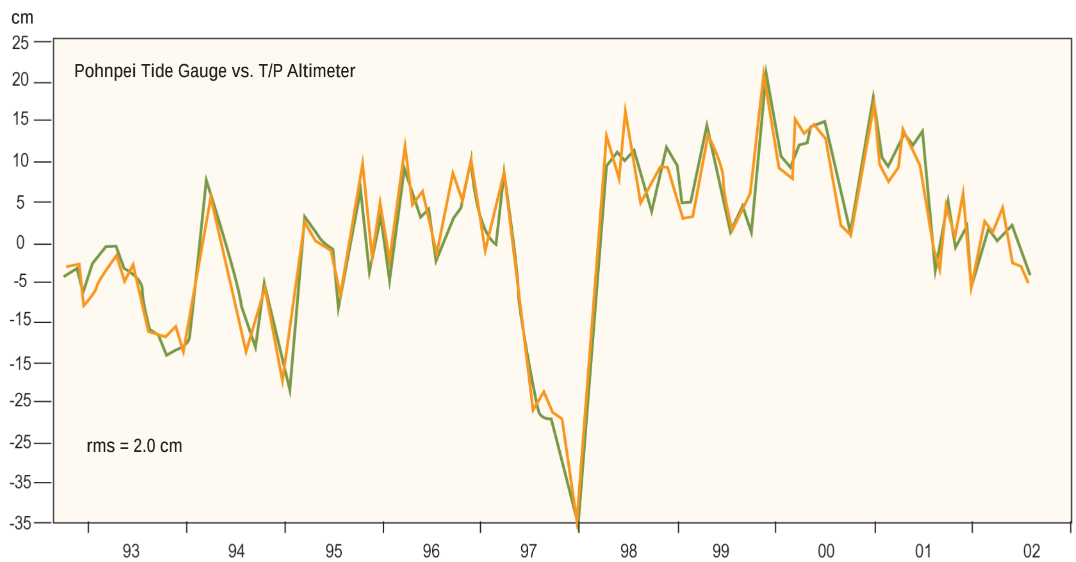
Figure A1.11 Sea-Level Projections for Pohnpei, Based on the Canadian GCM 1GS and the A1B Emission Scenario



cm = centimeters; GCM = global climate model. Uncertainties related to GCM sensitivity are indicated by the blue, red, and green lines, representing high, best estimate, and low sensitivities, respectively.
Source: CCAIRR findings.

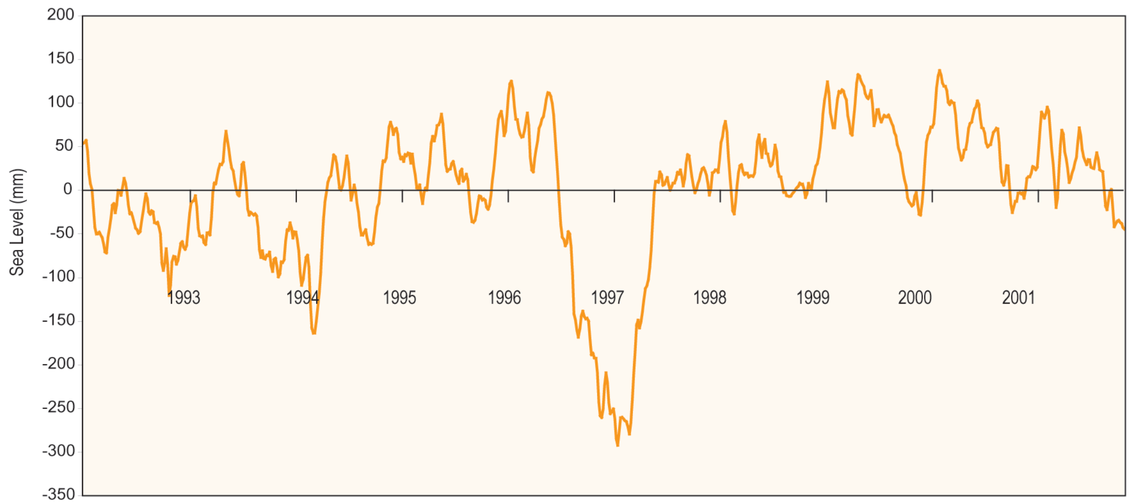
A high level of agreement occurs between the tide gauge and satellite measurements of sea level, at least for monthly averaged data (Figure A1.12).

Figure A1.12. Sea Level (departure from normal) as Determined by the Pohnpei Tide Gauge and by Satellite



rms = root mean square.
Source: CCAIRR findings..

Figure A1.13. Five-Day Mean Values of Satellite-Based Estimates of Sea Level for a Grid Square Centered on Kosrae (5.25° to 5.37°N; 162.88° to 163.04°E)

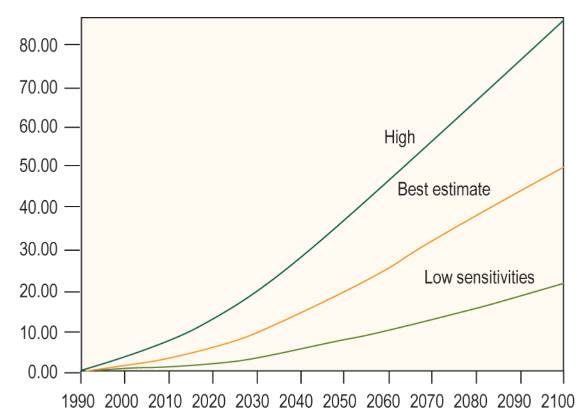


Note: Values are departures from the mean for the period of record: November 1992–August 2002.
Source: CCAIRR findings.

This reinforces confidence in the use of satellite data to characterize sea level for Kosrae. Figure A1.13 presents satellite-based estimates of sea level for a grid square centred on Kosrae.

Figure A1.14 presents the projected increase in sea level for Kosrae as a consequence of global warming. The global and regional components of sea-level rise for Kosrae are very similar to those for Pohnpei.

Figure A1.14. Sea-Level Projections for Kosrae, Based on the Canadian GCM 1 GS and the A1B Emission Scenario



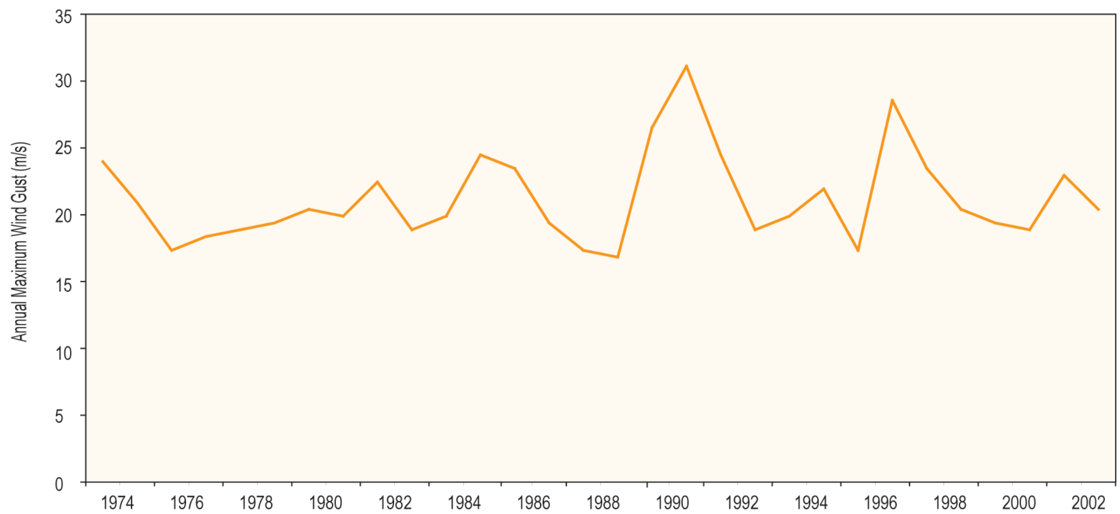
cm = centimeters; GCM = global climate model. Uncertainties related to GCM sensitivity are indicated by the blue, red, and green lines, representing high, best estimate, and low sensitivities, respectively.
Source: CCAIRR findings.

J. Strong Winds

Figure A1.15 shows the annual maximum wind gust recorded in Pohnpei for the period 1974–2003.

Table A1.4 presents return periods for extreme high winds in Pohnpei, based on observed data. Also shown are return periods for 1990–2020 and for 2021–2050. The latter are estimated from projections of maximum wind speed using the Canadian GCM 2 with the A2 emission scenario.

Figure 1.15. Annual Maximum Wind Gust Recorded in Pohnpei for the Period 1974–2003



Note: m/s = meters per second.
Source: CCAIRR findings.

Table A1.4. Return Periods for Maximum Wind Speed, Pohnpei
(years)

Wind Speed (m^{s-1})	Hourly 1974–2003	Daily 1961–1990	1991–2020	2021–2050
20	2	2	2	2
25	8	10	10	9
28	20	47	40	20

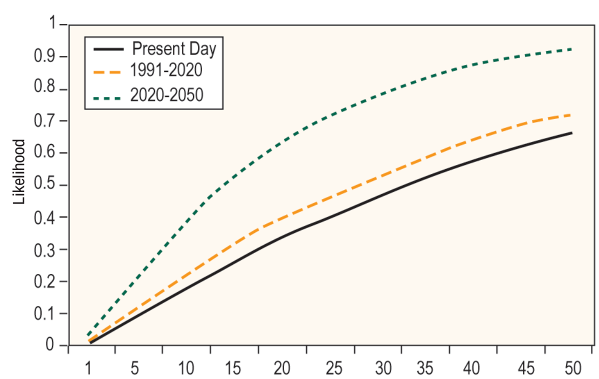
Source: CCAIRR findings.

Figure A1.16 depicts the impact of global warming on the likelihood of a maximum wind gust of 28 m^{s-1} for Pohnpei.

K. Extreme High Temperatures

Figure A1.17 presents the frequency distribution of daily maximum temperature for Pohnpei.

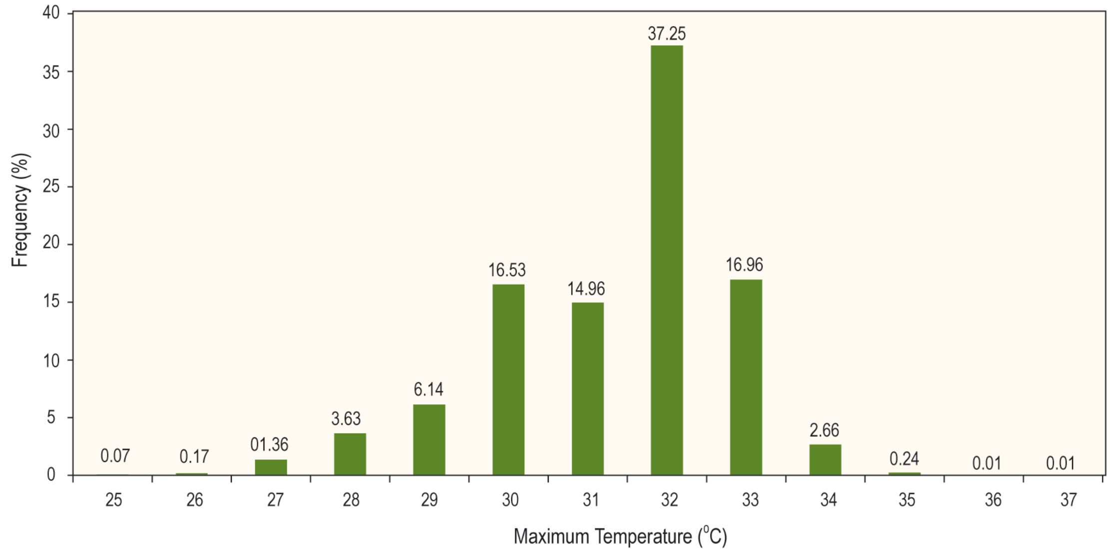
Figure A1.16 Likelihood of a Maximum Wind Gust of 28 m^{s-1} Occurring Within the Indicated Time Horizon in Pohnpei
(years)



0 = zero chance; 1 – statistical certainty.

Note: Values based on Canadian Global Climate Model 2, with A2 emission scenario.
Source: CCAIRR findings.

Figure A1.17. Frequency Distribution of Daily Maximum Temperature for Pohnpei



Source: Based on observed data 1953–2001.

Table A1.5 details the return periods for daily maximum temperature for Pohnpei, based on observed data (1953–2001) and projections using the Hadley Centre GCM and the A1B emission scenario.

Figure A1.18 depicts the impact of global warming on the likelihood of a daily maximum temperature of 36°C for Pohnpei.

Table A1.5. Return Periods for Daily Maximum Temperature, Pohnpei

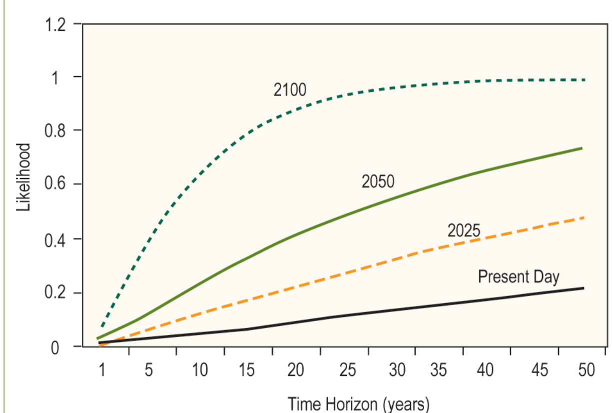
(years)

Maximum Temperature (°C)	Observed (1953–2001)	Projected		
		2025	2050	2100
32	1	1	1	1
33	1	1	1	1
34	4	2	2	1
35	24	11	6	2
36	197	80	39	10
37	2,617	1,103	507	101

Source: CCAIRR findings.

Figure A1.18. Likelihood of a Maximum Temperature of 36°C Occurring Within the Indicated Time Horizon in Pohnpei

(years)



Likelihood 0 = zero chance; 1 – statistical certainty.
Notes: Values based on observed data (1953–2001) and on projections from the Hadley Centre Global Climate Module (GCM) with A1B emission scenario and best estimate of GCM sensitivity.
Source: CCAIRR findings.

Appendix 2

The Cook Islands—Climate Risk Profile[1]

Summary

The likelihood (i.e., probability) components of climate-related risks in the Cook Islands are evaluated, for both present-day and future conditions. Changes into the future reflect the influence of global warming.

The risk events for which current and future likelihoods are evaluated are extreme rainfall events (both hourly and daily), drought, high sea levels, strong winds, and extreme high air temperatures. Tropical cyclone frequencies over the past century are also examined. Some climate-related human health and infrastructure risks are also investigated.

Projections of future climate-related risk are based on the output of global climate models, for given emission scenarios and model sensitivity.

All the likelihood components of projected climate-related risk show marked increases as a result of global warming.

A. Introduction

Formally, risk is the combination of the consequence of an event and the likelihood (i.e., probability) of that event taking place.

While the consequence component of a climate-related risk will be site or sector specific, in general the likelihood component of a climate-related risk will be applicable over a larger geographical area and many sectors. This is due to the spatial scale and pervasive nature of weather and climate. Thus, the likelihood of, say, an extreme event or climate anomaly is often evaluated for a country, state, small island, or similar geographical unit. While the likelihood may well vary within a given unit, information is often insufficient to assess this spatial variability, or the variations are judged to be of low practical significance.

The following climate conditions are considered to be potential sources of risk:

- extreme rainfall events,
- drought,
- high sea levels and extreme wave heights,
- strong winds, and
- extreme high air temperatures.

Some climate-related human health and infrastructure risks are also investigated.

B. Methods

Preparation of a climate risk profile for a given geographical unit involves an evaluation of current likelihoods of all relevant climate-related risks, based on observed and other pertinent data.

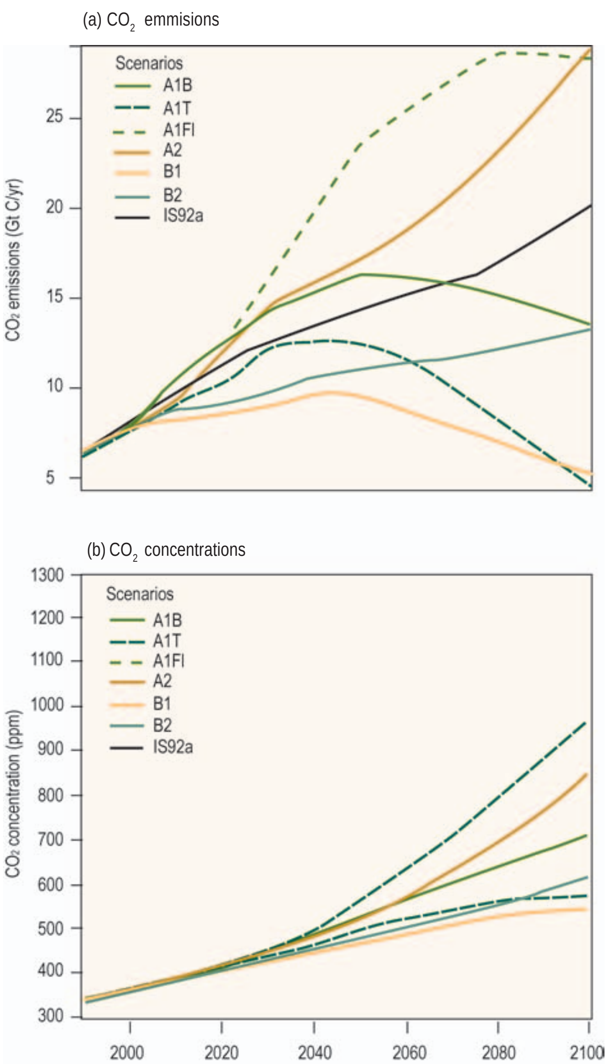
Climate change scenarios are used to develop projections of how the likelihoods might change in the future. For rainfall and temperature projections, the Australian Commonwealth Scientific and Industrial Research Organization global climate model (GCM) was used, as it is considered to work best in the South Pacific. For drought, strong winds, and sea level, the Canadian GCM was used to

[1] At this time the profile is limited to Rarotonga.

develop the projections, as this was the only GCM for which the required data were available.

The SRES A1B greenhouse gas emission scenario was used when preparing rainfall, temperature, and sea-level projections. Figure A2.1 shows that this scenario is close to the middle of the envelope of projected emissions, and hence of greenhouse gas concentrations. For drought, both the A2 and B2 emission scenarios were used, while for extreme wind gusts, only the A2 scenario was used. Again, the required projections were available only for these scenarios.

Figure A2.1. Scenarios of CO_2 Gas Emissions and Consequent Atmospheric Concentrations of CO_2



Notes: CO_2 = carbon dioxide; Gt C/yr = gigatonnes of carbon per year.
Source: IPCC 2001.

C. Information Sources

Daily and hourly rainfall, daily temperature, and hourly wind data were obtained through the Cook Islands Meteorological Service Office. Sea-level data for Rarotonga were supplied by the National Tidal Facility, The Flinders University of South Australia, and are copyright reserved.

D. Uncertainties

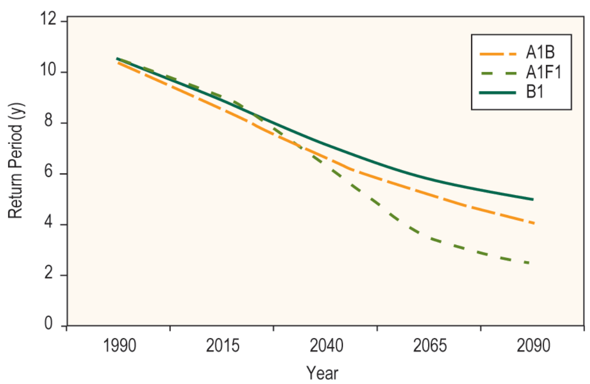
Sources of uncertainty in projections of the likelihood components of climate-related risks are numerous. These include uncertainties in greenhouse gas emissions and those arising from modelling the complex interactions and responses of the atmospheric and ocean systems. Figure A2.2 shows how uncertainties in greenhouse gas emissions impact on estimates of the return periods of a daily precipitation of at least 250 mm for Rarotonga.

Similar graphs can be prepared for other GCMs and extreme events, but are not shown here. Policy and decision makers need to be cognizant of uncertainties in projections of the likelihood components of extreme events.

E. Graphical Presentations

Many of the graphs that follow portray the likelihood of a given extreme event as a function of a time horizon. This is the most appropriate and useful way in which to depict risk, since design life (i.e., time horizon) varies depending on the nature of the infrastructure or other development project.

Figure 2.2. Return Periods for Daily Rainfall of 200 mm in Rarotonga for Given Greenhouse Gas Emission Scenarios



Note: Calculations used Hadley Center global climate model (GCM) with Best Judgment of Sensitivity.
Source: CCAIRR findings.

F. Extreme Rainfall Events

Daily Rainfall

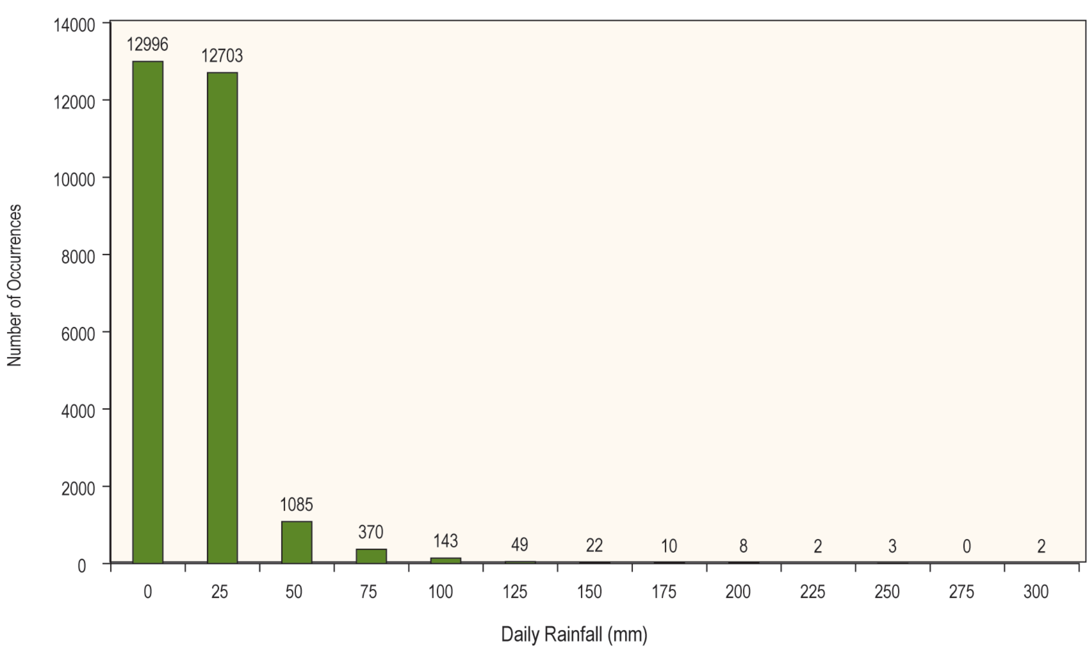
Figure A2.3 shows the frequency distribution of daily precipitation for Rarotonga. A daily total above 200 millimeters (mm) is a relatively rare event, with a return period (i.e., recurrence interval) of 11 years.

