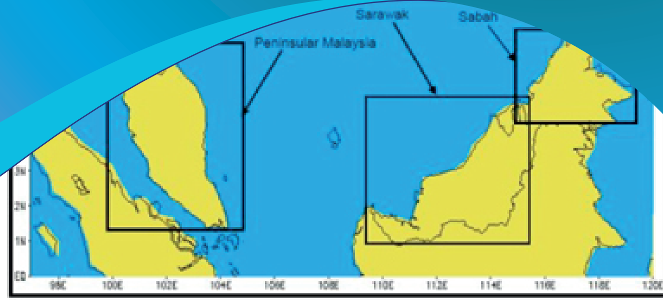
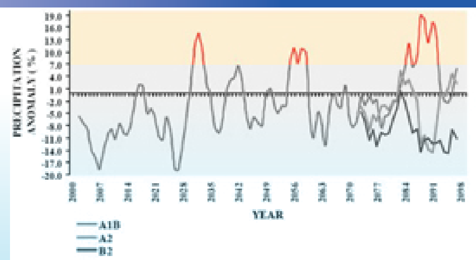
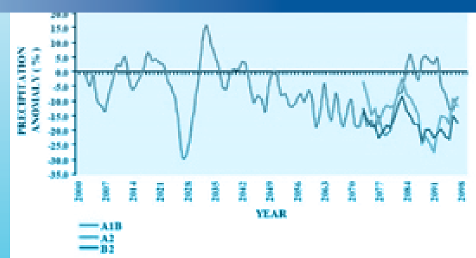
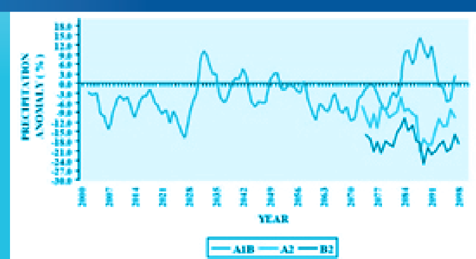
ASM Study Report 1/2011





Study on the Status of Climate Change Impact on Water-related Issues





AKADEMI SAINS MALAYSIA

Study on the Status of Climate Change Impact on Water-related Issues

(Final Report)

Academy of Sciences Malaysia: Task Force on Climate Change and Water Resources

December 2010

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Foreword

I would like to congratulate the ASM Task Force on Climate Change and Water Resources for producing the Study Report on the Status of Climate Change Impact on Water-Related Issues. This is yet another credible output of the ASM Water Committee.

The Study Report is the output of an ASM-commissioned study to present a synthesized set of summary conclusions and recommendations after perusing various documentations (both "hard-copy" and electronic media) of all available information on past and current initiatives and programmes undertaken within Malaysia and in areas within the same climatic zone with regard to the impact of climate change on water-related issues.

Water is a critical ingredient in all social and economic endeavours. Climate change is expected to further exacerbate extreme variability in rainfall patterns, escalating flood and drought events, which are sometimes accompanied by river bank breaches, soil erosions, landslides and forest fires. There will also be the anticipated heat waves and rising sea levels. These extreme events will affect economic and social activities, health, ecosystem and biodiversity. In Malaysia, increase in extreme climate variability is already being felt in the form of shifting rainfall patterns, escalating floods and drought occurrences, as well as an increase in their intensities.

The Study Report is yet another important deliverable of the Academy of Sciences Malaysia and we are confident that the findings contained therein would lead to taking concrete steps towards developing and agreeing on a strategy plan in line with Integrated Water Resources Management (IWRM) and on a plan of action for implementation over the long term within the 10th Malaysia Plan period and beyond.