Figure A2.4 shows the likelihood of such an extreme rainfall event occurring in Rarotonga within a given time horizon ranging from 1 to 50 years.

It is clear that the frequency of extreme rainfall events has increased markedly since 1929, when records began.

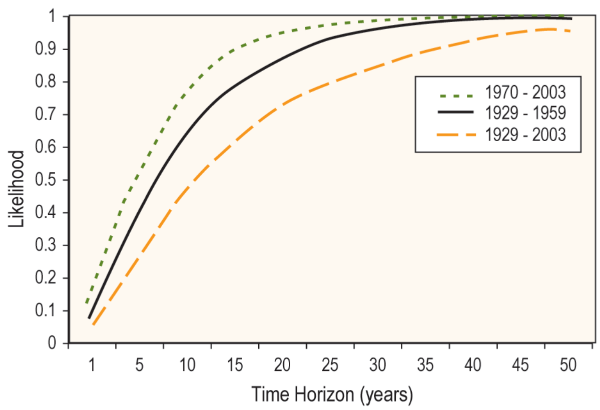
As shown in Table A2.1, global warming will significantly alter the return periods, and hence the likelihoods, of the extreme rainfall events. For example, Figure A2.5 illustrates how the likelihood of a daily rainfall of 200 mm will increase over the remainder of the present century.

Figure A2.3. Frequency Distribution of Daily Precipitation for Rarotonga
(1929–2003)



Note: The values above the bars represent the number of occurrences, for the given data interval.
Source: CCAIRR findings.

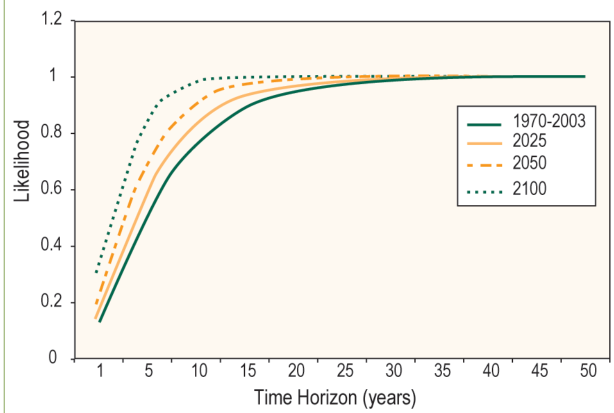
Figure A2.4. Likelihood of a Daily Rainfall of at Least 200 mm Occurring within the Time Horizon
(years)



Note: 0 = zero chance; 1 = statistical certainty. Data for Rarotonga, for indicated data periods.

Source: CCAIRR findings.

Figure A2.5. Likelihood of a Daily Rainfall of at Least 200 mm Occurring within the Indicated Time Horizon
(years)



Note: 0 = zero chance; 1 = statistical certainty. Data for Rarotonga.

Source: CCAIRR findings.

Table A2.1: Return Periods and Likelihood of Occurrence in 1 Year[1] for Daily Rainfall in Rarotonga

Rainfall (mm) (at least)	Present (1970–2003)		2025		2050		2100	
	RP	LO	RP	LO	RP	LO	RP	LO
100	1	0.78	1	.81	1	0.83	1	0.87
150	3	0.34	3	.38	2	0.44	2	0.56
200	7	0.14	6	.16	5	0.20	3	0.31
250	18	0.06	13	.08	10	0.10	6	0.17
300	38	0.03	26	.04	19	0.05	11	0.09
350	76	0.01	47	.02	35	0.03	19	0.05
400	141	0.01	81	.01	59	0.02	31	0.03
450	248	0	130	.01	95	0.01	50	0.02
500	417	0	201	0	148	0.01	78	0.01

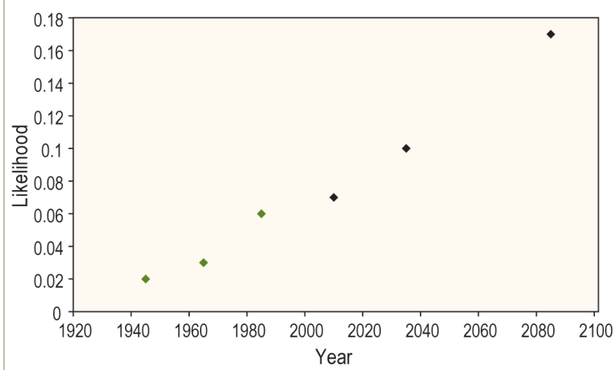
Notes: RP = return period; LO = likelihood of occurrence.

[1] A likelihood of 0 equals zero chance while a likelihood of 1 equates to a statistical certainty that the event will occur within a year.

Source: CCAIRR findings.

An obvious question arises: are the past changes in the probability component consistent with the changes projected to occur in the future as a result of global warming? The trend of increasing likelihood that was apparent in the historical data for much of the last century is projected to continue, in a consistent manner, through the present century. Observed and projected likelihoods of at least 250 mm of rain falling in a day are presented in Figure A2.6. A high degree of consistency is apparent. It is important to note that this consistency does not prove the existence of a global warming signal in the observed data. More detailed analyses are required before any such attributions can be made.

Figure A2.6. Observed and Projected Likelihoods of a Daily Rainfall of at Least 250 mm Occurring in a Year

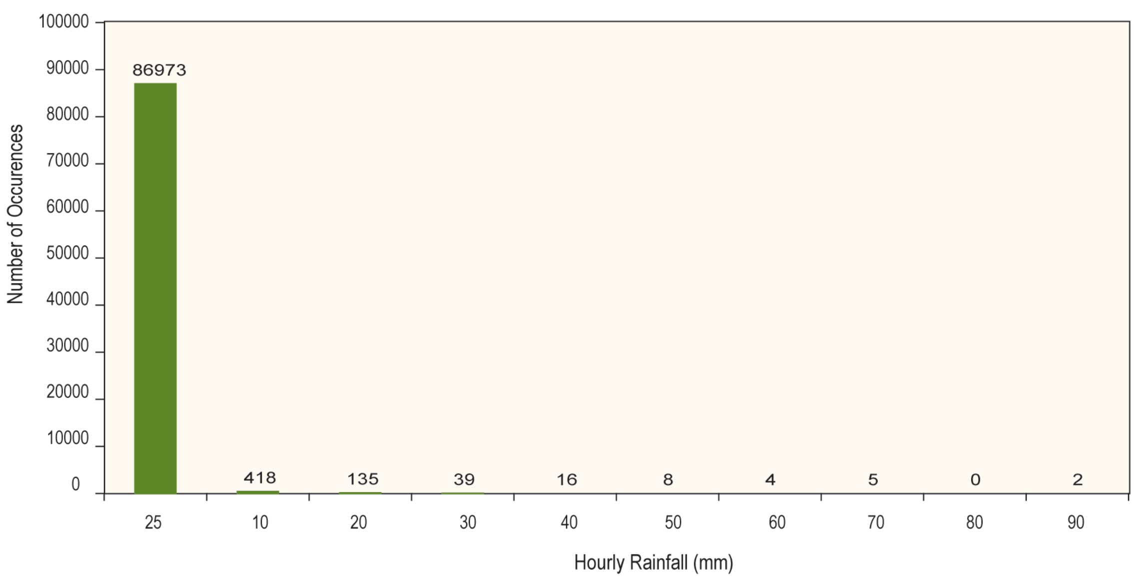


Notes: black symbols = observed likelihoods; green symbols = projected likelihoods. Data for Rarotonga.
Source: CCAIRR findings.

F. Hourly Rainfall

Figure A2.7 shows the frequency distribution of hourly precipitation for Rarotonga. An hourly total above 50 mm is a relatively rare event. Table A2.2 shows such a rainfall has a return period of 3 years, and that global warming will have a significant impact on the return periods of extreme rainfall events.

Figure A2.7. Frequency Distribution of Hourly Precipitation for Rarotonga



Notes: Data for 1970–1979. The values above the bars represent the number of occurrences for the given data interval.
Source: CCAIRR findings.

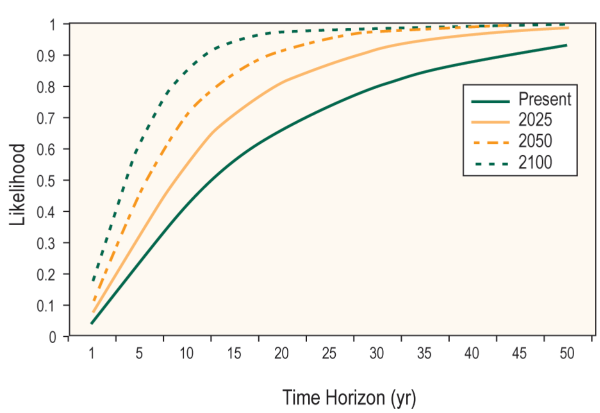
Table A2.2: Return Periods and Likelihood of Occurrence in 1 Year for Daily Rainfall Rarotonga

Rainfall (mm) (at least)	Present		2025		2050		2100	
	RP	LO	RP	LO	RP	LO	RP	LO
25	1	0.93	1	0.92	1	0.93	1	0.93
50	3	0.29	3	0.36	3	0.39	2	0.45
75	18	0.05	12	0.08	8	0.12	6	0.18
100	91	0.01	57	0.02	25	0.04	13	0.08
125	384	0	246	0	67	0.01	25	0.04
150	N/A	N/A	980	0	159	0.01	46	0.02

Notes: RP = return period in years; LO = likelihood of occurrence.
Source: CCAIRR findings.

Figure A2.8 depicts the impact of global warming on the likelihood of an hourly rainfall of 75 mm for Rarotonga.

Figure A2.8. Likelihood of an Hourly Rainfall of at Least 75 mm Occurring Within the Indicated Time Horizon in Rarotonga
(years)



Notes: Likelihood 0 = zero chance; 1 = statistical certainty. Values for present day based on observed data for 1980–2002, with gaps.
Source: CCAIRR findings.

F. Drought

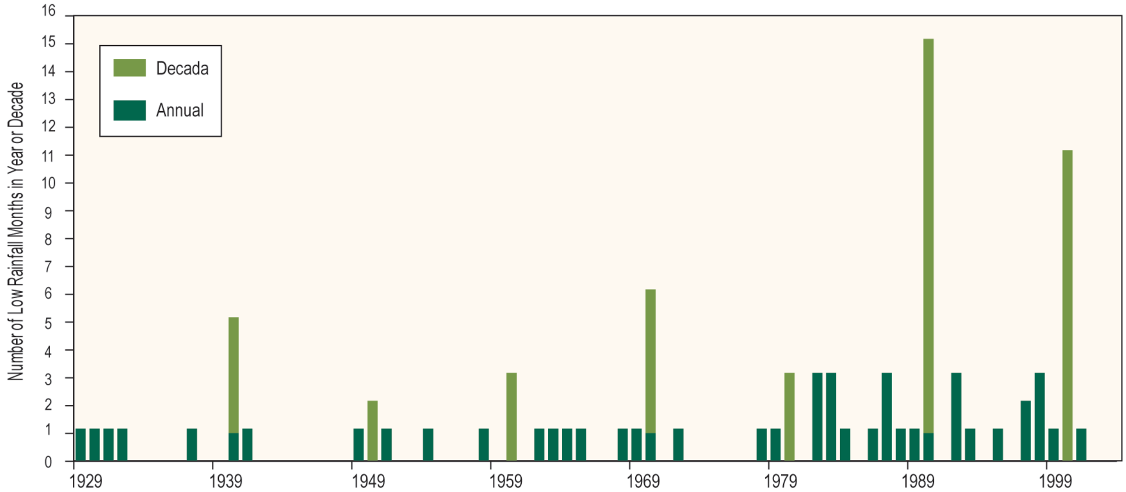
Figure A2.9 presents, for Rarotonga, the number of months in each year (1929–2003) and each decade for which the observed precipitation was below the 10th percentile. Monthly rainfall below the fifth percentile is used here as an indicator of drought.

Most of the low rainfall months are concentrated in the latter part of the period of observation, indicating that the frequency of drought has increased since the 1930s. The years with a high number of months below the fifth percentile coincide with El Niño Southern Oscillation (ENSO) events.

Figure A2.10 shows the results of a similar analysis, but for rainfall estimates (1961–1990) and projections (1991–2100).

The results indicate that prolonged and more intense periods of drought will occur during the remainder of the 21st century.

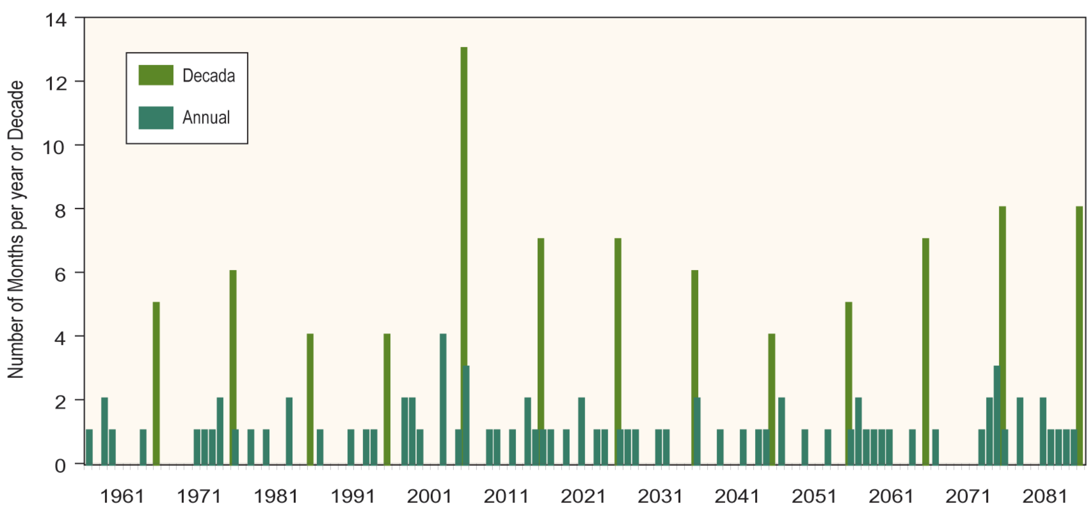
Figure A2.9. Number of Months in Each Year and Decade for which the Precipitation was Below the Fifth Percentile



Note: data for Rarotonga.

Source: CCAIRR findings.

Figure A2.10. Number of Months Per Year and Per Decade for Which Precipitation in Rarotonga was Observed, and is Projected to Be, Below the Fifth Percentile



Notes: data from the Canadian global climate module (GCM), with A2 emission scenarios and best estimate for GCM sensitivity.

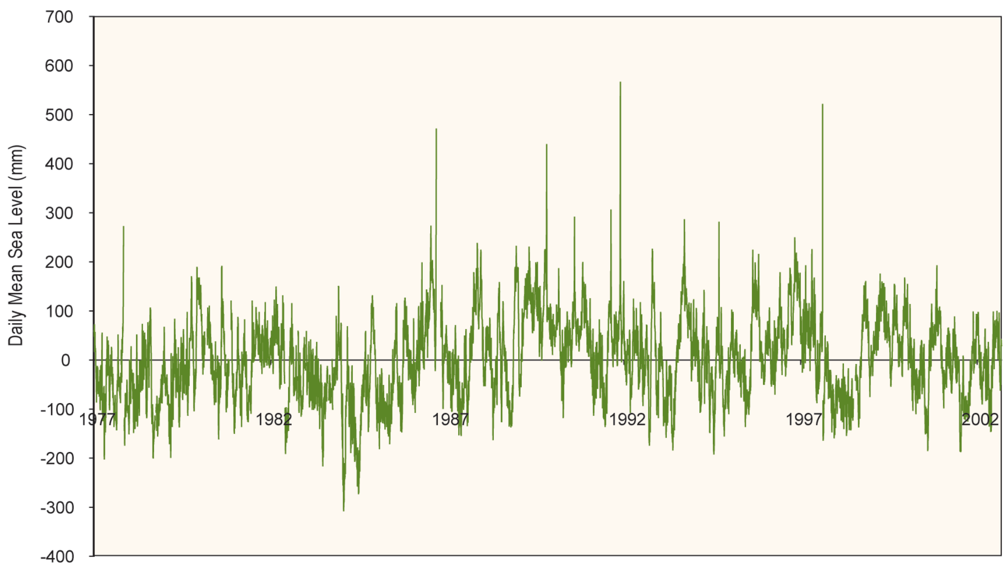
Source: CCAIRR findings.

G. High Sea Levels and Extreme Wave Heights

Figure A2.11 shows daily mean values of sea level for Rarotonga, relative to mean sea level. Large interannual variability occurs in sea level. The exceptionally high sea levels shown in Figure A2.11 are all associated with the occurrence of tropical cyclones.

Even more extreme high sea levels occur for time scales less than a day. Table A2.3 provides return periods for given significant on-shore wave heights for Rarotonga, for the present day and projected future. The latter projections are based on the Canadian GCM 1 GS and the A1B emission scenario.

Figure A2.11. Daily Mean Values of Sea Level for Rarotonga
(1977–2002)



Source: CCAIRR findings.

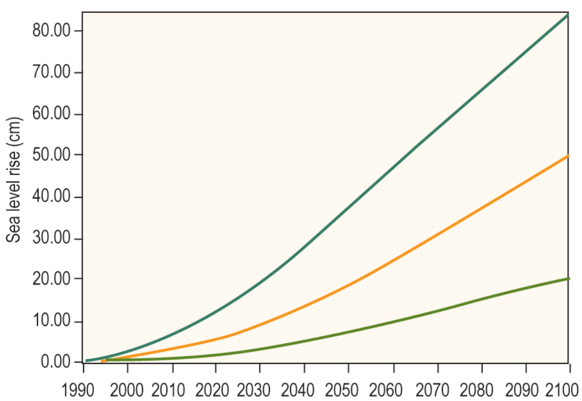
Table A2.3. Return Periods for Significant On-shore Wave Heights, Rarotonga
(years)

Sea Level (m) (at least)	Present Day		2025		2050		2100	
	RP	LO	RP	LO	RP	LO	RP	LO
2	2	0.51	2	0.59	2	0.65	1	0.75
4	4	0.25	3	0.31	3	0.35	2	0.45
6	10	0.10	8	0.13	7	0.15	5	0.21
8	30	0.03	23	0.04	18	0.05	12	0.08
10	112	0.01	80	0.01	62	0.02	39	0.03
12	524	0	349	0	258	0	149	0.01

Notes: LO = likelihood pf occurrence; RP = return period.
Source: CCAIRR findings.

The indicated increases in sea level over the next century are driven by global and regional changes in mean sea level as a consequence of global warming. Figure A2.12 illustrates the magnitude of this contribution.

Figure A2.12. Sea Level Projections for Rarotonga



Notes: Uncertainties related to global climate model sensitivity are indicated by the blue, red and green lines, representing high, best estimate, and low sensitivities, respectively.

Source: CCAIRR findings.

H. Strong Winds

Figure A2.13 shows the annual maximum wind gust recorded in Rarotonga for the period 1972–1999.

Figure 2.14 presents the likelihood of a wind gust of at least 40 m/sec occurring at Rarotonga within the specified time horizon.

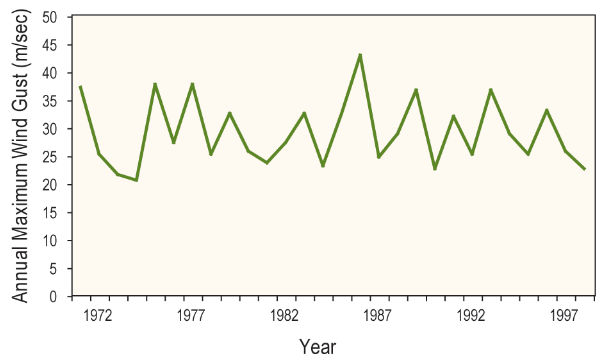
Table A2.4 presents the return periods based on an analysis of the observed maximum hourly wind gust data and the adjusted GCM wind speed data.

The return period estimates of Kirk are for open water conditions. Strong agreement is observed between these and the return periods based on observed data, suggesting that the Rarotonga anemometer provides extreme gust estimates that are reasonably representative of open water conditions.

Comparison of the return period estimates for the 1961–1990 GCM data with the observed data also reveals good agreement, though the GCM data tend to show slightly shorter return periods for lower extreme wind speeds and slightly longer return periods for higher extreme wind speeds.

Arguably the most important finding arising from this analysis is the suggestion that, over the coming 50 years or so, the return periods for the most extreme wind speeds will reduce significantly, decreasing by approximately half by 2050.

Figure A2.13. Annual Maximum Wind Gust Recorded in Rarotonga for the Period 1972–1999



Source: CCAIRR findings.

Figure A2.14. Likelihood of a Wind Gust of 40 m/sec (78 kt) Occurring Within the Indicated Time Horizon, Rarotonga

Notes: 0 = zero chance; 1 = statistical certainty. Data for Rarotonga, Cook Islands (1972–1999). A wind gust of 40 ms^{-1} has a return period of 20 years.

Source: CCAIRR findings.

Table A2.4: Estimates of Return Periods for Given Maximum Wind Speeds, Rarotonga
(years)

Wind Speed (m/sec)	Return Period (years)				
	Kirk (1992)	Observed Data (1972–1999)	GCM Based Maximum Wind Speed Data		
			1961–1990	1991–2020	2021–2050
28.5	2	2	1	1	1
33.9	5	5	2	2	2
37.5	10	11	3	4	4
38.8	13	14	5	5	6
41.9	25	29	18	16	14
44.9	50	57	60	45	31
47.8	100	113	120	95	64

Note: GCM = global climate module.
Source: CCAIRR findings.

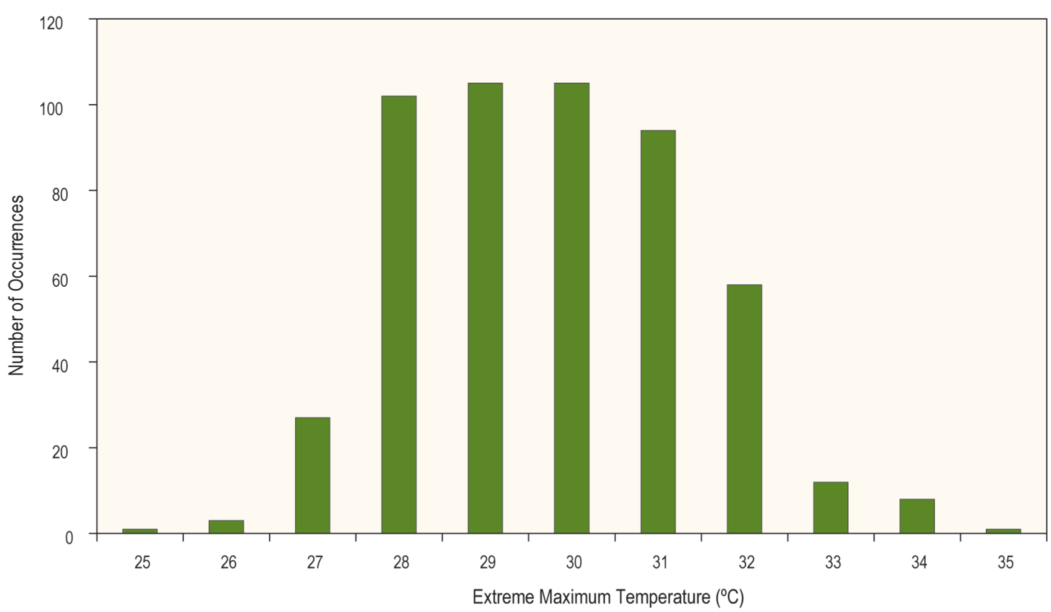
I. Extreme High Temperatures

Figure A2.15 presents the frequency distribution of daily maximum temperature for Rarotonga.

Table A2.5 details the return periods for daily maximum temperature for Rarotonga, based on observed data (1961–2003) and GCM projections.

Figure A2.16 shows the likelihood of a maximum temperature of at least 35°C occurring within the indicated time horizon.

Figure A2.15. Frequency distribution of Monthly Extreme Maximum Temperature for Rarotonga



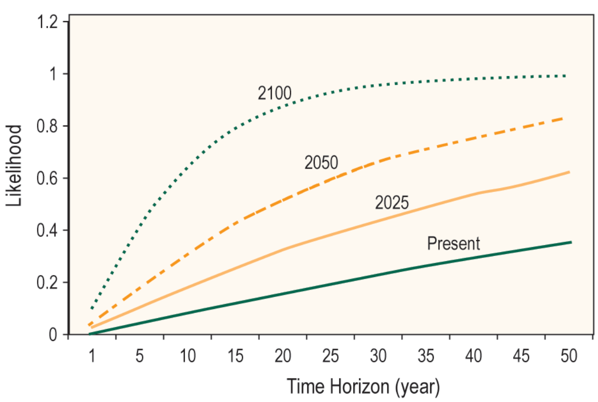
Note: Based on observed data from 1961 to 2003.
Source: CCAIRR findings.

Table A2.5. Return Periods for Monthly Extreme Maximum Temperature, Rarotonga
(years)

Maximum Temperature (°C)	Observed (1961-2003)		Projected					
			2025		2050		2100	
	RP	LO	RP	LO	RP	LO	RP	LO
31	1	0.72	1	0.90	1	0.97	1	1
32	3	0.33	2	0.54	1	0.71	1	0.94
33	9	0.12	5	0.22	3	0.34	2	0.64
34	29	0.03	14	0.07	9	0.12	3	0.29
35	108	0.01	52	0.02	29	0.03	10	0.10
36	435	0	208	0	115	0.01	37	0.03

Notes: LO = likelihood of occurrence; RP = return period.
Source: CCAIRR findings.

Fig A2.16 Likelihood of a Maximum Temperature of at Least 35°C Occurring Within the Indicated Time Horizon in Rarotonga
(years)



Note: 0 = zero chance; 1 = statistical certainty.
Source: CCAIRR findings.

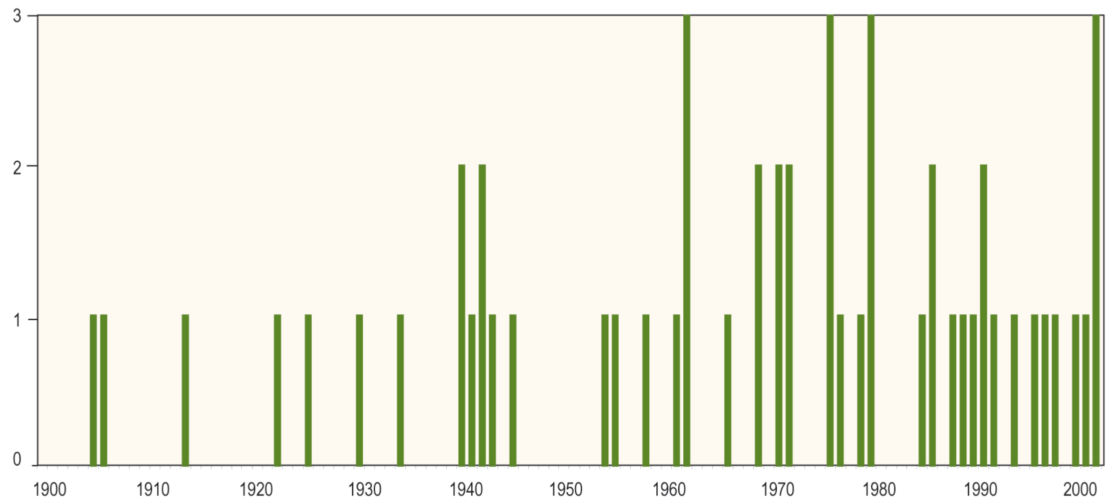
J. Tropical Cyclones

The number of tropical cyclones passing close to, and affecting Rarotonga appears to have increased during the last century (Figure A2.17). However, since observing and reporting systems improved substantially over the same time period, it is unwise to read too much into the marked contrast in frequency between the first and second halves of the 20th century. The record for the last few decades is much more reliable, hence the doubling in decadal frequencies between the 1950s and 1990s may well be closer to the truth. It is certainly consistent with the fact, since the 1970s that El Niño episodes have tended to be more frequent, without intervening La Niña events. The duration of the 1990–95 El Niño is unprecedented in the climate record of the past 124 years.

Studies by Australia's Bureau of Meteorology (Figure A2.18a and b) reveal the consequences of the weakened trade winds and eastward movement of the warm waters of the western tropical Pacific during El Niño events. Because convective systems (e.g., thunderstorms and rainstorms) and tropical cyclones preferentially occur over warmer waters, changes in the pattern of sea surface temperatures is reflected in the distribution of rainfall and tropical cyclones.

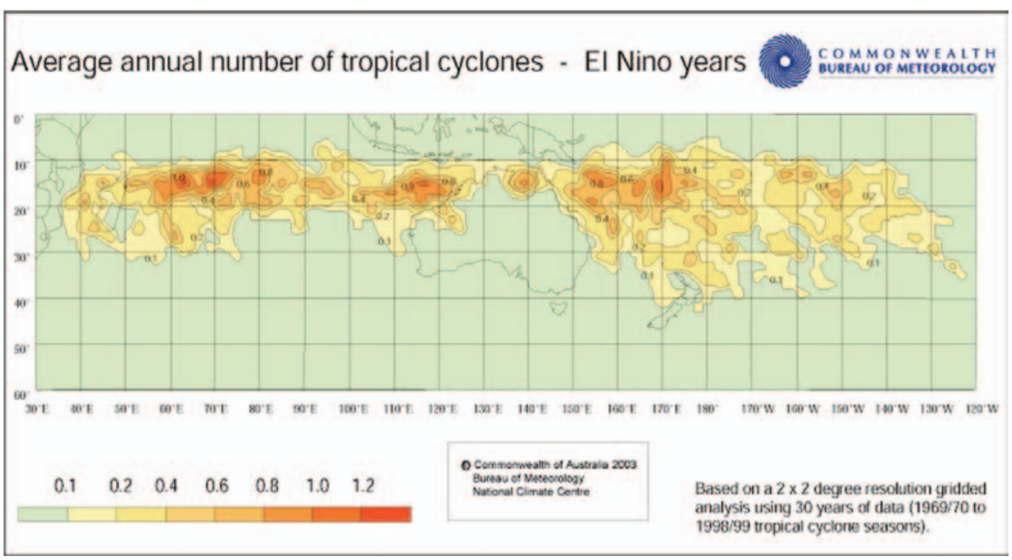
A possible consequence of the increased persistence of El Niño conditions in recent decades is the apparent intensification of tropical cyclones, as reflected in the systematic increase in upper 10 percentile heights of open water waves associated with tropical cyclones occurring in the vicinity of Rarotonga (Table A2.6).

Figure A2.17. Number of Tropical Cyclones per Year passing Close to, and Affecting, Rarotonga



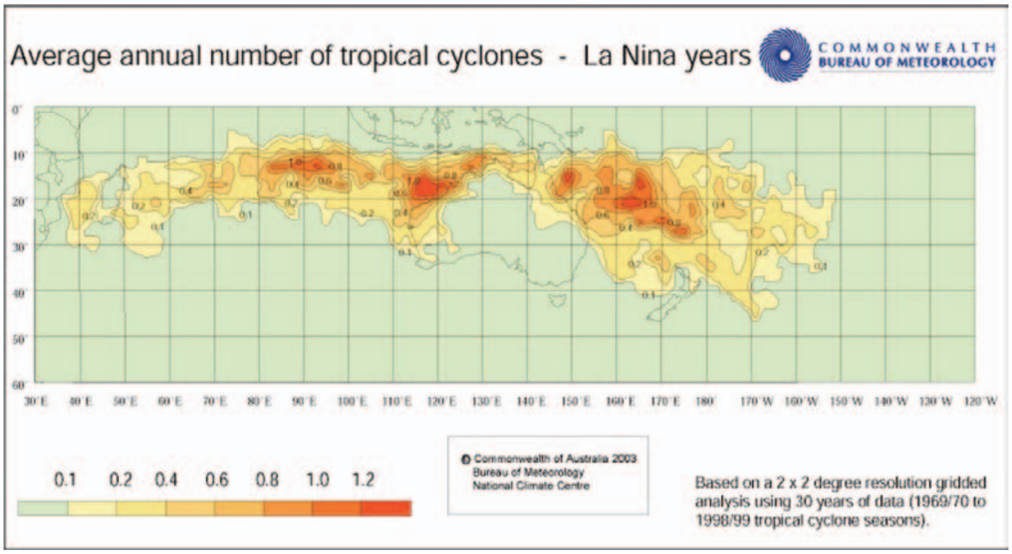
Sources: Kerr 1976, Revell 1981, Thompson et al. 1992, d'Aubert and Nunn 1994, Fiji Meteorological Service 2004, and Ready (personal communication).

Figure A2.18a. Average Annual number of Tropical Cyclones for El Niño Years



Source: Australian Bureau of Meteorology, n.d. Reproduced by permission

Figure A2.18b. Average Annual number of Tropical Cyclones for La Niña Years



Source: Australian Bureau of Meteorology, n.d. Reproduced by permission

Table A2.6. Open Water Wave Height (Average of Top 10%) Associated with Tropical Cyclones Recently Affecting Rarotonga

Cyclone (name and year)	Wave Height (m)
Charles (1978)	11
Sally (1987)	10
Val (1991)	14
Pam (1997)	14
Dovi (2003)	17
Heta (2004)	17
Nancy (2005)	22
Percy (2005)	19

Source: Dorrell (personal communication).

Appendix 3

Guidelines for Policy and Decision Makers and Other Key Players—Federated States of Micronesia

A. Background and Purpose of these Guidelines

Under its Climate Change Adaptation Program for the Pacific, the Asian Development Bank (ADB) is facilitating preparation of case studies[1] that demonstrate a risk-based approach to adapting to climate variability and change (including extreme events), and the mainstreaming of the adaptation process. The present Guidelines for mainstreaming adaptation to climate change are based on the findings of the case studies. They are also informed by experience gained through other investigations and by operational practice.

The Guidelines are intended to assist the Government of the Federated States of Micronesia (FSM) and other relevant stakeholders in implementing policies, plans, and operational procedures that result in integrating adaptation to climate variability and change into national and local development planning, decision making and operations as an an integral and sustainable part of the development process.

The Guidelines are presented in the context of a series of questions that arose, and were answered, in the course of preparing the case studies. Each guideline has an associated box that provides a practical example of the application of the guideline, with respect to one of the case studies prepared in the Federated States of Micronesia (FSM).

Mainstreaming adaptation is the principal focus of these Guidelines. They do not refer explicitly to other related and important matters, including

- adaptation policy frameworks—for details on this topic refer, for example, to UNDP-GEF (2003); and
- adaptation measures as such—for national examples see Government of the FSM (1999) and for regional examples see Hay et al. (2003).

B. Basic Principles for Adaptation to Climate Change

Although, as mentioned above, these Guidelines focus on the mainstreaming of adaptation, rather than adaptation per se, a listing of some of the basic principles for adaptation to climate change will provide a useful foundation for considering the mainstreaming process. These include the following:

- Adaptation is, in large part, a continuous, dynamic process that reduces the exposure of society to risks arising from climatic variability and extremes.
- Adaptation must reflect both recurrent historical risks and new risks associated with climate change.
- Exploring and undertaking actions to adapt to current climate extremes and variability is of value, both in dealing with today's problems and

[1] Three case studies were carried out in the FSM and three in the Cook Islands. Details are provided in the main part of this book.

as an essential step toward building long-term resilience to withstanding the pending changes in climate;
- Many disaster and climate change response strategies are the same as those that contribute in a positive manner to sustainable development, sound environmental management, and wise resource use; they are also appropriate responses to climate variability and other present-day and emerging stresses on social, cultural, economic, and environmental systems.
- Effective management of climate-related risks prevents precious resources from being squandered on disaster recovery and rehabilitation.
- While many climate-related risks and losses are manifested locally, measures to alleviate them have important national and international dimensions.
- If adaptation is reactive, as opposed to anticipatory, the range of response options is likely to be narrower and adaptation may well prove more expensive, socially disruptive, and environmentally unsustainable.
- Many development plans and projects at present under consideration have life expectancies requiring that due consideration be given to future climate conditions and sea levels.
- It is easier to enhance the ability of ecosystems to cope with climate change if they are healthy and not already stressed and degraded.
- Adaptation requires enhancement of institutional capacity, development of expertise, and the building of knowledge. All these take time.
- People will, as a result of their own resourcefulness or out of necessity, adapt to climate variability and change (including extreme events), based on their understanding and assessment of the anticipated or observed effects, and on the perceived options and benefits for response. In many cases, such adaptations will be adequate, effective, and satisfactory.
- However, under some circumstances, such adaptation may not be satisfactory or successful; an external entity, such as central or local government, may need to facilitate the adaptation process to ensure that obstacles, barriers, and inefficiencies are addressed in an appropriate manner.

C. What is Meant by "Mainstreaming Adaptation"?

In the context of addressing climate change and related issues, the term "mainstreaming" is used to describe the integration of policies and measures to address climate change in ongoing and new development policies, plans, and actions. Mainstreaming adaptation aims to enhance the effectiveness, efficiency, and longevity of initiatives directed at reducing climate-related risks, while at the same time contributing to sustainable development and improved quality of life.

Mainstreaming also endeavors to address the complex tensions between development policies aimed at immediate issues and the aspects of climate policy aimed at longer-term concerns. The tensions often become most apparent when choices have to be made about the disbursement of limited government funds—for example, choices between supporting education and health care programs on the one hand and funding climate change adaptation initiatives on the other. Indeed, mainstreaming is largely about reducing tensions and conflicts, and avoiding the need to make choices, by identifying synergistic, win-win situations. Thus mainstreaming focuses on "no regrets" measures for adaptation.[2]

D. Why Mainstream Adaptation?

Even in the near future, climate change is likely to impose untenable social, environmental, and economic costs on the FSM. Most of the country is already experiencing disruptive conditions that are consistent with many of the anticipated adverse consequences of climate change, including extensive coastal erosion, drought, flooding and associated landslides, coral bleaching, and higher sea levels.

The risks associated with the full spectrum of climate-related hazards, from extreme events to the consequences of long-term changes in the climate,

[2] "No regrets" measures for adaptation are consistent with sound environmental management and wise resource use, and are thus appropriate responses to natural hazards and climate variability, including extreme events; they are therefore beneficial and cost effective, even if no climate change occurs.

should be managed in a holistic manner as an integral part of national development planning and management (Figure A3.1). Most countries already have policies and plans to manage financial risks, human health risks, biosecurity risks, agricultural risks, transport sector risks, and energy supply risks. Climate-induced disasters, and climate change and variability, should also be included in the national risk management portfolio.

National and state development plans and sector plans should include disaster risk management strategies and climate change adaptation measures to ensure that risks are reduced to acceptable levels. These measures, and the related strategies, will help strengthen decision-making processes by requiring that specific programs and projects include plans and measures to manage risks associated with extreme events and with climate change and variability. The overall goal should be to manage, in a holistic manner and as an integral part of national development planning, the risks associated with the full spectrum of weather, climate, and oceanic hazards, from extreme events to the consequences of long-term climate change.

Guideline 1

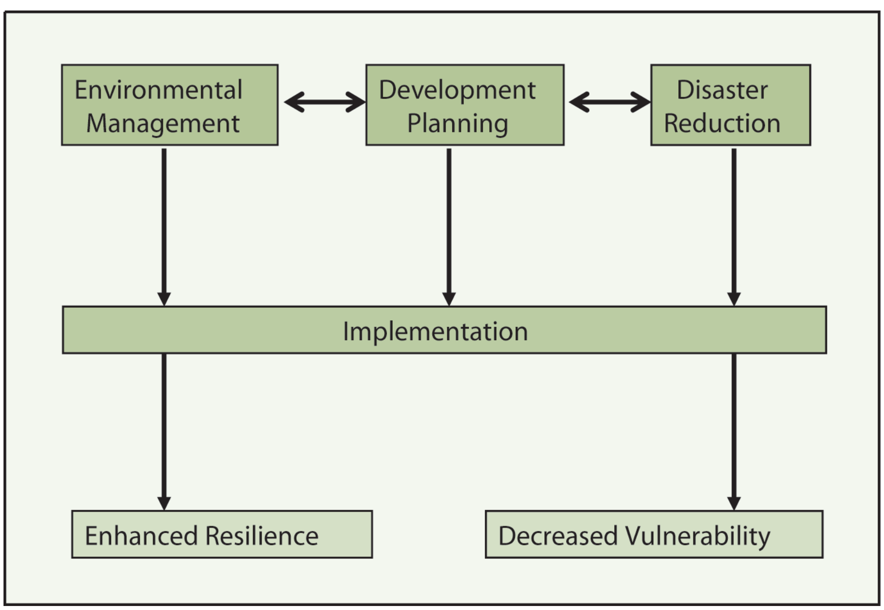
Document the relevant major risks to the economy and society resulting from climate variability and change (including extreme events), characterizing these in terms of their probabilities of occurrence and associated economic and social consequences (Box A3.1).

F. At a Practical level, What Does Adaptation Mainstreaming Entail?

Adaptation mainstreaming has two key practical components:

- creating and strengthening the enabling environment for adaptation; and
- integrating adaptation planning and implementation into existing and new development policies, plans, and actions.

Figure A3.1. The "Optimal Response " to Climate Change

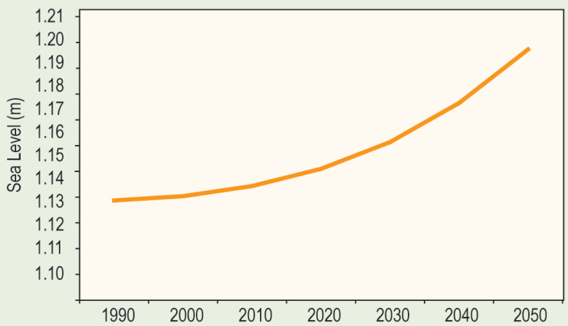


Sources: adapted from Kay and Hay (1993), Hay and McGregor (1994), and Campbell and de Wet (1999).

Box A3.1

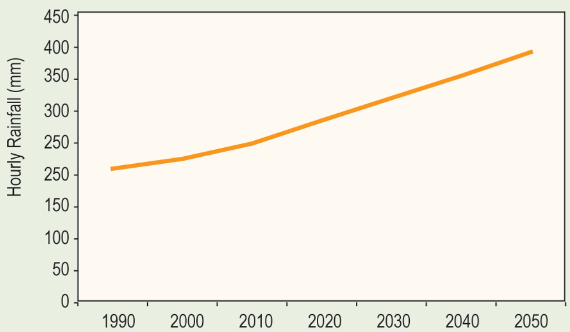
In Sokehs community, Pohnpei, climate change will alter the risk of flooding due to high sea levels.

Hourly Sea Level for Recurrence Interval of 25 Years —Pohnpei



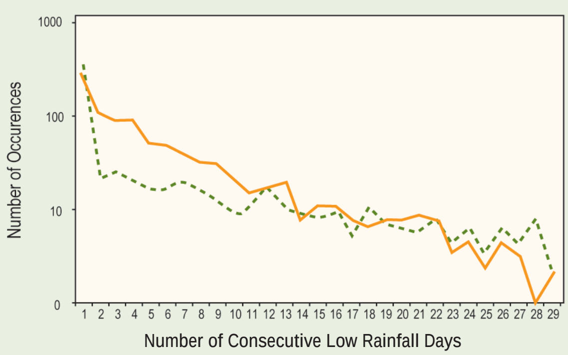
For a roadbuilding project in Kosrae, climate change alters construction requirements and costs if the design risk is kept at 1 in 100 years.

Hourly Sea Level for Recurrence Interval of 25 Years —Pohnpei



For Pohnpei public health, climate change will alter the frequency and duration of drought, the ending of which is associated with major outbreaks of gastroenteritis.

Frequency and Duration of Drought–Pohnpei



G. What is the "Enabling Environment" for Adaptation?

The "enabling environment" for adaptation comprises the systems and capabilities that foster the adaptation process, including innovation, revitalization of traditional practices, application of human knowledge and skills, policies, financing, legislation and regulations, information, markets, and decision support tools. It provides the context within which development projects and related initiatives occur (Figure A3.2) and ensures that they are effectively "climate proofed".[3]

The multiple dimensions of the enabling environment are evident in Figure A3.3. Longer-term interventions at national and subnational levels, often with support from the international community, are required to create and strengthen the enabling environment.