Tan Sri Dr Ahmad Tajuddin Ali, F.A.Sc.
President
Academy of Sciences Malaysia

Preface

One of the Task Forces under the Academy of Sciences Malaysia (ASM) Water Committee is the Task Force on Climate Change and Water. The roles of the Task Force are:

- To support the IWRM processes in adaptation to impacts of climate change on water related issues in a "No-Regret" agenda, starting with harvesting of "low hanging fruits" based on the precautionary principle; and
- To look at understanding the extent of these water-related issues in order to propose an appropriate and holistic framework for strategic actions, including costs and benefits, wherever possible and necessary, through:
  - Assessing and prioritizing the emerging and potential issues and gaps exacerbated due to climate change, amongst which include information and/or knowledge management, research and development, capacity building, etc. and
  - Providing recommendations in each of the required specific areas, such as socio-economics (including floods), health (including pollution), agriculture, water supply, etc.

In fulfilling its roles in the first quarter of 2010, the Task Force on Climate Change and Water commissioned a desk study to undertake the following scope:

(i) To review past and current initiatives and programmes undertaken within Malaysia and in areas within the same climatic zone with regards to the impacts of climate change on water-related issues including references to previous study reports, and conference/workshop proceedings

(ii) To extract, compile, synthesize and summarize the findings and conclusions from such reports and proceedings, and

(iii) To undertake gap analysis in relation to item (i) and to propose comprehensive recommendations pertaining to required adaptation to impacts of climate change on water-related issues in Malaysia.

This Study Report is the culmination of the commissioned work and the findings in this Report will go towards developing a Strategy Plan document by ASM for managing the resource through Integrated Water Resource Management (IWRM) principles in the light of climate change impacts on the nation.

To this end I would like to thank the ASM Council and the Chair of ASM Water Committee for agreeing to conduct the study, the Task Force members, and their respective organizations, that have steered the Study, the consultants for accepting our invitation to carry out the Study and ASM Secretariat who had gelled and facilitated us in this task.

Ir. Dr Salmah Zakaria, F.A.Sc
Chairman,
ASM Task Force on Climate Change and Water

Acknowledgements

The Academy of Sciences Malaysia (ASM) would like to thank the following organisations which had contributed in one way or another to the successful completion of the ASM Study Report entitled "Study on the Status of Climate Change Impact on Water Related Issues":

Economic Planning Unit, Prime Minister's Department
Irrigation and Drainage Department
National Hydraulic Research Institute of Malaysia
Department of Environment
Department of Statistics
Town and Country Planning Department
Forestry Department Peninsular Malaysia
Forest Research Institute Malaysia
Institute of Medical Research
Department of Water Supply
Muda Agriculture Development Authority
Malaysian Agricultural Research and Development Institute
Malaysian Green Technology Corporation
Malaysian Meteorological Department
Ministry of Science, Technology and Innovation
Ministry of Agriculture
Ministry of Health
Ministry of Energy, Green Technology and Water
Southeast Asia Disaster Prevention Research Institute, UKM

Appreciation is also due to the following members of the ASM Task Force on Climate Change and Water Resources for having ably guided and giving valuable input throughout the duration of the Study:

Ir. Dr Salmah Zakaria, F.A.Sc. (Chairman, ASM Task Force on Climate Change and Water Resources)
Dr Abdul Rahim Nik, Forest Research Institute Malaysia (FRIM)
Ir. Hj. Mohd Fauzi Mohamad, National Hydraulic Research Institute of Malaysia (NAHRIM)
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Pn. Nor Zaliza Mohd Puzi, Town and Country Planning Department, Peninsular Malaysia (JPBD)
Prof Joy Jacqueline Pereira, Southesat Asia Disaster Prevention Research Institute, UKM

Last but not least, the Academy of Sciences Malaysia and the Task Force on Climate Change and Water Resources would like to convey its heartfelt gratitude to Dr Lee Jin and Ms Lavanya Rama Iyer for having accepted the onerous task of undertaking the Study and having completed it successfully within the time frame set.