H. How can the Enabling Environment for Adaptation be Enhanced?

Guideline 2

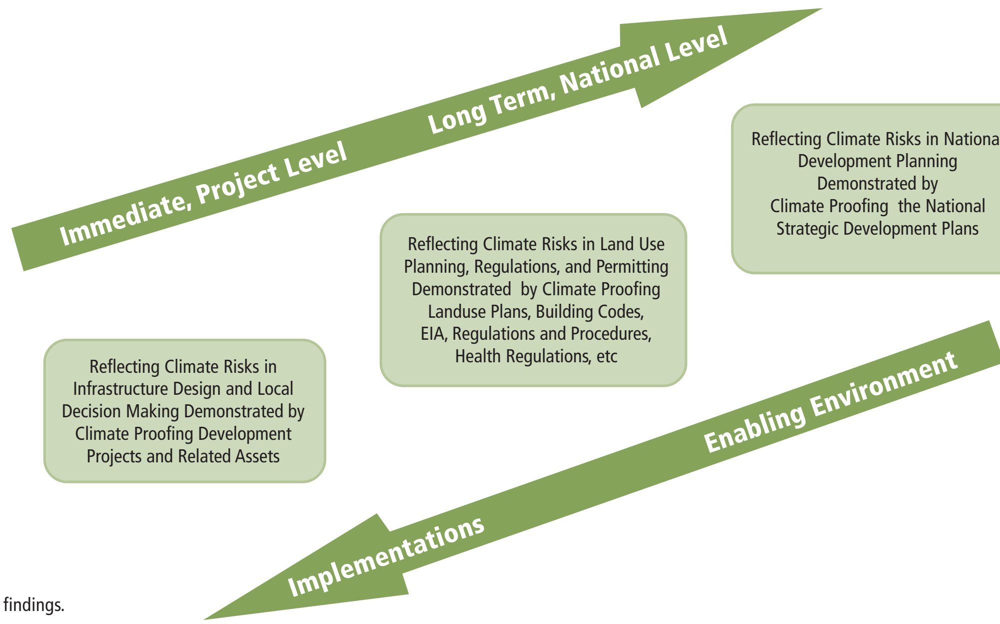
Organize and strengthen institutions in ways that

- enhance communication between climate risk assessors and adaptation policy makers and implementers;
- reduce the likelihood of conflict and duplication of effort when managing climate-related risks;
- lessen the chances of mistrust and misunderstanding between decision and policy makers and other stakeholders in adaptation activities; and
- overall, help to provide consistent, defensible, and useful advice to decision and policy makers with respect to adaptation priorities and practices (Box A3.2).

---

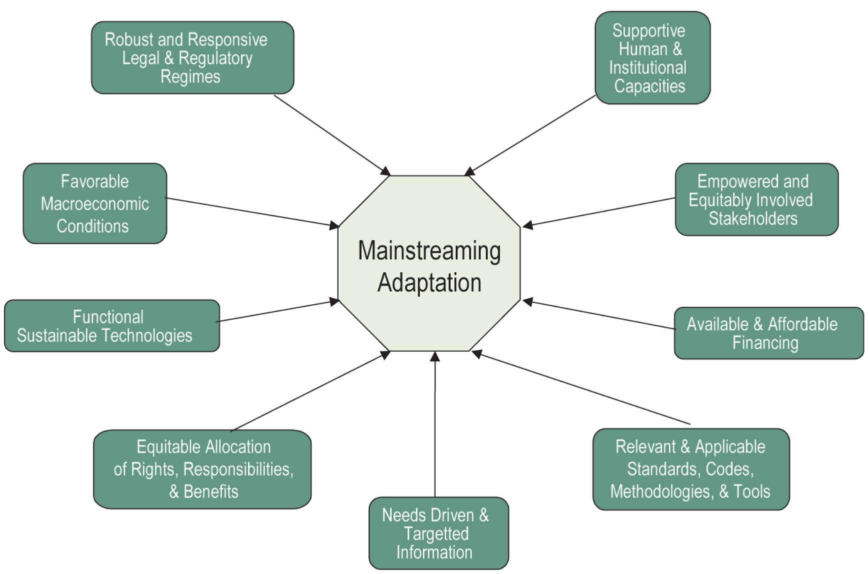
[3] Climate proofing is a shorthand term for identifying risks to a development project, or any other specified natural or human asset, as a consequence of climate variability and change, and ensuring that those risks are reduced to acceptable levels through long-lasting and environmentally sound, economically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

Figure A3.2: Linkages Between Longer-Term Activities to Create an Enabling Environment for Adaptation and the Climate Proofing of Shorter-Term Development Projects and Protection of Natural and Human Assets



Source: CCAIRR findings.

Figure A3.3. The Multiple Dimensions of the Enabling Environment for Adaptation to Climate Variability and Change



Source: CCAIRR findings.

BOX A3.2

When the Climate Change Adaptation through Integrated Risk Reduction project was in its early stages, Pohnpei's governor established an Inter-Agency Task Force to Assess and Manage Weather- and Climate-Related Risks, to oversee the ongoing program of climate risk assessments and implementation of adaptation in Pohnpei. At that time, the Governor decreed that the Task Force would have oversight for the coordination and cooperation required to ensure timely and cost-effective assessments of, and responses to, the weather- and climate-related risks facing Pohnpei. He also required that in no case would it disrupt the existing allocation of responsibilities and resources afforded to government agencies. Rather, it would be a mechanism for exploring and implementing collaborative activities that are of mutual benefit to the agencies involved, as well as to the people of Pohnpei.

The Director of the Task Force is a member of the National Climate Change Country Team for the Federated States of Micronesia, and chairs its meetings on a rotational basis.

At the technical level, the Task Force is being assisted by the Pohnpei Climate Change Adaptation through Integrated Risk Reduction Team, made up of technical specialists, key individuals from nongovernment organizations, and representatives of the Sokehs and wider communities.

Source: CCAIRR findings.

Guideline 3

Wherever possible and practical, make use of existing information and information management systems. This may well require additional initial effort to source and harmonize dispersed and disparate sets of information, but it is likely to result in a strengthening of existing information management systems as opposed to their marginalization (Box A3.3).

BOX A3.3

For the Sokehs case study, local data holdings were identified, including information in geographic information systems maintained by the Environmental Protection Agency, the Department of Lands, the Public Utilities Corporation, (all state agencies) and the Census Division of the national Government. Health data for the state and the Sapwohn community were obtained from the Pohnpei State Hospital. The Conservation Society of Pohnpei and the local office of The Nature Conservancy also had relevant information. Aerial photographs and maps were obtained from the Department of Lands. Relevant historical information is held by the Micronesian Seminar. Some weather data were obtained from the (US) National Oceanic and Atmospheric Administration (NOAA) National Weather Service Office in Pohnpei. Additional weather data were sourced from the National Climate Data Center in the USA, via the NOAA office in Guam, while tide gauge data were obtained from the University of Hawaii and from the National Tidal Centre in Australia. Documents such as the First National Communication to the United Nations Framework Convention on Climate Change and state and national disaster reports were also consulted.

Spot heights and locations of structures and infrastructure in the Sapwohn study area were determined using a Total Station survey system. At the same time, detailed descriptive and flood damage information were obtained for each structure, through visual inspection and interviews conducted by members of the Pohnpei Climate Change Adaptation through Integrated Risk Reduction (CCAIRR) Team.

All data used in the case study have been placed in a cooperative archive maintained by the Department of Lands on behalf of the Pohnpei CCAIRR Team.

Source: CCAIRR findings.

Guideline 4

Enhance and employ in-country expertise in the technical and policy dimensions of adaptation to climate change (Box A3.4).

Guideline 5

The enabling environment for adaptation is enhanced when legislation and regulations that facilitate adaptation are introduced and strengthened, and also when the compliance monitoring and enforcement capabilities of relevant regulatory agencies are improved (Box A3.5).

Guideline 6

Wherever possible and practical, make use of existing decision support tools and regulatory instruments to guide selection and facilitate implementation of adaptation measures; examples include environmental impact assessments and building codes. This is likely to result in a strengthening of existing tools and regulations, rather than weakening them through confusion and inadequate enforcement (Box A3.6).

Guideline 7

Identify the motivations that drive various stakeholders to engage in the adaptation process, and replicate these motivations in other players, through education, training, and other initiatives (Box A3.7).

Guideline 8

Build the willingness and ability of communities to adapt continuously to new circumstances and challenges, and to realize this increased potential. High levels of awareness, motivation, and empowerment within the public and private sectors and in civil society will help ensure that people, communities, and wider societies are able to adapt continuously to new circumstances and challenges. This requires a long-term approach to developing and delivering comprehensive and targeted awareness-raising and educational programs (Box A3.8).

BOX A3.4

Local technical capabilities in such areas as geographical information systems (GIS), surveying, and vulnerability and adaptation assessments were identified, with technically qualified personnel forming the Pohnpei Climate Change Adaptation through Integrated Risk Reduction (CCAIRR) Team. Members of the team undertook the field work to determine spot heights and locations of structures and infrastructure in the Sapwohn study area, as well as gathering detailed descriptive and flood damage information through visual inspection and interviews. All information for the Sapwohn study area was imported to a GIS and members of the CCAIRR Team processed it.

BOX A3.5

The Sokehs case study resulted in a recommendation that the Building Code, the Environmental Impact Assessment Regulations and other appropriate regulatory instruments overseen by the state of Pohnpei be amended to provide that when new buildings are constructed, or existing buildings are modified substantially, allowance is made for:

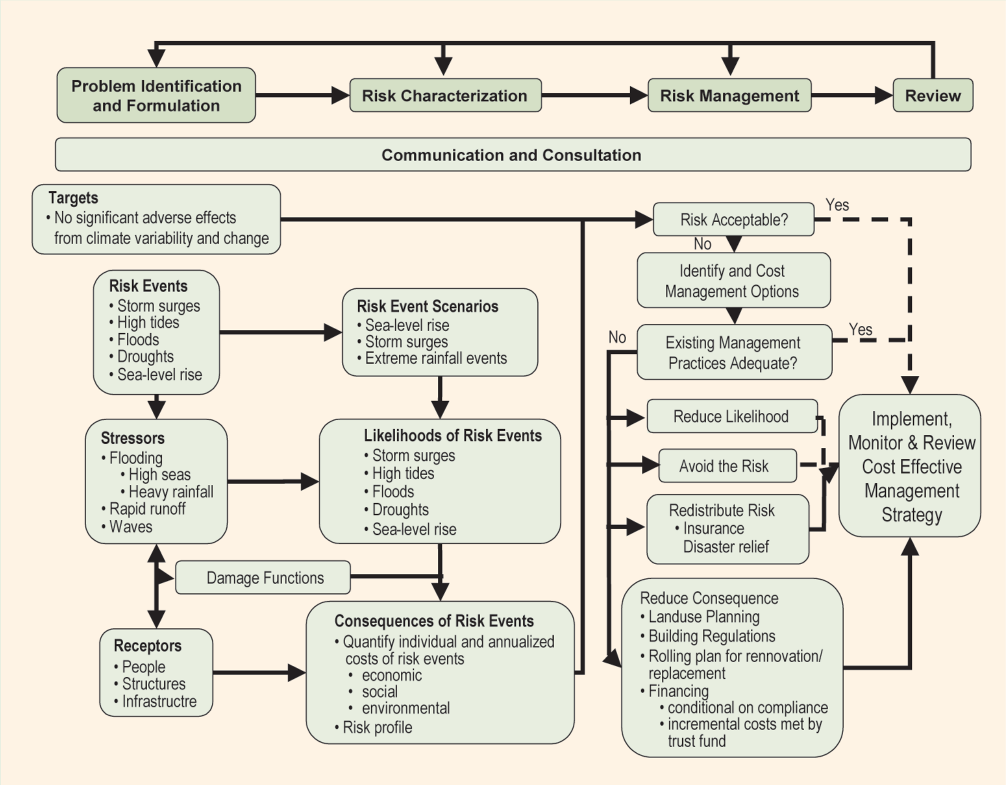
- surface flooding as a result of hourly rainfall intensities of at least 40.6 centimeters (such an event has a projected return period of 25 years in 2050);
- surface flooding as a result of sea level being at least 1.2 m above mean sea level (such an event has a projected return period of 25 years in 2050 (the requirement in the draft building code is 3 m); and
- the possibility of wind gusts exceeding 209 kilometers per hour (kph) (this event has a projected return period of 25 years in 2050; current practice is to use 193 kph as the design wind speed).

It is also recommended that Pohnpei State strengthen existing policies and plans in ways that reflect projected increases in the following:

- extended periods of low rainfall (i.e., drought); and
- outbreaks of gastroenteritis.

Source: CCAIRR findings.

BOX A3.6



The risk-based approach to adaptation used in the Climate Change Adaptation Program for the Pacific case studies follows methods consistent with international risk management standards, including Australia and New Zealand standard 4360**.**

The Risk Assessment Framework Used in the CLIMAP Case Studies

The assessment of climate-related risks, and the cost-benefit analyses of adaptation measures, have been facilitated by the use of SimClim, an "open-framework" modelling system to integrate data and models for examining impacts of and adaptation to climate variability and change. User-friendly, Windows-based interfaces allow users to import climate (and other) data for geographical areas and spatial resolutions of their own choice and to attach impact models for relevant sectors (e.g., agricultural, coastal, health, water resources). By selecting among emission scenarios, global climate model (GCM), climate change patterns, climate sensitivity values, and time horizons, the user has considerable flexibility in generating scenarios of future climate changes that can be used to drive impact models. SimClim contains a custom-built geographic information system for spatial analyses of results and tools for examining site-specific time-series data, including analyzing extreme events and estimating return periods.

SimClim combines site-specific and spatial data (from global, regional, and national to local scale, depending on user specification). Required inputs include spatially interpolated monthly climatologies for precipitation and minimum, maximum, and mean temperature; GCM spatial patterns of climate changes; and site time-series climate data (hourly, daily, and/or monthly). Key outputs are user-specified spatial and temporal patterns and parameters of baseline climatologies; scenarios of future climates; and outputs from the climate-driven impact model.

Source: CCAIRR findings.

BOX A3.7

Coping strategies already in use in the Sapwohn study area: a raised external threshold (above) and elevated living areas (below.

Through formal and informal consultative processes, including workshops and interviews, stakeholder perceptions of climate-related risks to the Sokehs community were identified. These included flooding resulting from high rainfall events, inundation due to high sea levels, wind damage, and illness from water-borne and other diseases during times of weather extremes. Data were analyzed using SimClim (see Box A3.6) in order to characterize these risks and examine potential adaptation options.

Interviews and direct observations revealed a range of existing coping mechanisms that, given the preference for "no regrets" adaptation options, provided a basis for identification of possible adaptation measures.

Subsequently, preparedness, training ("transfer and apply"), and awareness-raising workshops were used, along with public awareness campaigns and a national forum, to ensure that all stakeholders were familiar with the study's findings and committed to their uptake and application.

Source: CCAIRR findings.

BOX A3.8

Informal consultation goes on in Sapwohn Village (left) and Kosrae.

Formal and informal meetings and discussions were held with stakeholders. The initial meetings concerned selection of the case studies; they were continued on an ongoing basis to ensure that stakeholders were kept fully informed regarding progress of the case studies and were able to contribute information and opinions as well as receive updates regarding interim findings and the eventual conclusions.

Source: CCAIRR findings.

Guideline 9

Address the present reluctance of banks and other lending institutions to finance adaptation activities, due to the perception that they involve longer-term projects that have high levels of risk. Help reduce this barrier by promoting institutions, arrangements, and mechanisms that can provide innovative financing, including microfinance, green finance, secured loans, leasing arrangements, and public-private partnerships, thereby allowing adaptation to proceed without government intervention (Box A3.9).

Guideline 10

Decisions as to when and how to adapt to climate change should be based on credible, comparable, and objective information. Ideally, the measurements and assessments required to provide this information will be made using internationally recognized, but locally adapted, methodologies and tools, thereby helping to ensure comparability among data collected by different assessors (Box A3.10).

BOX A3.9

All lenders have an interest in protecting the value of the asset against which a loan is secured. In Pohnpei, new residential construction and substantive improvements in existing dwellings are financed through low-interest loans from the Rural Development Bank. Senior officials in the Bank are aware of the incremental risks due to climate change and are considering making approval of loans contingent on the climate proofing of construction.

The Government is also considering seeking support from the international community to meet the documented incremental costs of adaptation to climate change, with a focus on the Climate Fund established by the United Nations Framework Convention on Climate Change and overseen by the Global Environment Facility. The intention would be to establish a trust fund for the community. Interest from the fund would cover, on an ongoing basis, the incremental costs of adaptation for new dwellings and for the replacement and renovation of existing residences.

Source: CCAIRR findings.

BOX A3.10

Cost-benefit analysis of climate-related risks and adaptation measures uses a state-of-the-art model. The damage arising from any given event is valued as the percentage of the current baseline value of each of the sectors that is destroyed by the event, e.g., a flood of a certain magnitude destroys *x*% of the current housing stock plus *y*% of public buildings, etc.,—i.e., the "damage function" is specified. These damage values are summarized for each event, e.g., a specified flood will result in damage valued at $X million to infrastructure and land forms. Given the probability of the damage occurring or, to put it differently, the average frequency with which it occurs under the baseline or under climate change, an annual expected damage value for each scenario is calculated, thus forming a time series of expected damage values associated with each possible event. In each case study, the expected damages resulting from all relevant events are summarized for each year. The difference between the annual expected damage values under (i) a climate change scenario and (ii) the baseline is the annual increase in expected damage due to climate change. This difference is the maximum potential benefit under the scenario of introducing adaptation measures.

Cost-Benefit Analysis of Climate Proofing Parts of the Kosrae Circumferential Road

	New Road Section (6.3 km)	Existing Road Section (3.5 km)
Cost to Build Road		
Original Design	$1,895,000	$ 924,000
Climate Proofed Design	$2,406,000	$1,700,000
Incremental Cost	$ 511,000	$ 776,000
Internal Rate of Return	11%	13%

Thus, while retroactive climate proofing is more costly, the high internal rate of return shows it is still a viable investment.

Source: CCAIRR findings.

Guideline 11

Adaptation activities should be based on cooperation to bring about desired changes, from the bottom up as well as from the top down. This calls for enduring partnerships at all stages of the adaptation process, ensuring active and equitable participation of private and public stakeholders, including business, legal, financial, and other stakeholders (Box A3.11).

Guideline 12

Transfer and use of inadequate, unsustainable, or unsafe technologies for adaptation must be avoided. Technology recipients should be able to identify and select technologies that are appropriate to their actual needs, circumstances, and capacities and are classed as "sustainable technologies"—i.e., environmentally sound, economically viable, and socially acceptable. For example, some approaches to coastal protection have proven to be inadequate (e.g., weight of rocks making up a breakwater, relative to energy of the significant wave), unsustainable (e.g., sea walls often accelerate erosion for adjacent, unprotected areas of the coast) or unsafe (e.g., a breakwater may, in some instances, exacerbate the volume and speed of seawater overtopping the foreshore area) (Box A3.12).

BOX A3.11

Successful adaptation is dependent on an increased awareness of climate change issues and a commitment to taking action to address them. Often people with technical backgrounds are reasonably aware of the issues involved in climate change and the responses required, but, overall, policy makers are not so well informed on the issues and hence not so aware of the actions that are required. Their buy-in can be facilitated by enabling them to recognize that both disasters and climate change are significant impediments to successful economic development—i.e., they represent risks to regional, national, and local economies—and that countries are already experiencing the manifestations of these risks, in the form of recent disasters, but also via climate variability. Such information will help secure high-level political endorsement for adaptation activities, ensuring their efficient and effective implementation.

Source: CCAIRR findings.

BOX A3.12

To help avoid the uptake and application of inadequate, unsustainable, or unsafe technologies, the United Nations Environment Programme has developed a decision support tool for use by stakeholders, including communities and local governments. Environmental Technology Assessment (EnTA) is a systematic procedure whereby a proposed technology intervention is described and appraised in terms of its potential influence on the environment, the implications for sustainable development, and the likely cultural and socioeconomic consequences. Furthermore, the assessment process requires consideration of alternative technologies and other options, thereby providing a mechanism for comparing the impact of a variety of possible interventions.

EnTA is designed to facilitate multistakeholder dialogue leading to consensus decision making. It helps planners, decision makers in government, the private sector, communities, and other stakeholders to reach a consensus on the proposed technology investment, by facilitating an agreement to select a technology that will be the most environmentally sound, socially acceptable, and economically viable, for a specified location and application.

Through early recognition of key issues, possible alternatives, potential solutions, and areas of consensus, EnTA allows further effort to focus on points of major conflict and dispute. This reduces information and time requirements and facilitates disclosure of all relevant information to decision makers, so that a fully informed decision can be made.

Source: CCAIRR findings.

Guideline 13

Macroeconomic conditions that favor successful adaptation activities include those that foster economic transparency. Such conditions are needed in order to ensure that climate-related risks are not masked or compensated for by hidden subsidies and are thereby transferred to the wrong parties. Involvement of the private sector in adaptation (e.g., investors and other players in the finance sector) will be encouraged by macroeconomic conditions that include low inflation; stable and realistic exchange and interest rates; pricing that reflects the true (marginal and fully internalized) costs of materials, energy, labor and other inputs; deregulation; free movement of capital; operation of competitive markets; open trade policies; and transparent foreign investment policies (Box A3.13).

BOX A3.13

An adaptation plan under consideration for Sapwohn Village is for international agencies and aid providers to make initial contributions to a trust fund. Subsequently, interest from the fund would be used to cover the incremental costs of adaptation. For example, when a home is rebuilt or renovated, the State Building Code and other regulations will require the owner to "climate proof" the structure. The additional expense involved would be covered by the trust fund, thus reducing the size of the loan the homeowner would need to obtain from the financial sector.

Source: CCAIRR findings.

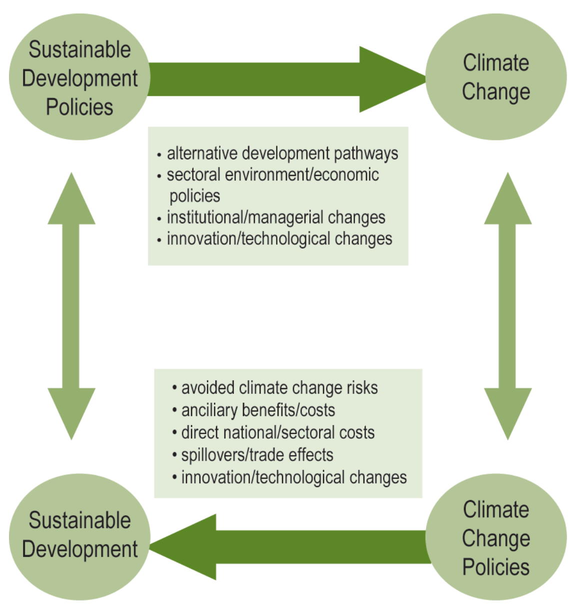
I. Why Integrate Adaptation into Development?

The linkages between socioeconomic development and the need for adaptation are becoming increasingly clear. The linkages between sustainable development, climate change, and the respective policies form a cyclic process (Figure A3.4).

Climate change is largely the result of greenhouse gas emissions associated with human activities. The latter are driven by socioeconomic development patterns characterized by economic growth, technology uptake and application, population growth and migration, and adjustments in governance. In turn, these socioeconomic development patterns influence vulnerability to climate change, as well as the human capacity for mitigation and adaptation. The cycle is completed when climate change impacts on human and natural systems, to influence socioeconomic development patterns and, thereby, greenhouse gas emissions.

The artificial separation of these activities results in missed opportunities for synergies, in unrecognized and undesirable trade-offs, and in mutual interference in ensuring successful outcomes. The benefits arising from integrating climate policy into wider development policies can be greater than the sum of concurrent, unrelated policy initiatives. Effective management of the risks to natural and human systems that arise from climate variability and change and their integration with planning for sustainable development gives rise to additional guidelines.

Figure A3.4: Linkages Between Sustainable Development, Climate Change, and the Policies in These Areas



Source: after Swart et al. 2003.

Guideline 14

Any risks that present generations may find unacceptable should not be imposed on future generations (Box A3.14).

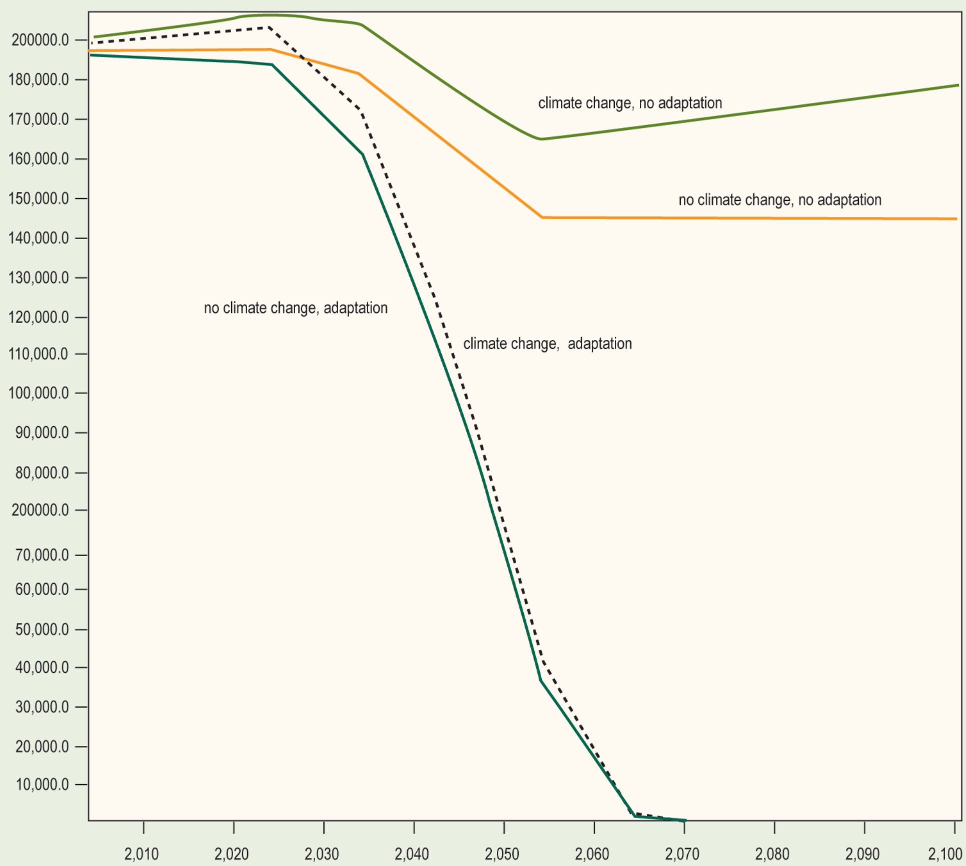
Guideline 15

Policymaking, planning practices, and development activities should ensure that all future generations will be able to enjoy every important aspect of life, including peace and security, a healthy environment, a small risk of preventable catastrophe, conservation of knowledge, stable governance, a good life for children, and opportunities for living (Box A3.15).

Guideline 16

Successful adaptation to climate variability and change requires a programmatic approach that provides institutional and operational support for individual projects. This will help minimize the limitations resulting from the short-term and narrow nature of projects, thus reducing administrative and related burdens and providing much more control over the direction taken by individual projects. The approach also increases the possibility of sustaining the benefits of a project, even after funding has ceased, and expedites the proposal development and approval processes, as well as implementation (Box A3.16).

BOX A3.14



Indicative damage costs (upper green line) for Sapwohn Village as a result of flooding from heavy rainfall events are shown. Without adaptation, the damage costs increase over time, and will have to be covered by future generations.

Source: CCAIRR findings.

BOX A3.15

The Federated States of Micronesia (FSM) has recently completed preparation of its first National Strategic Development Plan, with financial and technical support provided by the Asian Development Bank (ADB).

For this case study, the ADB technical advisory team worked with relevant government officials and with the ADB consultants who drafted the Plan for the sectors identified during the consultations as being the appropriate foci for climate proofing, namely infrastructure, health care, and environment.

The following examples taken from the Plan show how it provides an enabling environment that fosters climate-proofed development, and the links with sustainable development.

Infrastructure

Criteria by which to rank projects nationally across sector and state include

- impact of the project on the national economy;
- cost-benefit of project, taking into account economic and social benefits;
- contribution of the project toward the health and safety of the community;
- contribution of the project toward development of the workforce in FSM to meet the social and economic challenges;
- contribution of the project to institutional strengthening and restructuring of government infrastructure agencies;
- contribution of the project to promoting private sector development; and
- viability, sustainability, potential social benefit and environmental impact, and risk exposure of the infrastructure development project.

Risk Assessments Related to Natural Hazards

These studies should be conducted at the state level and focus on existing risks to infrastructure (e.g., typhoons, landslides, drought) as well as determining how those risks will be increased as a result of changes in the future, including the consequences of global climate change. The study will develop guidelines and identify and recommend other measures to ensure that the exposure of infrastructure to current and future risks is reduced to acceptable levels.

Strengthen and adapt new building and other relevant regulations and codes of good practice.

Infrastructure [should be] located, built and maintained in line with codes and practices that provide full functionality for projected life time.

Infrastructure [should be] designed, located, built, and maintained to avoid unacceptable risks to infrastructure associated with natural hazards, including weather and climate extremes, variability, and change.

Conduct risk assessments at state level and develop national- and state-level guidelines to ensure that risks to infrastructure development projects are identified and addressed in a cost-effective manner at the design stage (Office of the President, FSM 2004).

Health

Climate variability and change, including sea-level rise, are important determinants of health and of growing concern in FSM (as it is in all Pacific island countries). The impacts are mostly adverse. Climate variability and change can result in reduced quality and quantity of water supplies, loss of coastal resources, reduction in ecosystem productivity, and a decline in agricultural productivity. Potential health impacts that have been identified include vector-borne diseases (such as dengue fever and malaria), water-borne diseases (such as viral and bacterial diarrhea), diseases related to toxic algae (such as ciguatera fish poisoning, which is important in FSM where the protein source is fish), food-borne diseases, food security and nutrition, heat stress, air pollution, and extreme weather and climate events (such as cyclones, high tides, droughts and storm surges). Especially on atoll islands of FSM, storm surges can result in injury and drowning. The adverse impacts of many of these events will be exacerbated by sea-level rise. Thus, climate change should be an important consideration when assessing environmental health issues and the consequent priorities for the health of people in FSM (Office of the President, FSM 2004).

Environment

STRATEGIC GOAL 1: Mainstream environmental considerations, including climate change, in economic development *(**NEMS,** FSMCCC, NBSAP, CES)*.

[Adopt] strategies and plans that address unacceptable risks to the natural environment and built assets, including those arising from natural hazards such as weather and climate extremes, variability, and change. Develop and implement integrated environmental and resource management objectives that enhance resilience

(continued)

BOX A3.15 (continued)

of coastal and other ecosystems to natural hazards such as those associated with extreme weather events, climate change, high tides, and sea-level rise.

All FSM communities will develop and implement risk reduction strategies to address natural hazards such as those related to current weather and climate extremes and variability, while at the same time preparing for anticipated impacts of climate change.

Identify structures, infrastructure, and ecosystems at risk and explore opportunities to protect critical assets.

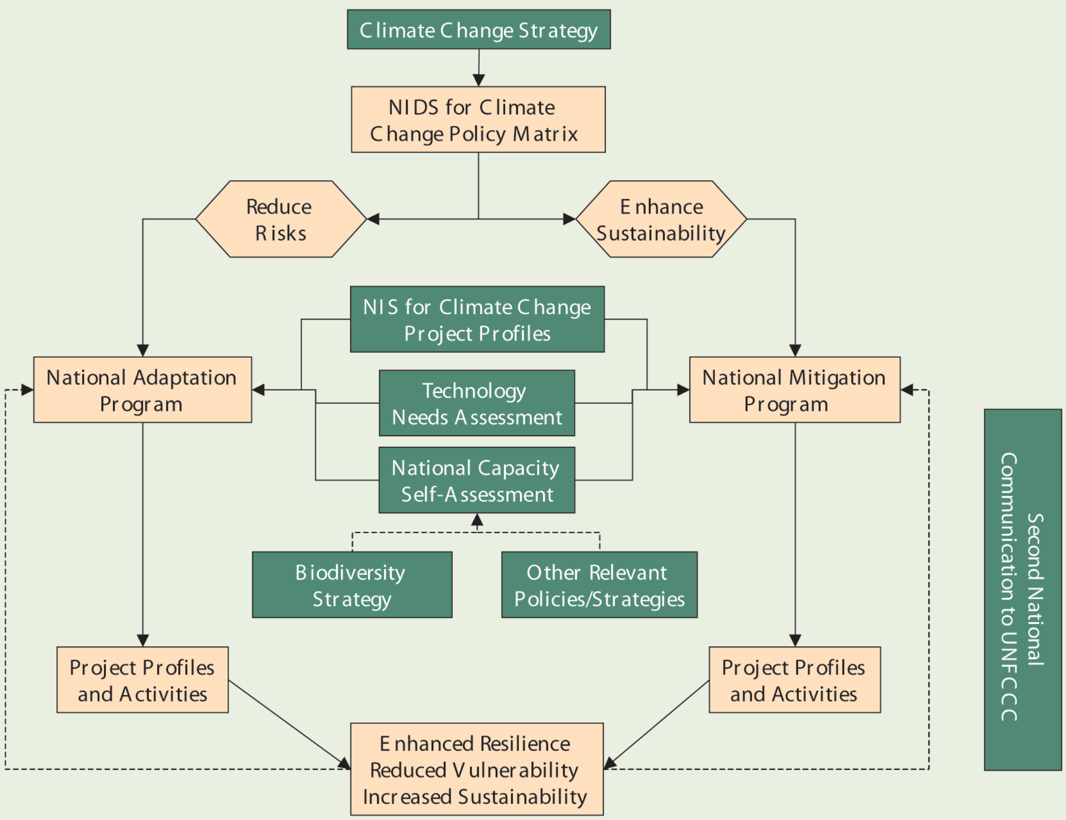
Integrate considerations of climate change and sea-level rise into strategic and operational (e.g., land use) planning for future development, including that related to structures, infrastructure, and social and other services.

Document low-lying agricultural areas at risk from the effects of natural hazards, including sea-level rise, and implement appropriate land use planning and other measures.

Determine impact of climate change on the tuna industry as a result of such effects as changed migration patterns of Pacific tuna stocks, and implement strategies to minimize impacts on this important industry (Office of the President, FSM 2004).

Source: CCAIRR findings.

BOX A3.16



NDS = national development strategy; UNFCCC = United Nations Framework Convention on Climate Change.

Source: CCAIRR findings.

Guideline 17

Emphasis must be placed on coordinating activities—taking advantage of synergies, minimizing duplication, and avoiding redundancies—in order to complement other development efforts. Priority should be given to adaptation activities that deliver tangible and visible benefits, rather than on exploratory studies, i.e., to activities that deliver outputs and outcomes that are of at least equal relevance and value to those provided by mainline ministries; this can help offset the fact that climate change is often perceived as a longer-term issue, while other challenges, including food security, water supply, sanitation, education, and health care, require more immediate attention (Box A3.17).

BOX A3.17

The establishment and ongoing work of the Pohnpei Task Force to Assess and Manage Weather- and Climate-related Risks and of the Pohnpei Climate Change Adaptation through Integrated Risk Reduction Team (see Box A3.2) have resulted in improved coordination of climate-related activities at the state level. The climate proofing of the National Strategic Development Plan (see Box A3.15) and of relevant regulations (see Box A3.5) has also given direction to climate risk assessment and provided the mechanisms whereby climate-related risks can be managed within the planning and regulatory environments.

Source: CCAIRR findings.

Guideline 18

A commitment should be made to the ongoing practice of monitoring, reviewing, and strengthening adaptation activities. Methods used should emphasize transparency, consistency, and accountability, as well as fostering continued improvement in the efficiency with which outcomes are delivered, and in their contributing to sustainable national development.

BOX A3.18

A major requirement is the reviewing and revision of priorities, given that there will never be sufficient capacity (financial, human, technological, etc.) to undertake all activities that could reduce national and local vulnerability to climate variability and change (including extreme events). A key question that must be asked continually is whether the activities to be implemented will be sufficient to allow the country to maintain its economic, social, and environmental systems despite changes in the climate. The Federated States of Micronesia's climate-proofed National Strategic Development Plan will help ensure an affirmative response to this question.

Source: CCAIRR findings.

Appendix 4

Guidelines for Policy and Decision Makers and Other Key Players—Cook Islands

A. Background and Purpose of these Guidelines

Under its Climate Change Adaptation Programme for the Pacific, the Asian Development Bank (ADB) is facilitating preparation of case studies[1] that demonstrate a risk-based approach to adapting to climate variability and change (including extreme events), and the mainstreaming of the adaptation process. These Guidelines for Mainstreaming Adaptation to Climate Change are based on the findings of the case studies. They also reflect experience gained through other investigations and by operational practice.

The Guidelines are intended to assist the Government of the Cook Islands and other relevant stakeholders in implementing policies, plans, and operational procedures that result in integrating adaptation to climate variability and change into national and local development planning, decision making and operations as an an integral and sustainable part of the development process.

Prior to presenting the specific Guidelines, important background information is provided by asking and answering a series of questions that arose in the course of preparing the case studies. With respect to the Guidelines themselves, each has an associated box that provides a practical example of the application of the Guideline, with respect to one of the case studies prepared in the Cook Islands.

[1] Three case studies were carried out in the FSM and three in the Cook Islands. Details are provided in the main part of this book.

Mainstreaming adaptation is the principal focus of these Guidelines. They do not refer explicitly to other related and important matters, including

- adaptation policy frameworks—for details on this topic refer, for example, to UNDP-GEF (2003); and
- adaptation measures as such—for national examples see "First National Communication of Cook Islands to the UNFCCC"; for regional examples see Hay et al. (2003).

B. What is Meant by "Mainstreaming Adaptation"?

In the context of addressing climate change and related issues, the term "mainstreaming" is used to describe the integration of policies and measures to address climate change into ongoing and new development policies, plans, and actions. Mainstreaming adaptation aims to enhance the effectiveness, efficiency, and longevity of initiatives directed at reducing climate-related risks, while at the same time contributing to sustainable development and improved quality of life.

Mainstreaming also endeavors to address the complex tensions between development policies aimed at immediate issues and the aspects of climate policy aimed at longer-term concerns. The tensions often become most apparent when choices have to be made about the disbursement of limited government funds—for example, choices between supporting education and health care programs on the one hand and funding climate change adaptation initiatives on the other. Indeed, mainstreaming is largely about reducing tensions and conflicts, and avoiding the need to make choices, by identifying synergistic, win-win situations. Thus mainstreaming focuses on "no regrets" measures for adaptation.[2]

C. Why Mainstream Adaptation?

Even in the near future, climate change is likely to impose untenable social, environmental, and economic costs on the Cook Islands. Most of the country is already experiencing disruptive conditions that are consistent with many of the anticipated adverse consequences of climate change, including extensive coastal erosion, drought, flooding and associated landslides, coral bleaching, and higher sea levels.

The risks associated with the full spectrum of climate-related hazards, from extreme events to the consequences of long-term changes in the climate, should be managed in a holistic manner as an integral part of national development planning and management. Most countries already have policies and plans to manage financial risks, human health risks, biosecurity risks, agricultural risks, transport sector risks, and energy supply risks. Climate-induced disasters and climate change and variability should also be included in the national risk management portfolio.

National and state development plans and sector plans should include disaster risk management strategies and climate change adaptation measures to ensure that risks are reduced to acceptable levels. These measures, and the related strategies, will help strengthen decision-making processes by requiring that specific programs and projects include plans and measures to manage risks associated with extreme events and with climate change and variability. The overall goal should be to manage, in a holistic manner and as an integral part of national development planning, the risks associated with the full spectrum of weather, climate, and oceanic hazards, from extreme events to the consequences of long-term climate change.

[2] "No regrets" measures for adaptation are consistent with sound environmental management and wise resource use, and are thus appropriate responses to natural hazards and climate variability, including extreme events; they are therefore beneficial and cost effective, even in the absence of climate change.

D. What are the Strategic Considerations that Underpin Adaptation to Climate Change?

Key strategic considerations regarding adaptation include the following:

- Just as today's development decisions will influence tomorrow's climate, so too will tomorrow's climate influence the success of today's development decisions.
- Effective management of climate-related risks prevents precious resources from being squandered on disaster recovery and rehabilitation.
- Many disaster and climate change response strategies are the same as those that contribute in a positive manner to sustainable development, sound environmental management, and wise resource use; they are also appropriate responses to climate variability and other present-day and emerging stresses on social, cultural, economic, and environmental systems.
- Many development plans and projects under consideration at present have life expectancies that require future climate conditions and sea levels to be given due consideration;
- Exploring and undertaking actions to adapt to current climate extremes and variability is of value, both in dealing with today's climate-related problems and as an essential step in building long-term resilience to withstand the pending climate changes.
- While many climate-related risks and losses are manifested locally, measures to alleviate them have important national and international dimensions.
- If adaptation is reactive, as opposed to anticipatory, the range of response options is likely to be narrower and adaptation may well prove more expensive, socially disruptive, and environmentally unsustainable.
- It is easier to enhance the ability of ecosystems to cope with climate change if they are healthy and not already stressed and degraded.

- Adaptation is, in large part, a continuous dynamic process that reduces the exposure of society to risks arising from climatic variability and extremes.
- Adaptation must reflect both recurrent historical risks and new risks associated with climate change.
- Adaptation requires enhancement of institutional capacity, development of expertise, and the building of knowledge. All these take time.
- People will, as a result of their own resourcefulness or out of necessity, adapt to climate variability and change (including extreme events), based on their understanding and assessment of the anticipated or observed effects, and on the perceived options and benefits for response. In many cases, such adaptations will be adequate, effective, and satisfactory.
- Under some circumstances, however, such adaptation may not be satisfactory or successful; an external entity, such as central or local government, may need to facilitate the adaptation process to ensure that obstacles, barriers, and inefficiencies are addressed in an appropriate manner.

E. At a Practical Level, What does Adaptation Mainstreaming Entail?

Adaptation mainstreaming has two key practical components:

- creating and strengthening the enabling environment for adaptation; and
- integrating adaptation planning and implementation into existing and new development policies, plans, and actions.

F. What is the "Enabling Environment" for Adaptation?

The "enabling environment" for adaptation comprises the systems and capabilities that foster the adaptation process, including innovation, revitalization of traditional practices, application of human knowledge and skills, policies, financing, legislation and regulations, information, markets, and decision support tools. It provides the context within which development projects and related initiatives occur and ensures that they are effectively "climate proofed" (Table A4.1).

G. The Adaptation Mainstreaming Guidelines

The following Guidelines are grouped into three categories, related to

- the principles underlying the mainstreaming of adaptation,
- enhancing the enabling environment for adaptation, and
- the process of mainstreaming adaptation.

Guidelines Relating to the Principles Underpinning the Mainstreaming of Adaptation

Guideline 1

Manage climate risks as an integral part of sustainable development. Climate change is largely the result of greenhouse gas emissions associated with human activities. The latter are driven by socioeconomic development patterns characterized by economic growth, technology uptake and application, population growth and migration, and adjustments in governance. In turn, these socioeconomic development patterns influence vulnerability to climate change, as well as the human capacity for mitigation and adaptation. The cycle is completed when climate change impacts on human and natural systems, to influence socioeconomic development patterns and, thereby, greenhouse gas emissions.

The artificial separation of these activities results in missed opportunities for synergies, unrecognized and undesirable trade-offs, and mutual interference in ensuring successful outcomes. The benefits arising from integrating climate policy into wider development policies can be greater than the sum of concurrent but independent policy initiatives. Effective management of the risks to natural and human systems that arise from climate variability

Table A4.1. The Multiple Dimensions of the Enabling Environment

Enabling Environment for Sustainable Development	Enabling Environment for Climate-Proofed Development	Climate-Proofed Development
Favorable macroeconomic conditions Available and affordable financing Robust and responsive legal and regulatory regimes		
Climate-proofed national development strategy	Climate Proofed: • Development plans • Resource use plans • Regulations • Codes • Permitting procedures	Economic and social development programs and projects that are compliant with climate-proofed policies and plans
Empowered and equitable involved stakeholders Equitable allocation of rights, responsibilities, and benefits Needs-driven and targeted information Relevant and applicable standards, codes, methodologies, and tools Functional, sustainable technologies (hard and soft) Supportive human and institutional capacities		

Note: Longer-term interventions at national and subnational levels, often with support from the international community, are required to create and strengthen the enabling environment.

Source: CCAIRR findings.

and change, and their integration with planning for sustainable development, gives rise to additional guidelines.

Policy making, planning practices, and development activities should ensure that all future generations will be able to enjoy every important aspect of life, including peace and security, a healthy environment, a small risk of preventable catastrophes (including those related to climate variability and change), conservation of knowledge, stable governance, a good life for children, and opportunities for living (Box A4.1).

Guideline 2: Ensure Intergenerational Equity Related to Climate Risks

Any climate-related risks that present generations may find unacceptable should not be imposed on future generations (Box A4.2).

Guideline 3

Adopt a coordinated, integrated, and long-term approach to adaptation. Successful adaptation to climate variability and change requires a programmatic approach that provides institutional and operational support for individual projects; this will help minimize the limitations resulting from the short-term and narrow nature of projects, thus

BOX A4.1

The Cook Islands is currently preparing a National Development Strategy, with financial and technical support provided by the Asian Development Bank and regional organizations. The Climate Change Adaptation Program for the Pacific technical assistance team worked with relevant government officials and other stakeholders, and suggested ways in which the strategy might be climate proofed.

Examples of the way in which the strategy provides an enabling environment that fosters climate-proofed development, and the links with sustainable development, are provided below.