Contents

List of Acronyms

CH4	Methane
CO_2	Carbon dioxide
CO_2e/CO_2eq	Carbon dioxide equivalent
COP	Conference of Parties
DID	Department of Irrigation and Drainage
DOE	Department of Environment
DOS	Department of Statistics
EPU	Economic Planning Unit
FDPM	Forestry Department Peninsular Malaysia
FRIM	Forest Research Institute Malaysia
GAW	Global Atmospheric Watch
GCM	Global Climate Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICT	Information and Communications Technologies
IMR	Institute of Medical Research
IPCC	Intergovernmental Panel on Climate Change
IRBM	Integrated River Basin Management
ISMP	Integrated Shoreline Management Plan
IWRM	Integrated Water Resources Management
JBA	Department of Water Supply/Jabatan Bekalan Air
LULUCF	Land Use, Land Use Change and Forestry
MADA	Muda Agriculture Development Authority
MARDI	Malaysian Agricultural Research and Development Institute
MCB	Malaysian Cocoa Board
MGTC	Malaysian Green Technology Corporation or GreenTech Malaysia /Pusat Teknologi Hijau (formerly Malaysia Energy Centre or Pusat Tenaga Malaysia/PTM)
MMD	Malaysian Meteorological Department
MOA	Ministry of Agriculture
MOH	Ministry of Health
MOT	Ministry of Transport
MPOB	Malaysian Palm Oil Board
MRB	Malaysian Rubber Board
NA1	Non Annex 1 (Developing country parties to the UNFCCC)
NAHRIM	National Hydraulic Research Institute of Malaysia
NC2	Second National Communication
NCVI	National Coastal Vulnerability Index
NRE	Ministry of Natural Resources and Environment
PM	Peninsular Malaysia
PRECIS	Providing Regional Climates for Impacts Studies
PTM	Pusat Tenaga Malaysia (now known as Malaysia Green Technology Corporation or GreenTech Malaysia/Pusat Teknologi Hijau Negara)
R&D	Research and Development
RCM	Regional Climate Model

RegHCM-PM	Regional Hydro-Climate Model for Peninsular Malaysia
SLR	Sea Level Rise
UKM	Universiti Kebangsaan Malaysia
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
V&A	Vulnerability and Adaptation

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Executive Summary

The Academy of Sciences Malaysia (ASM), under its Sustainable Water Management Programme, has established a Task Force on "Climate Change and Water Resources" (TF-CCW). The TF-CCW is planning a series of stakeholder consultation workshops to identify and streamline the required strategic actions to address the water-related issues arising from the potential impacts of climate change in Malaysia. As part of the preparation for the workshops this desktop study has been carried out to provide the necessary background information for the workshops and to identify the current implementation gaps to address the impacts and adaptation to climate change on water.

As part of the literature review for the study a brief synopsis of the following key local and international documents was carried out:

1. *IPCC Technical Paper VI on Climate Change on Water (2008)*
2. *The Stern Review: Economics of Climate Change (2006)*
3. *The Economics of Climate Change in South East Asia: A Regional Review (2009)*
4. *APWF Framework Document on Water and Climate Change Adaptation (Draft Nov. 2010)*
5. *Malaysia's Second National Communication to the UNFCCC (NC2) (Draft September 2010)*

This Report also gives a brief introduction to climate change modeling and provides a description of the available climate projections relating to Malaysia. It also discusses how these projections relate to each other, as well as to more general regional and global projections. In addition, a synthesized overview of the subject of climate change impact, vulnerability and adaptation for the water sector is also given. The overview is based on the compiled extracts from the *Stern Review on the Economics of Climate Change (2006)* and *The Economics of Climate Change in Southeast Asia: A Regional Review (2009)* by ADB.

A summary of the current status of water management to address the impacts of climate change on water for the following seven thematic areas is also given, together with key gaps and recommendations to address them:

(a) Governance and Institutional Capacity
(b) Climate Change Projections and R&D Capacity
(c) Information Management Capacity
(d) Stakeholder Awareness and Participation
(e) Water Bodies Management Capacity
(f) Water Use Management Capacity; and
(g) Water Management Capacity.