Strategic Priority 4: Improved Quality of Health Services

Key Challenges	Key Objectives	Key Actions Required
Establish long-term preventive health care programs that take into account climate variability and change.	Improve the health and well-being of Cook Islanders.	• Strengthen public health programs. • Conduct assessments of climate-related health risks.
Address the impacts of climate variability and change (including extreme events) on the health and welfare of Cook Islanders.	Recognize and strengthen contingency response plans for disease outbreaks.	• Improve the effectiveness of the *tutaka* (annual health department inspection of properties). • Use technical and scientific tools to map and predict disease outbreaks. • Strengthen border control.

Strategic Priority 4: Improved Quality of Health Services

Key Challenges	Key Objectives	Key Actions Required
Recognize that high-quality environment is the key to a viable tourism business.	All tourism businesses are committed and use environmentally friendly practices.	• Implement PATA guidelines for tourist businesses. • Establish stringent performance standards for tourism. • Recognize the impacts of over-water resorts and their high vulnerability to extreme weather and climate events.
Reduce the vulnerability of the tourism sector to climate variability and change, including extreme events.	Implement risk management strategies that reduce the impact of extreme climate events on tourism to acceptable levels.	• Identify and prioritize the climate-related risks facing the tourism industry.·Strengthen disaster management. • Develop in-house risk management strategies.

Note: PATA = Pacific Asia Travel Association.

Source: CCAIRR findings.

(continued)

BOX A4.1 (continued)

Strategic Priority 9: Protection, Conservation, and Sustainable Management of the Environment and Natural Ecosystems[1]

Key Challenges	Key Objectives	Key Actions Required
Maintain the quality of the environment and of natural ecosystems.	Develop robust regulations and guidelines that protect the environment.	• Strengthen EIA procedures in ways that reduce political interference in environmental management. • Ensure that Outer Islands opt into the Environment Act. • Strengthen National and Island Environmental Councils.
Minimize the adverse consequences of climate change on the economy, society, and environment.	Develop climate change adaptation strategies that address unacceptable risks arising from natural hazards including climate change. Integrate climate change and sea-level rise in strategic and operational impact assessments and other regulatory procedures.	• Develop simple and easy-to-follow procedures. • Improve technical expertise and decision-making processes. • Strengthen national institutional arrangements for the effective implementation of climate change policies and plans.
Harmonize responses to climate change with other sustainable development initiatives.	Increase efficiency of energy use and convert to renewable energy sources to minimize greenhouse gas emissions.	• Formulate a national energy sector policy. • Decrease the use of imported petroleum fuels through conservation, efficiency, use of renewable energy, and other measures.

Note: EIA = environmental impact assessment.

[1] A strategic priority related to the environment is being developed and discussed by the National Task Force. The information provided here is intended to assist and guide the Task Force in its work concerning the strategic priority on the environment.

Source: CCAIRR findings.

reducing administrative and related burdens and giving much more control over the direction taken by individual projects. The approach also increases the possibility of sustaining the benefits of a project even after funding has ceased, and expedites the proposal development and approval processes, as well as implementation (Box A4.3).

Guideline 4

Achieve the full potential of partnerships. Adaptation activities should be based on cooperation to bring about desired changes, from the bottom up as well as from the top down; this calls for enduring partnerships at all stages of the adaptation process, ensuring active and equitable participation of private and public stakeholders, including business, legal, financial, and other stakeholders (Box A4.4).

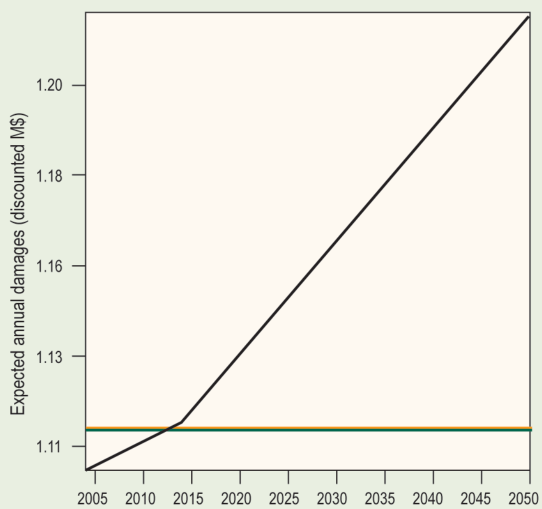
Guideline 5

Adaptation should exploit the potential of sustainable technology transfer; use of inadequate, unsustainable, or unsafe technologies for adaptation must be avoided. Technology recipients should be able to identify and select technologies that are appropriate to their actual needs, circumstances, and capacities and are classed as "sustainable technologies"—i.e., environmentally sound, economically viable, and socially acceptable. For example, some approaches to coastal protection have proven to be inadequate (e.g., weight of rocks making up a breakwater is inadequate relative to the energy of the significant wave), unsustainable (e.g., sea walls often accelerate erosion for adjacent, unprotected areas of the coast) or unsafe (e.g., a breakwater may, in some instances, exacerbate the volume and speed of seawater overtopping the foreshore area) (Box A4.5).

Guideline 6

Base decisions on credible, comparable, and objective information. Ideally, the measurements and assessments required to provide this information will be made using internationally recognized, but locally adapted, methodologies and tools, thereby helping to ensure comparability between information collected by different assessors (Box A4.6).

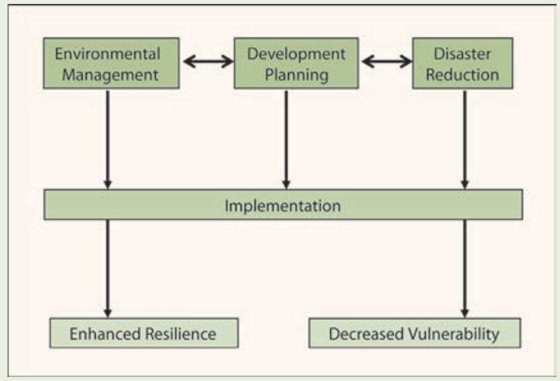
BOX A4.2



Indicative damage costs are shown (sloping line) for the Avatiu-Ruatonga study area as a result of flooding from heavy rainfall events. Without adaptation, the damage costs increase over time, and will be an imposition on future generations.

Source: CCAIRR findings.

BOX A4.3



Adaptation aims to enhance the resilience and decrease the vulnerability of the society, economy, and environment to the adverse consequences of climate variability and change, including extreme events. In most situations, this will be carried out through a combination of effective social and economic development planning, sound environmental management, and pro-active approaches to disaster reduction. The challenge is to ensure that all three are harmonized through a long-term and coordinated approach.

Source: Adapted from Raymund Hay (1993), Hay and MacGergor (1994), and deWet (1999).

BOX A4.4

Successful adaptation is dependent on increased awareness of climate change issues, and a commitment to taking action to address them. Often people with technical backgrounds are reasonably aware of the issues related to climate change and the responses that are required, but overall, policy makers are not so well informed on the issues and, hence, not so aware of the actions that are required. Their buy-in can be facilitated by having them recognize that both disasters and climate change are significant impediments to successful economic development—i.e., they represent risks to regional, national, and local economies—and that countries are already experiencing the manifestations of these risks, in the form of recent disasters, but also via climate variability. Such information will help secure high-level political endorsement for adaptation activities, ensuring their efficient and effective implementation.

Source: CCAIRR findings.

BOX A4.5

To help avoid the uptake and application of inadequate, unsustainable, or unsafe technologies, the United Nations Environment Programme has developed a decision support tool for use by stakeholders, including communities and local governments. Environmental Technology Assessment (EnTA) is a systematic procedure whereby a proposed technology intervention is described and appraised in terms of its potential influence on the environment, the implications for sustainable development, and the likely cultural and socioeconomic consequences. Furthermore, the assessment process requires consideration of alternative technologies and other options, thereby providing a mechanism for comparing the impact of a variety of possible interventions

EnTA is designed to facilitate multistakeholder dialogue leading to consensus decision making. It helps planners, decision makers in government, the private sector, communities, and other stakeholders to reach a consensus on the proposed technology investment, by facilitating an agreement to select a technology that will be the most environmentally sound, socially acceptable, and economically viable, for a specified location and application.

Through early recognition of key issues, possible alternatives, potential solutions, and areas of consensus, EnTA allows further effort to focus on points of major conflict and dispute. This reduces information and time requirements and facilitates disclosure of all relevant information to decision makers, so that a fully informed decision can be made.

Source: CCAIRR findings.

BOX A4.6

An important part of the Climate Change Adaptation Program for the Pacific is the cost-benefit analyses of climate-related risks and adaptation measures. These are undertaken using a state-of-the-art model. The damage arising from any given event is valued as the percentage of the current baseline value of each of the sectors that is destroyed by the event, e.g., a flood of a certain magnitude destroys *x*% of the current housing stock plus *y*%of public buildings, etc.—i.e., the "damage function" is specified. These damage values are summarized for each event, e.g., a specified flood will result in damage valued at $X million to infrastructure and land forms. Given the probability of the damage occurring or, equivalently, the average frequency with which it occurs under the baseline or under climate change, an annual expected damage value for each scenario is calculated, thus forming a time series of expected damage values associated with each possible event. In each case study, the expected damages resulting from all relevant events are summarized for each year. The difference between the annual expected damage values under (i) a climate change scenario, and (ii) the baseline is the annual increase in expected damage due to climate change. This difference is the maximum potential benefit under the scenario of introducing adaptation measures.

Cost-Benefit Analysis for Reduction of Flood Damage From Heavy Rainfall, Avatiu-Ruatonga[1]

Adaptation Option	Reduction in Damage Costs (%)		Adaptation Cost (NZ$ thousand)	Cost/Benefit (%)
	No CC	With CC		
Deepen Stream Bed 1 m	60.6	59.3	1,620	0.92
Increase Culvert to 1.4 m	0	0	78,571	0

Source: CCAIRR findings.

Guideline 7

Maximize the use of existing information and management systems. Wherever possible and practical, make use of existing management systems. This may well require additional initial effort to source and harmonize dispersed and disparate sets of information, but is likely to result in a strengthening of existing information management systems as opposed to their marginalization (Box A4.7).

Guideline 8

Strengthen and utilize in-country expertise in the technical and policy dimensions of adaptation to climate change (Box A4.8).

BOX A4.7

For the case studies undertaken in the Cook Islands, local data holdings were identified, including information in geographical information systems maintained by the Ministry of Works and the Statistics Office. Health care data for Rarotonga were obtained from the Public Health *tutaka* (annual inspection of properties by local health department officials), of the Ministry of Health. Aerial photographs and maps were obtained from the Ministry of Works. Relevant historic information is held by National Library and National Archive. Weather data were sourced through the Cook Islands Meteorological Service. Tide gauge data were obtained from the University of Hawaii and from the National Tidal Centre in Australia. Documents such as First National Communication to the United Nations Framework Convention on Climate Change and state and national disaster reports were also consulted.

Spot heights and locations of structures and infrastructure in the Avatiu-Ruatonga study area were determined using a global positioning survey survey system, supplemented by data available from earlier surveys. At the same time, detailed descriptive and flood damage information were obtained for each structure, through visual inspection and interviews conducted by members of the Cook Islands Climate Change Adaptation Program for the Pacific Team. All data used in the case study have been placed in a cooperative archive maintained by the Ministry of Works and the Meteorological Office.

Source: CCAIRR findings.

BOX A4.8

Local technical capabilities in such areas as geographical information system (GIS), surveying, and vulnerability and adaptation assessments were identified, with technically qualified personnel forming the Cook Islands Climate Change Adaptation Program (CLIMAP) for the Pacific Team. Members of the Team undertook the field work to determine spot heights and locations of structures and infrastructure in the Avatiu-Ruatonga study area, as well as gathering detailed descriptive and flood damage information through visual inspection and interviews. All information for the Avatiu-Ruatonga study area was imported to a GIS; members of the CLIMAP team based in the Ministry of Works undertook to process the information.

Source: CCAIRR findings.

Guideline 9

Wherever possible and practical, strengthen and maximize use of existing regulations, codes, tools, and regulatory instruments to guide selection and facilitate implementation of adaptation measures: examples of this process include environmental impact assessments and building codes. This is likely to result in a strengthening of existing tools and regulations, rather than weakening them through confusion and inadequate enforcement (Box A4.9).

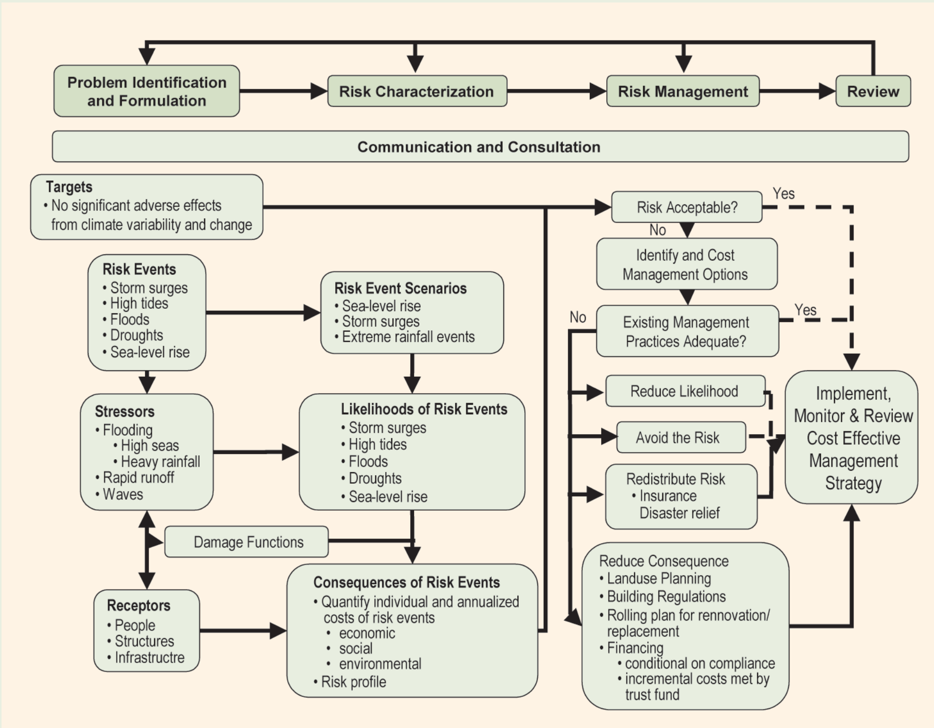
Guidelines Relating to Enhancing the Enabling Environment for Adaptation

Guideline 10

Climate proof relevant legislation and regulations. The enabling environment for adaptation is enhanced when legislation and regulations that facilitate adaptation are introduced and strengthened, and also when the compliance monitoring and enforcement capabilities of relevant regulatory agencies are improved (Box A4.10).

BOX A4.9

The risk-based approach to adaptation used in the Climate Change Adaptation Program for the Pacific case studies follows methods consistent with international risk management standards, including Australia and New Zealand standard 4360.



The Risk Assessment Framework Used in the CLIMAP Case Studies

The assessment of climate-related risks, and the cost-benefit analyses of adaptation measures, have been facilitated by the use of SimClim, an "open-framework" modelling system to integrate data and models for examining impacts of and adaptation to climate variability and change. User-friendly, Windows-based interfaces allow users to import climate (and other) data for geographical areas and spatial resolutions of their own choice and to attach impact models for relevant sectors (e.g., agricultural, coastal, health, water resources). By selecting among emission scenarios, global climate model (GCM) climate change patterns, climate sensitivity values, and time horizons, the user has considerable flexibility in generating scenarios of future climate changes that can be used to drive impact models. SimClim contains a custom-built geographic information system for spatial analyses of results, and tools for examining site-specific time-series data, including analyzing extreme events and estimating return periods.

SimClim combines site-specific and spatial data (from global, regional, national to local scale, depending on user specification). Required inputs include spatially interpolated monthly climatologies for precipitation and minimum, maximum, and mean temperature; GCM spatial patterns of climate changes; and site time-series climate data (hourly, daily, and/or monthly). Key outputs are user-specified spatial and temporal patterns and parameters of baseline climatologies; scenarios of future climates; and outputs from the climate-driven impact model.

Source: CCAIRR findings.

BOX A4.10

The Avatiu-Ruatonga case study resulted in a recommendation that the Building Code, health regulations, environmental impact assessment regulations, and other appropriate regulatory instruments be amended to include provisions such that when new buildings are constructed, or existing buildings are modified substantially, allowance is made for the following climate-derived risks:

- Within the next few decades, wind gusts may exceed the current design wind speed of 49 ms^{s-1};
- Erecting structures in locations where the risk of flooding as a consequence of heavy rainfall, storm surges, or these in combination is significant should be avoided.
- New structures are required to have a minimum floor height that prevents them from being flooded as a consequence of heavy rainfall, storm surges, or these in combination.

Source: CCAIRR findings.

BOX A4.11

During the early stages of planning for the Climate Change Adaptation Program for the Pacific Project (CLIMAP) in the Cook Islands, a decision was made not to establish a new body that would serve as the CLIMAP Project Liaison Committee. Rather, the existing National Climate Change Country Team was strengthened in both breadth and relevance of membership and the preparation and approval of formal terms of reference.

Among the key benefits of this approach:

- the Committee is already institutionalized and recognized by the Government and other stakeholders;
- the time of the limited number of national and local experts is used more efficiently and effectively;
- continuity and collective memory can be called on, as the Country Team is an ongoing entity;
- enhanced linkages exist with other climate-related projects being undertaken within the Cook Islands;
- the Government and other stakeholders will have one ongoing source of consistent advice;
- the Country Team includes representatives from the Outer Islands as well as Rarotonga; and
- the Country Team maintains effective linkages with regional organizations and climate change teams in other countries in the region.

Source: CCAIRR findings.

Guideline 11

Strengthen institutions to support the climate proofing of development**.** Organize and strengthen institutions in ways that

- enhance communication between climate risk assessors and adaptation policy makers and implementers;
- reduce the likelihood of conflict and duplication of effort when managing climate-related risks;
- lessen the chances of mistrust and misunderstanding between decision and policy makers and other stakeholders in adaptation activities; and
- overall, help to provide consistent, defensible and useful advice to policy and decision makers with respect to adaptation priorities and practices (Box A4.11).

Guideline 12

Ensure that macroeconomic policies and conditions favor climate proofing. Macroeconomic conditions that favor successful adaptation activities include those that foster economic transparency. Such conditions are needed in order to ensure that climate-related risks are not masked or compensated for by hidden subsidies and thereby transferred to the wrong parties. Involvement of the private sector in adaptation (e.g., investors and other players in the finance sector) will be encouraged by macroeconomic conditions that include low inflation, stable and realistic exchange and interest rates, pricing that reflects the true (marginal and fully internalized) costs of materials, energy, labor and other inputs; deregulation; free movement of capital; operation of competitive markets; open trade policies, and transparent foreign investment policies (Box A4.12).

BOX A4.12

An adaptation plan under consideration for Avatiu-Ruatonga is for international agencies and aid provider to make initial contributions to a trust fund. Subsequently, interest from the fund would be used to cover the incremental costs of adaptation. For example, when a home is rebuilt or renovated, the National Building Code and other regulations will require the owner to climate proof the structure. The additional expense to do this would be covered by the trust fund, thereby reducing the size of the loan the homeowner would need to obtain from the financial sector.

Source: CCAIRR findings.

Guideline 13

Ensure favorable access to affordable financing for climate-proofed development initiatives. Address the present reluctance of banks and other lending institutions to finance adaptation activities, due to the perception that they involve longer-term projects that have high levels of risk. Help reduce this barrier by promoting institutions, arrangements, and mechanisms that can provide innovative financing, including microfinance, green finance, secured loans, leasing arrangements, and public-private partnerships, thereby allowing adaptation to proceed without government intervention (Box A4.13).

Guidelines Relating to the Process of Mainstreaming Adaptation

Guideline 14

Document the relevant major risks to the economy and society resulting from climate variability and change (including extreme events), characterizing these in terms of their probabilities of occurrence, associated economic and social consequences, and degree that they require sustained attention (Box A4.14).

BOX A4.13

All lenders have an interest in protecting the value of the asset against which a loan is secured. In Rarotonga, new residential construction, and substantive improvements in existing dwellings, are financed through loans from a variety of private sector financial institutions. Senior officials in these institutions are aware of the incremental risks due to climate change and are considering making approval of loans contingent on the climate-proofing of any construction being..

The Government is also considering seeking support from the international community to meet the documented incremental costs of adaptation to climate change, with a focus on the Climate Fund established by the United Nations Framework Convention on Climate Change and overseen by the Global Eenvironment Facility. The intention would be to establish a trust fund for the community. Interest from the fund would cover, on an ongoing basis, the incremental costs of adaptation for new dwellings and for the replacement and renovation of existing dwellings.

Source: CCAIRR findings.

Guideline 15

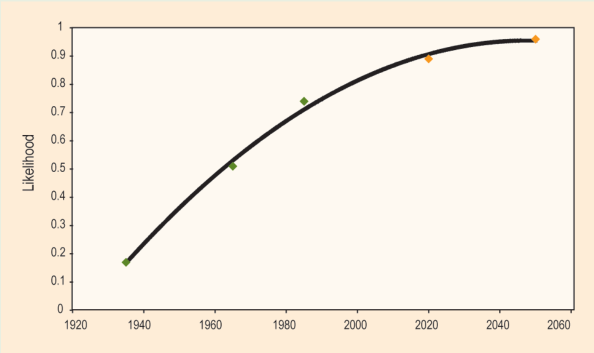
Replicate the knowledge, motivation, and skills that facilitate successful adaptation. Identify the motivations that drive various stakeholders to engage in the adaptation process, and replicate these motivations in other players, through education, training, and other initiatives (Box A4.15).

Guideline 16

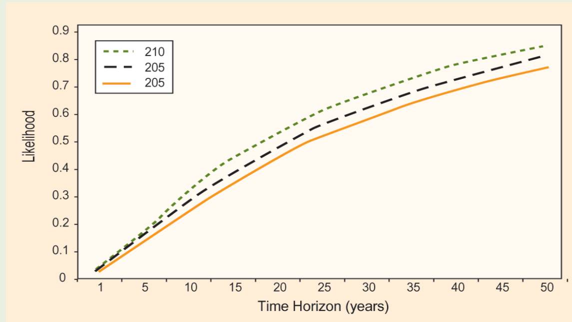
Enhance the capacity for continuous adaptation. Adaptive capacity is a complex and a dynamic mix of social, economic, technological, biophysical, and political conditions that determines the capacity of a system to adapt. These factors vary over time, location, and sector. The main features of communities, countries, and regions that determine their adaptive capacity include economic wealth, technology, information and skills, infrastructure, institutions, and equity. By addressing these factors, it is possible to enhance adaptive capacity (Box A4.16).

BOX A4.14

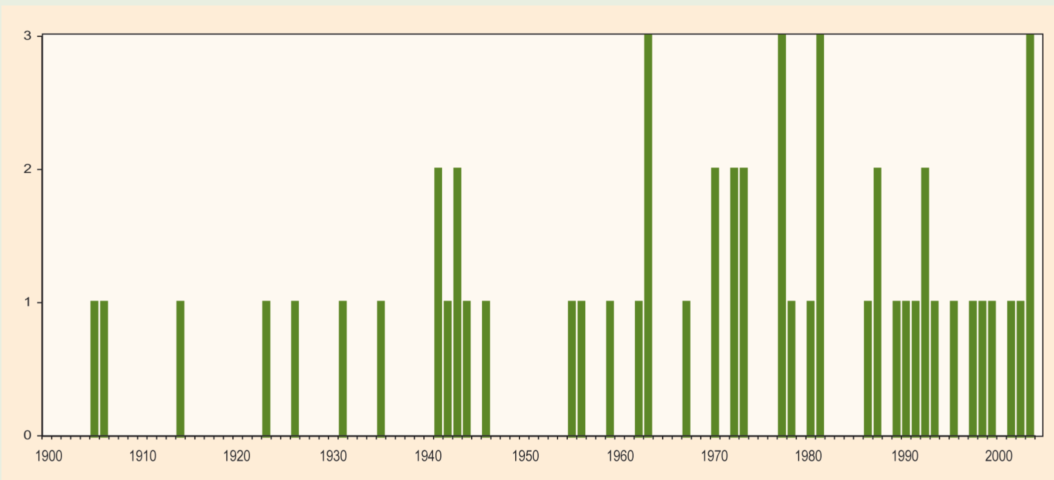
Climate change will alter the risk of flooding due to high sea levels.



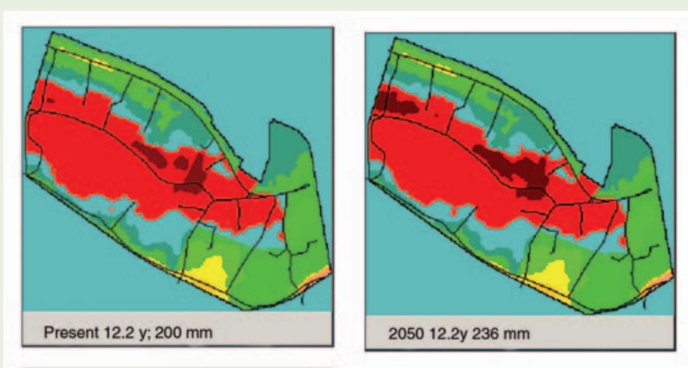
Number of tropical cyclones per year passing close to, and affecting, Rarotonga.



Observed and projected likelihoods of a 300-mm daily rainfall within a 50-year time horizon centered on the given data. Data are for Rarotonga. Projections are based on CSIRO global climate model (GCM) with A1B emissions scenario and "best estimate" for GCM sensitivity.



Source: Kerr (1976), Revell (1981), Thompson et al. (1992), d'Aubert and Nunn (1994), Fiji Meteorological Service (2004) and Ready (pers. comm.).



In Avatiu-Ruatonga, for a rainfall event with a 12.2-year return period, between the present and 2050, the area flooded is projected to increase and the maximum flood depth to increase from 1.6 m to 1.7 m.

Source: CCAIRR findings.

BOX A4.15

Among the coping strategies already in use in the Avatiu-Ruratonga study area is elevated living areas.

Through formal and informal consultative processes, including workshops and interviews, stakeholder perceptions of climate related risks to the Avatiu-Ruratonga community were identified. These included flooding resulting from high rainfall events, inundation due to high sea levels, wind damage, and illness from water-borne and other diseases during times of weather extremes. Data were analysed using SimClim (see Box 6) in order to characterize these risks and examine potential adaptation options.

Interviews and direct observations revealed a range of existing coping mechanisms which, given the preference for no regrets adaptation options, provided a basis for identification of possible adaptation measures.

Subsequently, preparedness, training ("transfer and apply") and awareness-raising workshops were used, along with public awareness campaigns and a national forum, to ensure that all stakeholders were familiar with the study's findings and committed to their uptake and application.

Source: CCAIRR findings.

BOX A4.16

Climate proofing the National Development Strategy for the Cook Islands will help develop the adaptive capacity of the country through the strengthening of governance, law and order; improving macroeconomic stability; supporting economic development; improving the quality of education and health services; improving the standard of infrastructure and the provision of utilities; increasing food self-sufficiency and security; enhancing the development and management of marine resources and tourism; and protecting, conserving, and managing the environment and natural ecosystems in a sustainable manner.

Source: CCAIRR findings.

Guideline 17

Ensure that climate-proofing activities complement other development initiatives. Emphasis must be placed on coordinating activities, taking advantage of synergies, minimizing duplication, and avoiding redundancies. This will help ensure that climate-proofing activities complement other development efforts. Priority should be given to adaptation activities that deliver tangible and visible benefits, rather than on exploratory studies—i.e., emphasis should be on activities that deliver outputs and outcomes that are of at least equal relevance and value to those provided by mainline ministries. This can help offset the fact that climate change is often perceived as a longer-term issue, while other challenges, including food security, water supply, sanitation, education, and health care, require more immediate attention (Box A4.17).

Guideline 18

Adaptation outcomes are a process of continual improvement. This necessitates a commitment to, and ongoing practice of, monitoring, reviewing, and strengthening adaptation activities; methods used should emphasize transparency, consistency and accountability, as well as fostering continued improvement in the efficiency with which outcomes are delivered and in their contributions to sustainable national development (Box A4.18).

BOX A4.17

Strengthened capacity and the ongoing work of the National Climate Change Country Team (see Box A4.11) have resulted in improved coordination of climate-related activities at both the national and local (e.g., Outer Island) levels. The climate proofing of the National Development Strategy (see Box A4.1) and of relevant regulations (see Box A4.10) has also given direction to climate risk assessment and provided the mechanisms by which climate-related risks can be managed within the planning and regulatory environments.

Source: CCAIRR findings.

BOX A4.18

A major requirement is the reviewing and revision of priorities, given that there will never be sufficient capacity (financial, human, technological, etc.) to undertake all activities that could reduce national and local vulnerability to climate variability and change (including extreme events). A key question that must be asked continually is whether the activities to be implemented will be sufficient to allow the country to maintain its economic, social, and environmental systems despite changes in the climate. The climate-proofed National Development Strategy for the Cook Islands will help ensure an affirmative response to this question.

Source: CCAIRR findings.

Appendix 5

Mainstreaming the Economic Analysis of Adaptation to Climate Change Within ADB

A. Introduction

The purpose of this Annex is to amplify the work of the Asian Development Bank's (ADB's) Climate Change Adaptation Program for the Pacific (CLIMAP) Technical Assistance regarding the economic impact of climate change risks and the costs and benefits of measures to reduce such risks. The ultimate objective of CLIMAP, after demonstrating the practical significance of climate change in the Pacific region, is to assist in the "mainstreaming" of climate change risk assessment and adaptation into economic development and investment planning in general, and into ADB program/project preparation in particular. Mainstreaming climate change considerations within ADB will have a direct impact on ADB's activities throughout Asian and Pacific countries, and is likely to have a substantial indirect impact on the parallel activities of member governments and other aid providers.

As described in the body of this book, the CLIMAP Technical Assistance has taken two complementary paths: i) an ADB-level review of attempts to deal with climate change in past projects in the Pacific, and recommendations based on lessons learned for incorporating ("mainstreaming") climate change considerations (including adaptation) into ongoing and future ADB projects and programs; and ii) a detailed, country-level, on-the-ground preparation of specific climate risk case studies in the Federated States of Micronesia (FSM) and Cook Islands, with quantification of climate risk in selected study areas and development of methodologies for assessing the costs and benefits of adaptation.

For ease of reference, the ADB-level reviews and country-level case studies that have been carried out by CLIMAP are summarized below (Table A5.1). The reviews provide a Climate Profile for each of eight Pacific island countries[1] and 19 Project Adaptation Briefs (preliminary project-level risk assessments) for ADB "pipeline" projects in those countries. The reviews do not include detailed specification or costing of adaptation options on which economic analysis could be performed; rather, this is identified as the next step in project development, to be undertaken by the respective project preparatory technical assistance (PPTA) consultants. The case studies in the FSM and Cook Islands provide six in-depth risk assessments of selected study areas based on physical and community surveys and detailed computer modeling, and include specification and costing of adaptation options and associated cost-benefit analyses.

The country-level case studies carried out in the FSM and Cook Islands have documented a substantial impact of climate change on infrastructure projects, sectors, and national development in those countries, mirrored at the project and sector level by the ADB-level reviews carried out for eight Pacific island countries. Climate change is a global issue of major concern, as it has a high potential to

[1] Cook Islands, Fiji Islands, FSM, Kiribati, Republic of the Marshall Islands, Samoa, Tonga, and Tuvalu.

Table A5.1. Climate Change Adaptation Program for the Pacific—ADB-Level Reviews

Countries with a Climate Profile	Projects for which a Project Adaptation Brief has been Prepared	Identified Risk Factors	Suggested Possible Adaptation Measures
Cook Islands	Water and Sanitation Project for Rarotonga and Aitutaki	Floods Drought Severe weather	Catchment protection Watershed management Design modifications Alternative sites
	Review of Electric Generation Capacity and Alternative Energy Project	Floods High winds	Flood prevention Daesign modifications Alternative sites
FSM	Omnibus Infrastructure Development Project	Floods Drought Sea-level rise Severe weather Storm surge	Watershed management Design modifications Alternative sites Erosion control
	Outer Island Transport Project		Design modifications Alternative sites Erosion control Breakwaters
	Waste Management and Environment Project	Floods Sea-level rise Severe weather Storm surge	Design modifications Alternative sites Erosion control Breakwaters
Fiji Islands	Fisheries Sector Review Project	Higher seawater temperatures (reducing catches) Lagoon and reef sedimentation Severe weather Storm surge	Coastal management Catchment protection Design modifications Alternative sites
	Fourth Roadbuilding Upgrade Project	Floods Sea-level rise Severe weather Storm surge Design modifications Alternative sites	Design modifications Alternative sites
	Tourism and Infrastructure Project		Alternative crops Design modifications Alternative sites
	Urban Development Project		Increased water storage Design modifications Alternative sites
Kiribati	Kiribati Mariculture Project	Higher seawater temperatures (reducing catches) Floods Sea-level rise Severe weather Storm surge	Change species cultivated Shift to alternative livelihoods
	Capacity Building for Water Use Project	Floods Drought Sea-level rise Severe weather Storm surge	Watershed management Design modifications Alternative sites Erosion control Breakwaters
	National Water Resources Assessment Project		

continued

Table A5.1. (continued)

Countries with a Climate Profile	Projects for which a Project Adaptation Brief has been Prepared	Identified Risk Factors	Suggested Possible Adaptation Measures
RMI	Outer Islands Basic Social Services Project	Floods Drought Severe weather Storm surge	Increased water storage Design modifications Alternative sites
	Outer Islands Transport Infrastructure Project	Floods Severe weather Storm surge	Design modifications Alternative sites
Samoa	Preparation of Sanitation and Drainage Project II	Floods Drought Sea-level rise Severe weather Storm surge	Design modifications Alternative sites Erosion control Breakwaters
	Savai'i Energy Project	Floods Drought Severe weather Storm surge	Watershed management Design modifications Alternative water sources Erosion control Breakwaters
Tonga	Agriculture Development Project	Floods Drought Sea-level rise Severe weather	Watershed management Design modifications Alternative sites Erosion control Breakwaters
Tuvalu	Waste Management and Recycling Project Water, Sanitation, and Waste Management Project	Flooding (contamination of groundwater) Drought (depletion of groundwater) Severe weather Storm surge	Catchment protection Design modifications Alternative sites

Notes: FSM = Federated States of Micronesia; RMI = Republic of Marshall Islands.
Source: ADB records.

undermine the process of economic development and growth in countries and across regions, and to reduce the returns on investment in infrastructure, social services, and income opportunities. Climate change represents a permanent long-term net cost. Adaptation to climate change is a means of minimizing, but not eliminating, that net cost. In this light, the economic analysis of climate change impacts and adaptation options is ultimately identical to the least-cost analysis normally undertaken by ADB and other agencies for mainstream project and program development. The purpose of the balance of this Appendix is to outline methods of integrating the economic analysis associated with climate change into ADB's conventional procedures, and to provide illustrative examples.

Table A5.2. Climate Change Adaptation Program for the Pacific Country-level Case Studies

Countries	Study Areas for which Detailed Analysis has been Completed	Identified Risk Factors	Adaptation Measures Specified
Cook Islands	Climate Proofing the Western Basin Breakwater, Avatiu Harbor, Rarotonga	Storm surges (at least 12 m) Sea-level rise (at least 0.5 m)	Modified design of the breakwater*
	Climate Proofing the Community of Avatiu-Ruatonga, Rarotonga	Flood (2-hourly rainfall with 12-year recurrence increases from present 200 mm to 236 mm by 2050) Storm surges Severe weather	Deeper drainage channels Better land use regulations and building codes
	Climate Proofing Cook Islands National Development Strategy	All climate-related impacts	Identification of sectors of high climate risk More sector-specific risk assessment Better climate-related information and better capacity to use it Appropriate legislation and local regulations as required
FSM	Climate Proofing a Portion of the Circumferential Road in Kosrae	Flooding (increase in design extreme rainfall event from 7 to 10 inches per hour) Storm surges	Modifications to the hydraulic design features
	Climate Proofing the Community of Sapwohn, Sokehs Island, Pohnpei	Flood (25-year hourly rainfall increases from present 210 mm to 393 mm by 2050) High sea levels	Modifications to drainage channels Better land use regulations and building codes
	Climate Proofing the FSM Sustainable Development Plan	All climate-related impacts (main focus on health care, environment, and infrastructure)	Identification of sectors of high climate-risk More sector-specific risk assessment Better climate-related information and better capacity to use it Appropriate legislation and local regulations as required

Notes: FSM = Federated States of Micronesia.

* Feasibility study delayed.

Source: ADB, CCAIRR findings.

B. Methodology

To mainstream a new concept such as climate change in ADB's preparation of programs and projects requires that documentation be i) sufficiently rigorous and appropriate to each step of the preparation process, from country strategy to project implementation, to ensure clear and defensible results; and ii) reasonably congruent with existing procedures, thus minimizing any additional burdens imposed on either staff time or consultant services. In outline, the documentation recommended by CLIMAP begins with a Climate Risk Profile (CRP), which provides a general assessment of climate risk at the country level and identifies climate-sensitive projects in the pipeline.[2] For the climate-sensitive projects, a Project Adaptation Brief (PAB) is then prepared, which provides a preliminary assessment of climate risk to the project. If the risk is assessed to be unacceptable, the PAB is then transferred into the PPTA process with appropriate changes to the PPTA terms of reference,[3] following which a more detailed Project Adaptation Assessment (PAA) is prepared by the PPTA consultants, containing a full risk assessment and analyzing a number of potential adaptation options with a comparative cost-benefit analysis.

This structure for documentation meets the above criteria in appropriate rigor at the various stages of project/program preparation, and is substantially integrated with the existing documentation structure. The CRP merges at the country level with preparation of the Country Strategy and Program (CSP) and CSP Update (CSPU), in which the project pipeline is identified. A PAB would be prepared only for those projects for which a significant climate risk is identified in the CRP. Finally, the PAA, if required, would be integrated into the conventional PPTA process. The structure provides for an appropriate level of review along the way to ensure that climate-related opportunities and constraints are not overlooked.

Preparation of intervention at ADB takes on a distinct character depending on the context in which projects and programs are set, and this will affect the details of how climate change aspects are incorporated. Broadly speaking, three basic contexts appear to be relevant for present purposes:

- **New projects.** The bulk of ADB lending and considerable ADB technical assistance are directed to new projects, mainly infrastructure such as roads, power sector facilities, etc. The climate change objective in this context is to specify a least-cost project that, among the usual design considerations, meets an acceptable climate-risk criterion. The methodology for economic analysis of such a project is identical with conventional methodology (i.e., will remain focused on the project's delivery of benefits to end-users), provided that the initial and operation and maintenance (O&M) cost estimates reflect the climate proofed design.

- **Climate-proofing existing facilities.** Countries will increasingly request ADB and other international development partners to strengthen existing facilities to lower climate risks, e.g., to harden an existing road with better drainage or build a breakwater to protect a port. Here the project is itself partly adaptation, and the economic methodology and decision will focus on the specific effectiveness of the selected adaptation option. For an existing facility, the economic decision regarding delivery of services to end-users has already been made and no longer needs to be considered.

- **Climate-proofing as a sector program.** Similarly, ADB and other aid providers will increasingly be asked for assistance in mainstreaming climate change analysis and adaptation at the country level, in respect of sectors such as transport, communications, water supply, and housing. In such cases, adaptation is a long-term process implemented in stages, and often in step with the retirement and replacement of existing assets. The financial costs of adaptation will fall on the sector owners, including, prominently, the private

---

[2] As described in the main text, the Climate Risk Profile could be prepared in conjunction with the Country Environmental Assessment (CEA), as the data required for the CRP are similar to those required for the CEA and could be collected without significant additional cost.

[3] The PABs prepared by CLIMAP contain project-specific suggested terms of reference for the PPTA consultants appointed to prepare each project. As the following discussion attempts to demonstrate, no additional requirements specific to economic analysis with respect to climate change or adaptation are recommended, as the methodology of such analysis follows conventional lines with which the PPTA consultants will already be familiar.

sector. Investments in adaptation will be motivated primarily by changing land use or environmental regulations and other policy changes imposed at the local, state, and national levels. In this context, economic analysis will be based on case studies designed to demonstrate that a new regulation or standard is economically justified.

In all three contexts, economic analysis is affected by climate change considerations after the context-specific climate risk is determined and proposed adaptation options for addressing it have been fully designed and costed. The cost of the adaptation options and their effectiveness in reducing climate risk determine the cost of addressing climate risk. The cost of the *optimum* adaptation option, i.e., the least-cost option that is effective in reducing risk to an acceptable level, is termed the *incremental cost* of climate change in the particular context under consideration. In the case where climate risk is assessed but no adaptation option is economically viable, incremental cost is the present value of additional maintenance and repair costs expected from climate change impacts within the project area.

Expectations regarding the extent and pace of climate change are "givens" in the economic analysis, and are provided by the global and higher-resolution local climate models and related analyses. These will define, for a particular project, the types of risks faced (e.g., higher rainfall and floods), the extent of expected impacts (e.g., flood levels at various recurrence periods, in meters above normal), the timing of expected impacts (e.g., flood levels at time intervals projected into the future, based on recurrence periods), and the extent of expected damage from such impacts (e.g., flood levels of a given recurrence period cause $X in damage to the existing and future assets in the project area). These data will result in an investment cost for the optimum adaptation option and a time series of damage values due to climate change that the adaptation option will be expected to prevent, on which a conventional net present value and internal rate of return analysis can be performed.

To illustrate the procedures of economic analysis related to climate change and how the procedures might be integrated into project preparation, three examples, one for each of the intervention "contexts" described above, are given below. The examples are derived from the highly quantitative CLIMAP country-level case studies of selected project areas in the FSM and the Cook Islands, as the climate risks and associated adaptation options have been assessed to a sufficient degree for illustrative economic analysis to be performed.[4] The examples given are highly simplified in order to maintain focus on climate-related aspects, and to facilitate comparisons between examples.

C. Examples

New Projects

The first context for intervention, by far the most common for ADB, is preparation of new projects for loan finance. As always, the main economic issue for proposed new projects is whether or not they deliver sufficient economic benefits to end-users to justify their investment cost. The effect of climate change is, potentially, to increase either the initial or annual O&M cost of the new project, or both, but not necessarily to have an impact on the benefits to end-users of the project itself.[5] The example below is of a new segment of the circumferential road in Kosrae, FSM.

The project is a 6.6-km length of new double-lane gravel road that will connect a cluster of rural communities to an urban area and markets for produce and employment. The road has an estimated useful life of 25 years. A PPTA consultant team specified the road design and estimated the total costs inclusive of sub- and top-surfacing materials, road furniture, drainage works, engineering and supervision services, and contingencies. The expected annual operation and maintenance costs

[4] The ADB-level project review studies might also be used for this purpose, except that the associated adaptation options have not been fully specified. As noted in the body of this book, the next step for the "review" projects is preparation of PPAs by PPTA consultants, in which adaptation options are identified in detail and costed. Economic analysis with the methodology described here can then be applied to those projects.

[5] Project benefits may be affected by climate change depending on the adaptation option specified to deal with climate risk (e.g., a climate-proofed road alignment, if longer than an alignment specified without climate change, will increase costs to users and decrease net benefits), but this only accentuates the economic impact of climate change on new projects, as discussed above. The effect of climate change on benefits is ignored for present purposes.

of the new road are as shown in Table A5.3. The estimated operating and maintenance costs are assumed to adhere to international “best practice” for maintenance of gravel roads, with major resurfacing works budgeted every 4th year and minor touch-ups scheduled in intervening years.

For present purposes, it is assumed initially that the design of the road (especially drainage works) and estimated costs do not reflect considerations of climate change, but rather are based on historical practice. Historical practice for this area is to design road drainage works to cater for the runoff from a design maximum rainfall of 178 mm per hour.

The estimated gross economic benefits (2nd column from the right in the table) are exogenous and based on an assessment of the road’s potential to improve the delivery of social services and increase the potential for income generation in the cluster of rural communities concerned. The economic internal rate of return (EIRR) is calculated on the stream of net economic benefits (gross economic benefits less total costs over each year of the road’s useful life). As shown, under these assumptions of costs and economic benefits, the EIRR is calculated at 17%, which comfortably exceeds the standard economic opportunity cost of capital (EOCC) of 12% and thus indicates an economically viable project. The project’s net present value discounted at the EOCC is $660,000.

When climate change is introduced to this scenario, the costs in the initial analysis conducted without climate change are seen to be underestimated, and the EIRR and net present value (NPV) are no longer valid. Climate change will result in heavier-than-anticipated rainfall; indicated best practice is to design road drainage works to cater for the runoff from a design maximum rainfall of 254 mm per hour, instead of 178 mm. Without the larger drainage works, climate change will result in substantially higher annual road maintenance costs, as shown in Table A5.4 below.

As shown, the higher maintenance costs and constant gross benefits of the project to end-users reduce the actual EIRR to below 14% and reduce the actual NPV by about two thirds, which indicates a marginally viable project. Allowing for variations in initial costs and benefits, as would be done in conventional sensitivity analysis, the project without design modifications is seen, under these assumptions, to be risky. In effect, it has not been demonstrated to be of least cost among the available alternatives.

With climate change appropriately recognized at the outset by the PPTA engineers, and incorporated into the project design and cost estimates, a least-cost solution can be found by increasing the capacity of the drainage works to cater for the higher design rainfall event. For simplicity, it is assumed that the larger drainage works are fully effective in preventing an increase in average maintenance costs due to increased runoff, as shown in Table A5.5.