In particular, the Report highlights the gaps and recommendations identified by the various NC2 working groups that contributed to the most recent and comprehensive domestic document on the issue of climate change and adaptation, i.e. the NC2 report. Recommendations from the other documents reviewed as listed in the Reference section have also been included as relevant. A summary of the recommendations for sections (a) – (d) above is appended as *Appendix 10*. The information that have been compiled and summarised in this report will provide the basis for the TF-CCW to organise the stakeholder consultation workshops to create awareness on the impacts of climate change on water-related sectors and issues, develop consensus among the stakeholders on the adaptation measures that are required in each water sector and the strategies to achieve them. The stakeholder workshops will also provide opportunities for the TF-CCW to gather additional information on what each of the stakeholders are doing in their respective sectors, and what they are planning to do to adapt to climate change.

The following are the conference and workshops that have been recommended for implementation to produce the desired set of strategic action plans for adaptation to the impacts of climate change for the various water sectors:

(a) National Conference on Water and Climate Change Adaptations
(b) Seven Thematic Workshops on Water and Climate Change Adaptations, as listed below:
    1. Governance and Institutional Capacity
    2. Climate Projections and R&D Capacity
    3. Information Management Capacity
    4. Stakeholder Awareness and Participation
    5. Water Bodies Management Capacity
    6. Water Use Management Capacity; and
    7. Water Management Capacity.

The objective of the National Conference is to create awareness among all the stakeholders on the key issues involved in water and climate change. In addition to the presentation of the key outputs from this study, paper presentations on key thematic topics from other stakeholders that have carried out work related to climate change and water shall also be included. The conference shall conclude with a panel discussions on the next steps forward — which is to conduct in-depth thematic, stakeholder workshops for the above seven themes.

The objectives of each of the seven thematic workshops are as follows:

(a) To agree on the key issues to be addressed in each theme to adapt to the impacts of climate change on water,
(b) To clarify, prioritise and define the strategic action plans and develop their list of activities to address each of the agreed issues; and

(c) To estimate the indicative costs, where possible, of each of the strategic action plan based on their list of activities.

To facilitate the organising of the workshop the information compiled in this Report and organised under the seven themes can be extracted and provided as background workshop materials, and as an initial framework and food-for-thoughts for the workshop participants' discussions.

CHAPTER 1. INTRODUCTION

1.1 Background

The Academy of Sciences Malaysia (ASM), under its Sustainable Water Management Programme, has established a number of Task Forces to address various matters of concern affecting the country's water sector. One of the Task Forces is on "Climate Change and Water Resources".

The roles of the ASM Task Force on Climate Change and Water Resources (ATF-CCW) are:

(a) To support the IWRM processes in adaptation to impact of climate change on water in a "No-Regret" agenda including to harvest low hanging fruits, and based on the precautionary principle; and
(b) To look at the extent of the issues and to propose a holistic framework for strategic actions in water-related issues, including the estimated cost and benefits, wherever possible and necessary, by:
    - Assessing potential issues and the gaps (e.g. but not limited to the following: information management/knowledge, R&D, capacity building, etc.) exacerbated by climate change; and
    - Providing recommendations in each of the specific areas of, but not limited to, socio-economics (including floods), health (including pollution), agriculture, water supply, etc.

In order to fulfill its role the ATF-CCW is planning a series of stakeholder consultation workshops to identify and streamline the required strategic actions, and to develop the holistic framework, to address the water-related issues arising from the potential impacts of climate change in Malaysia.

As part of the preparation for the stakeholder workshops the ATF-CCW has appointed the Consultants, Dr Lee Jin and Ms Lavanya Rama Iyer, to conduct a desktop study to review, compile and identify current implementation gaps to address the impacts and adaptation to climate change on water.

1.2 Study Objective

The overall objective of the Study, as stated in the Terms of Reference (TOR) for the Study, is as follows:

> *"To present to the Task Force on Climate Change and Water Resources a synthesized set of summary conclusions and recommendations after perusing various documentations (hard-copy and electronic media) of key available information on past and current*

initiatives and programmes undertaken within Malaysia and in areas within the same climatic zone with regard to the impact of climate change on water-related issues."