With these assumptions, the initial cost of the road project is increased relative to the previous cases, but annual maintenance costs are lower than they would be without the adaptation to climate change (in this case, larger road drainage works). The project is least-cost with respect to initial costs and annual O&M costs taken together, and results, for a constant stream of gross economic benefits to end-users, in an EIRR of about 15% and an NPV of about $470,000. Both are lower than the without-climate-change case, but higher than the with-climate-change case when climate risk is ignored.

This highly simplified example has been designed to bring to the fore two considerations in respect of new projects:

- Ignoring climate change in project design is likely to lead to underspecification of the technical components and result in higher life-cycle project costs (i.e., will not result in a least-cost design); and
- Including the optimum climate-adaptive element in project design allows straightforward conventional economic analysis to indicate the “true” economic performance of the project under changing climate conditions, which in nearly all cases will be below the economic performance of the same project in the absence of climate change.

The cost of the optimum adaptation option included in climate-proofed project design is equivalent to the incremental cost of climate change to the beneficiaries of the new project.

Table A5.3. New Road Project under Current Design Without Climate Change Impact

	Total Cost under Current Design (No Climate Change)					
	Investment Costs					
Years	Drainage Works	All Other Technical Component	O&M Costs ($)	Total Costs ($)	Gross Economic Benefits ($)	Net Economic Benefits ($)
		1,254,414		1,894,647		(1,894,647)
1			15,875	15,875	345,901	330,026
2			18,343	18,343	352,819	334,476
3			20,811	20,811	359,875	339,065
4			197,863	197,863	367,073	169,210
5			17,304	17,304	374,414	357,110
6			19,902	19,902	381,903	362,001
7			22,586	22,856	389,541	366,955
8			215,670	215,670	397,332	181,661
9			18,574	18,574	405,278	386,704
10			21,561	21,561	413,384	391,822
11			24,534	24,534	421,651	397,117
12			235,081	235,081	430,085	195,004
13			20,133	20,133	438,686	418,554
14			23,409	23,409	447,460	424,051
15			26,685	26,685	456,409	429,724
16			256,238	256,238	465,537	209,299
17			21,945	21,945	474,848	452,903
18			25,515	25,515	484,345	458,830
19			29,086	29,086	494,032	464,946
20			279,299	279,299	503,913	224,613
21			23,920	23,920	513,991	490,071
22			27,812	27,812	524,271	496,459
23			31,704	31,074	534,756	503,052
24			304,436	304,436	545,451	241,015
25			26,072	26,072	556,360	530,288
					EIRR =	**17.02%**
Road Investment Cost per mile:			**$ 462,109**		**NPV @ 12%**	**$ 660,332**

EIRR = Estimated internal rate of return; NPV = net present value; O&M = operation and maintenance.

Source: CCAIRR findings.

Table A5.4. New Road Project under Current Design with Climate Change Impact

	Total Cost under Current Design (With Climate Change)					
	Investment Costs					
Years	Drainage Works ($)	All Other Technical Component	O&M Costs ($)	Total Costs ($)	Gross Economic Benefits ($)	Net Economic Benefits ($)
	640,233	1,254,414		1,894,647		(1,894,647)
1			17,599	17,599	345,091	328,302
2			22,326	22,326	352,819	330,493
3			27,590	27,590	359,875	332,286
4			283,798	283,798	367,073	83,275
5			26,698	26,698	374,414	347,716
6			32,867	32,867	381,903	349,035
7			39,753	39,753	389,541	349,788
8			403,010	403,010	397,332	(5,678)
9			36,725	36,725	405,278	368,553
10			44,973	44,973	413,384	368,411
11			53,838	53,838	421,651	367,814
12			541,381	541,381	430,085	(111,296)
13			48,551	48,551	438,686	390,136
14			58,993	58,993	447,460	388,467
15			70,146	70,146	456,409	386,263
16			701,394	701,394	465,537	(235,857)
17			62,451	62,451	474,848	412,397
18			75,384	75,384	484,345	408,961
19			89,092	89,092	494,032	404,940
20			885,825	885,825	503,913	(381,912)
21			78,460	78,460	513,991	435,530
22			94,248	94,248	524,271	430,023
23			110,880	110,880	534,756	423,876
24			1,097,771	1,097,771	545,451	(552,320)
25			96,846	96,846	556,360	459,515
					EIRR =	**13.90%**
Road Investment Cost per mile:			**$ 462,109**		**NPV @ 12%**	**$ 204,979**

EIRR = Estimated internal rate of return; NPV = net present value; O&M = operation and maintenance.

Source: CCAIRR findings.

Table A5.5. New Road Project under Adapted Design with Change Impact

	Total Cost under Current Design (With Climate Change)					
	Investment Costs					
Years	Drainage Works	All Other Technical Component	O&M Costs ($)	Total Costs ($)	Gross Economic Benefits ($)	Net Economic Benefits ($)
	850,00	1,254,414		2,104,414		(2,104,414)
1			15,875	15,875	345,901	330,026
2			18,343	18,343	352,819	334,476
3			20,811	20,811	359,875	339,065
4			197,863	197,863	367,073	169,210
5			17,304	17,304	374,414	357,110
6			19,902	19,902	381,903	362,001
7			22,586	22,856	389,541	366,955
8			215,670	215,670	397,332	181,661
9			18,574	18,574	405,278	386,704
10			21,561	21,561	413,384	391,822
11			24,534	24,534	421,651	397,117
12			235,081	235,081	430,085	195,004
13			20,133	20,133	438,686	418,554
14			23,409	23,409	447,460	424,051
15			26,685	26,685	456,409	429,724
16			256,238	256,238	465,537	209,299
17			21,945	21,945	474,848	452,903
18			25,515	25,515	484,345	458,830
19			29,086	29,086	494,032	464,946
20			279,299	279,299	503,913	224,613
21			23,920	23,920	513,991	490,071
22			27,812	27,812	524,271	496,459
23			31,704	31,074	534,756	503,052
24			304,436	304,436	545,451	241,015
25			26,072	26,072	556,360	530,288
					EIRR =	**15.28%**
Road Investment Cost per mile:			**$ 513,272**		**NPV @ 12%**	**$ 473,040**

EIRR = Estimated internal rate of return; NPV = net present value; O&M = operation and maintenance.

Source: CCAIRR findings.

Climate Proofing Existing Facilities

The second main context for intervention relates to the protection of existing facilities from the effects of climate change. It is likely that, as climate change is progressively mainstreamed among the ADB member countries, governments and the private sector will increasingly request assistance in protecting facilities that were originally designed without taking climate change into account and are therefore at rising risk. The gross economic benefit to end-users of services from the existing facility has already formed the basis of the past decision to invest in the facility, and need not be considered further. Rather, economic analysis in this context focuses on whether a "retrofitted" adaptation option provides sufficient benefits in the form of avoided future maintenance and repair costs to justify its initial cost. The economic analysis of retrofit climate proofing can be demonstrated by continuing the previous example, this time by applying higher capacity road drainage works to an *existing* segment of the circumferential road in Kosrae, FSM.

The project venue is a 3.2-km length of existing double-lane gravel road, for which higher operating and maintenance costs are expected due to runoff that exceeds the capacity of the existing drainage works, originally designed for a maximum 178-mm-per-hour rainfall event. The "project" entails removal of the existing road drainage works and replacement with larger works that can absorb the runoff of a 254-mm-per-hour rainfall event. Economic costs in this case include removing the existing drainage and replacing it with larger capacity drainage. The gross economic benefits are the expected future savings in road maintenance costs due to the new drainage.

In Case Study 1 in this book, it was estimated that the total resource cost of retrofitting larger capacity drainage onto the existing 3.2-km gravel road segment was about $370,000, or about $243,000 per km (nearly three times as much additional cost as climate proofing an as-yet-unbuilt road to the same standard in the same area, as per the previous example). Illustrative road maintenance costs with and without larger drainage works installed are shown in Table A5.6; net economic benefits of the adaptation project are equal to the difference between O&M costs without the project and with the project. Although substantial future cost savings are projected, the calculated EIRR of the adaptation project is about 7 percent, reflecting the higher cost and lower return of retrofitting adaptation onto an existing road (and by analogy, any facility). However, an EIRR of about 7% may still be acceptable for this or similar retrofit projects to proceed, dependent largely on the source of funds for the investment.[6]

Three general comments are suggested by this example:

- In this context, in contrast with the previous example, the economic focus is on the adaptation option itself, rather than on the economic benefit of the facility to ultimate users.
- In comparison with the previous example and with the economic analysis of "new projects" in general, investments to retrofit adaptation onto existing facilities will be less attractive than incorporating equivalent adaptation into new projects before they are built.
- The economic analysis of an adaptation option as a retrofit "project" follows entirely conventional methodology, provided that all resource costs associated with the retrofit are accounted for (including the costs of removing existing assets that may have substantial residual life) and that benefits of adaptation are accurately expressed as future operating and maintenance cost savings.

Consistent with the previous example, the cost of the optimum (i.e., least-cost) adaptation option chosen for retrofit is equivalent to the incremental cost of climate change to the beneficiaries of the existing facility. In many "retrofit" cases, the optimum adaptation option will be *do nothing*: dealing with the consequences of climate change as they come, in the form of higher maintenance and repair costs and possibly shortened asset life, may make more sense economically than an up-front investment in retrofit adaptation. In such cases, the incremental cost of climate change is

[6] The aid provider community is earmarking increasing resources to assist small and vulnerable developing countries to meet the incremental costs of adaptation. These funds are essentially nonfungible.

equivalent to the present value of the higher maintenance and repair costs so borne.

Climate Proofing as a Sector Program

The third main context for intervention relates to country-level mainstreaming of climate change considerations into long-term infrastructure and economic planning at the national, state, and local levels. Vulnerability to climate change, as discussed above, is certainly demonstrable at the project level, but also affects entire communities and sectors such as health care, education, transport, agriculture, water/wastewater, power supply, and urban development. At these macro levels, it is generally not feasible to retrofit effective adaptation in the short term. Rather, adaptation will proceed in step with the retirement and replacement of assets and through the construction of new assets. The costs of implementation will be borne by communities and governments and, to a highly significant degree, by the private sector. The investments of these groups will be guided by voluntary good practices and regulations generated by government agencies, private sector professional societies, and others, that increasingly reflect awareness of climate change impacts. In this way, climate change will be mainstreamed into economic planning, land use regulations and zoning codes, commercial bank lending guidelines, and the like.

The economic issue in this context is whether proposed regulations or planning guidelines are

Table A5.6. Retrofitting Adaptation: Total Road Costs with Climate Change

Total Costs under Current Design			Total Costs under Upgrade Design			Net Benefits of Upgrade Design		
Investment (Drainage Works)	Maintenance Costs ($)	Total Costs ($)	Investment (Drainage Works) ($)	Maintenance Costs ($)	Total Costs ($)	Investment (Drainage Works)	Maintenance Costs ($)	Total Costs ($)
			370,331		370,331	(370,331		(370,331
	8,364	8,364		7,744	7,774		620	620
	10,379	10,379		8,948	8,948		1,432	1,432
	12,588	12,588		10,152	10,152		2,436	2,436
	127,404	127,404		96,518	96,518		30,886	30,886
	11,817	11,817		8,441	8,441		3,376	3,376
	14,368	14,368		9,708	9,708		4,660	4,660
	17,187	17,187		11,018	11,018		6,170	6,170
	172,536	172,536		105,205	105,205		67,331	67,331
	15,584	15,584		9,060	9,060		6,524	6,524
	18,932	18,932		10,518	10,518		8,414	8,414
	22,500	22,500		11,968	11,968		10,532	10,532
	224,760	224,760		114,674	114,674		110,087	110,087
	20,034	20,034		9,821	9,821		10,214	10,214
	24,208	24,208		11,419	11,419		12,789	12,789
	28,637	28,637		13,017	13,017		15,620	15,620
	284,987	284,987		124,994	124,994		159,992	159,992
	25,263	25,263		10,705	10,705		14,558	14,558
	30,370	30,370		12,447	12,447		17,923	17,923
	35,755	35,755		14,188	14,188		21,566	21,566
	354,233	354,233		136,244	136,244		217,990	217,990
	31,270	31,270		11,668	11,668		19,602	19,602
	37,444	37,444		13,567	13,567		23,878	23,878
	43,992	43,992		15,465	15,465		28,456	28,456
	433,636	433,636		148,506	148,506		285,131	285,131
	38,155	38,155		12,718	12,718		25,436	25,436
NPVs@	**3.0%**	**$ 1,280,368**			**$ 990,771**		**EIRR =**	**6.73%**

EIRR = estimated internal rate of return; NPV = net present value.
Source: CCAIRR findings.

economically justified, or whether existing regulations have begun to impose hidden costs due to climate change. Does the process of planning and development take proper account of climate constraints? What are the long-term opportunities to minimize climate-related costs affecting communities, sectors, or the country as a whole?

As demonstrated in several of the CLIMAP country-level case studies, the initial stages of addressing such questions take a considerable effort in primary surveys, studies, scenario generation, and analyses. CLIMAP has developed an analytic tool, SimClim, that greatly helps these processes. It is expected that as climate mainstreaming proceeds, well-founded regulations and guidelines will gradually replace the need for primary surveys and analyses, and climate-aware development will become self-sustaining. However, as long as mainstreaming is in its preliminary stages, much work remains to be done across a wide variety of sectors and communities in a large number of countries.

The example briefly discussed here is of the case study of the Sapwohn coastal community in Pohnpei, FSM, described in detail as Case Study 4. The following focuses on the methods of analysis used in the case study, as a model of the kind of analysis that may have to be replicated for other communities and sectors in the FSM and in other countries.

Sapwohn is a coastal "bedroom" community on Sokehs Island close to the Pohnpei state capital, Kolonia. The sample area for the case study contains 178 structures, mostly residential, which form the assets that are vulnerable to climate change. The main climate risks, based on observations and consultations with community leaders and residents, are flooding from extreme rainfall events and sea level changes. In order to quantify the risk, it was necessary to undertake a detailed structure-by-structure survey of the sample area, to determine each structure's precise elevation, proximity to runoff channels, orientation to the sea, uses of the structure, and materials of its construction. Discussions with experienced building contractors in Pohnpei provided estimates of the cost to repair or replace structures that suffered various levels of damage from natural causes, based on replacement value.

Because each structure in the sample area has a unique location and hence a unique risk of flooding, and is composed of particular materials with different abilities to withstand flood damage, it was necessary to construct an economic model that included *each* structure, and correlate the results to develop a composite picture of the sample area. Buildings were categorized by construction materials. For each category, damages caused by floods were estimated on a sliding scale of flood heights, thus allowing a damage estimate to be derived for each structure for any given flood event, which depends only on the structure's three-dimensional location and construction materials. The necessity of this type of structure-by-structure analysis was the most time-consuming and analytically intensive part of the case study of the sample area.

Sector analysis differs from the project analysis of the previous examples in terms of the applicable time horizon. Whereas the useful life of infrastructure projects rarely exceeds 25–30 years, a sector or a community is subject to events occurring over a much longer time frame, say 50–100 years. Within such periods, very little can be considered "fixed." For certain, the climate changes palpably; human activities evolve; and the local, state, national, and world economies change. Thus, risk assessments at the sector or community level must take into account not only climate risks but also land use changes due to population pressures or transforming economic activity. Land use changes are at once a "risk factor," in that they may increase the vulnerability of a community to a given extreme event, and an opportunity to adapt gradually and in a robust way to increasing climate risk. The SimClim model features a land use scenario generator that allows analysts to simulate future economic development in the study area as an adaptive response to climate change, providing a powerful tool for development and testing of adaptation guidelines.

The case study in Sapwohn (and a similar case study in Rarotonga, Cook Islands) highlighted the fact that "modern" communities in coastal areas of island countries (and very likely communities in other environments of developing countries) are highly vulnerable to natural disasters that, because of climate change, are becoming increasingly probable. It would appear that the process of economic development over the decades since World War II, involving a transformation away from traditional subsistence toward reliance on a cash economy and external markets, has resulted in increasing vulnerability to natural disasters that has overwhelmed any attempts to adapt. The case studies found that the communities are highly vulnerable, irrespective of climate change, but that climate change significantly exacerbates the vulnerability. Climate-related sector analysis is thus indicated as an urgent need, difficult and demanding as it may be initially; such case studies should be repeated in other communities and in other countries.

The economic model developed for the community case studies of Sapwohn and Rarotonga provides a structure-by-structure assessment of climate-related risk in the communities, a valuation of the assets, and integration across structures and across extreme events of the damage expected to be sustained from various climate change scenarios, making it possible to test the effectiveness of different development scenarios and long-term adaptive responses and select for voluntary-guideline and regulatory purposes. The economic model is built in as an integral component of the SimClim software developed for CLIMAP, and is available for use in similar case studies.

In the context of economic analysis for adaptation, the following observations are relevant:

- Sector analysis is *long term* and involves transformations in the local climate and local economy that may be opposed or mutually reinforcing.
- The appropriate adaptation response to assessed risks is gradual and implemented through voluntary guidelines; where necessary, land use regulations are designed to minimize individual and community costs.
- A large portion of the costs of adaptation in this context will be borne by individuals and the private sector rather than by governments, and is therefore less amenable to direct ADB intervention than is conventional project finance.
- The practical methodology of economic analysis is highly dependent on the sector or particular community selected as the study area.
- The analysis involves highly complex integrations spatially and temporally, and will be aided by use of the SimClim software developed for CLIMAP, or a similar tool.
- Sector analysis will constitute an increasing focus of government and multilateral agencies as climate awareness is increasingly mainstreamed into local, state, and national planning processes.

Conclusions

The three "contexts" for climate-related analysis described above, viz, (i) new projects, (ii) retrofitting existing assets, and (iii) sector analysis are in approximate order of current priority for governments and international agencies, given the emerging state of climate awareness. The primary focus on analysis for new projects stems from an awareness of the potential for climate change to undermine the effectiveness of new projects and their potential to contribute to development and poverty reduction. The secondary focus on retrofitting existing assets stems essentially from the same concerns and a recognition that many assets with considerable useful life remaining are ill-designed to cope with climate impacts.

The third context, however, is most directly related to local, national, and global mainstreaming of climate awareness, and is of paramount importance for the long term, albeit relatively remote from immediate concerns. Though comparatively difficult and complex to carry out, sector and community case studies will provide valuable insights to guide robust and economically well-founded adaptive responses to climate change in the future. Application of requisite resources for them in the near term is a kind of bellwether of the success of mainstreaming efforts in general. The need for primary research will gradually lessen as data are gathered, organized, and applied across similar sectors, communities, and countries as mainstreaming proceeds.

Efforts within ADB to mainstream climate awareness into project and program development will have a powerful effect, not only on activities directly financed by ADB, but indirectly on parallel projects and sectors addressed by governments and other aid providers, as ADB's institutional credibility promotes wider acceptance of climate-aware processes and procedures.

Appendix 6

Land Use Change Model

A. Function

The land use change model simulates changes in use of land over time. It accepts targets for future land use and determines how they are likely to evolve in new patterns. The model is stochastic: it determines likelihoods for transitions between current and (potential) future land uses and uses a Monte Carlo approach[1] to generate one (out of many) outcomes.

B. Inputs

The land use change model requires the certain inputs, shown in Table A6.1.

C. Outputs

The land use change model produces several outputs (Table A6.2).

Table A6.1. Inputs for Land Use Change Model

Land use types	A set of land use types that are relevant for the model area. This can be a list of the different structures that are discerned (i.e., residential, commercial, community), and/or a list of features (i.e., agriculture, forest, urban, road, water).
Current land use pattern	A grid with one assigned land use type per grid cell.
Rules	A series of data-matrices that describe elements of the transition likelihood (i.e., possible and impossible land use transitions, preference for certain land use types in dependency of the density of neighboring types, suitability of a specific grid cell for changing into a certain land use type, masks (overlays) with developing areas).
Neighborhood function	A function that describes the influence of neighboring cells on (the transition of) a specific cell. Cells of a certain type tend to cluster together (forest) or have a small distance in between. These functions can be defined for "near" and "far" neighbors.
Target areas	For certain land use types, future target areas (m^2) are specified. These depend on, among others, economic and demographic developments. The land use model takes these targets and makes a spatial allocation, based on the current land use pattern and the rules.
Properties list	A list of all the buildings, their value, floor height, location, age, and structure type (which determines their staged-damage-curve, which shows the percentage of damage done to the building as a function of the flood level).

Source: CCAIRR findings.

[1] Monte Carlo techniques first determine the likelihood of an event and then use a random number to determine if the event does take place.

Table A6.2. Outputs of Land Use Change Model

New land use pattern	A grid with all the (new) land use types, satisfying the total area (m^2) needed for each land use type.
Update properties list	A property list reflecting all the changes that have come into effect during the last year (e.g., age, floor level, location).
Transition balance	An overview of all the individual changes that have taken place, referencing the rules that have been used.
Costs	Costs of changes (usually associated with adaptation).

Source: CCAIRR findings.

D. Parameters

The land use change model implements certain rules and mechanisms with respect to structures. Some mechanisms are parameterized control their behavior (Table A6.3).

E. Cost-Benefit Model

The cost-benefit model calculates the discounted costs of damage to structures because of flood events (either from inland flooding or from storm surges) with and without climate change, as well as the benefits (under both conditions) of adaptation options (regarding the flood events).

F. Expected Damages

Given a list of structures with value (structure and contents), location, and the appropriate staged-damage curve, for any given flood event (characterized by flood-levels at all locations), the damages resulting from these flood events can be computed.

Each of these flood events has a return period and an associated probability of occurring. The expected costs for a certain event are its probability times the associated costs. The annual expected costs are the integral over all events.

As both the flood events (climate change) and the structures (land use change) can develop over time, the annual expected costs will be different for every year. All these future costs can be discounted to current dollars (using a discount rate) and correlated to find the total expected costs at the present time.

Table A6.3. Parameters for Land Use Change Model

Longevity	This parameter controls the aging and therefore the relocation or renovation of structures.
Acceptable risk	The risk (effects of flood events) that occupants of a structure accept before they decide to change (either renovate or relocate).
Structure parameters	Several parameters control the condition of new or renovated properties (e.g., a minimum floor level, either generic or depending on the local flood risks).
Rebuilding strategy	When structures are "renewed", it is possible to renovate them (on the spot) or rebuild them (possibly in a different location).
Neighborhood	Neighborhood is defined as the percentage of cells per land use type "around" a center cell at a certain distance ("near" or "far"). This percentage can be weighted with the distance.
Monte Carlo parameters	As the land use change model determines only the likelihood of transitions in land use, the actual transition is a stochastic process. Parameters can be set to control this process: to make selections based on the maximum likelihood or to repeat the random path (in order to reproduce results).

Source: CCAIRR findings.