The scope of work as stated in the TOR is as follows:

(i) to review past and current initiatives and programmes undertaken within Malaysia and in areas within the same climatic zone with regard to the impact of climate change on the country's water-related issues including reference to previous study reports, and conference/workshop proceedings, and
(ii) to extract, compile, synthesize and summarize the findings and conclusions;
(iii) To undertake gap analysis in relation to item (i) and propose comprehensive recommendations pertaining to required adaptation to impact of climate change on Malaysia's water-related issues; and
(iv) To submit a report, including a list of Malaysian experts and references to all perused documents, to ASM addressing items (i), (ii) and (iii).

1.3 Report Structure

The Consultants understand that the ATF-CCW will adopt a similar workshop process as that used by the ASM Task Force on Lakes and Reservoir Management to develop its strategic recommendations. In the Lakes and Reservoir Management workshops the workshop groups were organized under the following six themes:

(a) Governance Sector
(b) Capacity Building Sector
(c) Research Needs Sector
(d) Lake Management Sector
(e) Information Management Sector; and
(f) Stakeholder Participation Sector.

The objective of organizing the workshop groups by the above six themes is to enable ASM to get the consensus of the selected workshop participants on the current status, gaps and capacity required to address the above five cross-cutting thematic areas, and the lake technical management sector, to address the issues and problems related to lakes and reservoir management in Malaysia.

The information compiled from this Study will be used subsequently by the ATF-CCW to organize the stakeholder workshops on "Climate Change Impacts, Vulnerability and Adaptation for the Water Sector". Thus, to facilitate the ATF-CCW in implementing the subsequent workshop process, the Consultants have compiled and organized the information reviewed into the following four cross-cutting thematic areas, and three water management themes:

(a) Governance and Institutional Capacity
(b) Climate Projections and R&D Capacity
(c) Information Management Capacity
(d) Stakeholder Awareness and Participation
(e) Water Bodies Management Capacity
(f) Water Use Management Capacity; and
(g) Water Management Capacity.

By organizing the information in this way the outputs from this Study can easily be extracted and compiled later as the key information resources that the various thematic workshop participants can use in their workshop discussions.

Thus, this Study report is structured as follows:

Chapter 2 gives the literature review that has been carried out as part of the Study. It will provide a brief synopsis of the key local and international documents that have been reviewed in the course of this Study.

Chapter 3 gives a brief introduction to climate change modeling and provides an overview of the current status of climate change projections in Malaysia. It provides a description of available climate projections relating to Malaysia and discusses how these projections relate to each other as well as to more general regional and global projections. *Appendix 2* summarises the observed and projected changes for Malaysia.

Chapter 4 provides a synthesized overview of the subject of climate change impact, vulnerability and adaptation for the water sector, based on the compiled extracts from the *Stern Review on the Economics of Climate Change (2006)* and the report on *The Economics of Climate Change in Southeast Asia: A Regional Review (2009)* by ADB.

Chapter 5 gives a summary of the current status of water management in the country to address the impacts of climate change on water for seven thematic areas. It also highlights the gaps and gives the recommendations to address them; and

Chapter 6 presents the recommended process steps to take forward the outputs from this study.

CHAPTER 2. LITERATURE REVIEW

2.1 Review of Key International Documents

The following are the key international documents reviewed in this Study. A synopsis of each of the documents is presented below.

1. *IPCC Fourth Assessment Report: Climate Change 2007 (AR4)*
2. *IPCC Technical Paper VI on Climate Change on Water (2008)*
3. *The Stern Review: Economics of Climate Change (2006)*
4. *The Economics of Climate Change in South East Asia: A Regional Review (2009)*
5. *APWF Framework Document on Water and Climate Change Adaptation (Draft Nov. 2010)*

2.1.1 *IPCC Fourth Assessment Report: Climate Change 2007 (AR4)*

The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 jointly by the World Meteorological Organization and the United Nations Environment Programme to provide an authoritative international statement of scientific understanding of climate change. The IPCC's periodic assessments of the causes, impacts and possible response strategies to climate change are the most comprehensive and up-to-date reports available on the subject, and form the standard reference for all concerned with climate change in academia, government and industry worldwide.

The latest IPCC Assessment Report is the *Fourth Assessment Report (AR4) — Climate Change 2007*. The report is published in four volumes, comprising of a synthesis volume and three other volumes by three IPCC working groups. Through the three working groups, many hundreds of international experts assess climate change in the Report.

The four volumes (*Figure 2.1*) are:

1. *Climate Change 2007 — Synthesis Report*
2. *Climate Change 2007 — The Physical Science Basis*
3. *Climate Change 2007 — Impacts, Adaptation and Vulnerability;* and
4. *Climate Change 2007 — Mitigation of Climate Change.*

2.1.1.1 Climate Change 2007 — Synthesis Report

The Synthesis Report compiles the key findings from the assessments carried out by the three IPCC Working Groups (WGs). It provides an integrated view of climate change as the final part of the IPCC's *Fourth Assessment Report (AR4)*. The Report addresses a range of broad policy-relevant questions, structured around six topic headings agreed by the Panel, and it gives careful attention to cross-cutting themes.

The Report consists of two parts, a Summary for Policymakers (SPM) and a longer report. The sections of the SPM follow largely the topic structure of the longer report, but for brevity and clarity, certain issues covered in more than one topic are summarised in one section of the SPM. The Table of Content of the IPCC Synthesis Report Summary for Policy Makers is given in Figure 2.2.

The following are the 6 topics covered in the Synthesis Report.

(a) Topic 1 summarises observed changes in climate and their effects on natural and human systems, regardless of their causes.
(b) Topic 2 assesses the causes of the observed changes.
(c) Topic 3 presents projections of future climate change and related impacts under different scenarios.
(d) Topic 4 discusses adaptation and mitigation options over the next few decades and their interactions with sustainable development.
(e) Topic 5 assesses the relationship between adaptation and mitigation on a more conceptual basis and takes a longer-term perspective; and
(f) Topic 6 summarises the major robust findings and remaining key uncertainties in this assessment.

Figure 2.3 shows a schematic framework representing anthropogenic drivers, impacts of and responses to climate change, and their linkages. At the time of the IPCC Third Assessment Report (TAR) in 2001, information was mainly available to describe the linkages clockwise, i.e. to derive climatic changes and impacts from socio-economic information and emissions.

However, with the increased understanding of the linkages, the AR4 report manages to assess the linkages also counterclockwise, i.e. to evaluate possible development pathways and global emissions constraints that would reduce the risk of future impacts that society may wish to avoid.

2.1.1.2 Climate Change 2007 — The Physical Science Basis

The focus of the IPCC Working Group (WG) 1 Report on the scientific basis for climate change is on those aspects of the current understanding of the physical science of climate change that are judged to be most relevant to policymakers. The report does not attempt to review the evolution of scientific understanding or to cover all aspects of climate science.

The Table of Content of the IPCC WG1 Report is given in *Figure 2.4.*

2.1.1.3 Climate Change 2007 — Impacts, Adaptation and Vulnerability

The focus of the IPCC Working Group (WG) 2 Report is on the impacts of global warming that is already under way and the potential for adaptation to reduce the vulnerability to, and risks of climate change. The report draws on over 29,000 data series and provides a much broader set of evidence of observed impacts coming from the large number of field studies developed over recent years.

The analysis of current and projected impacts is carried out sector by sector in dedicated chapters. The report pays great attention to regional impacts and adaptation strategies, identifying the most vulnerable areas. A final section in the report provides an overview of the inter-relationship between adaptation and mitigation in the context of sustainable development.

The Table of Content of the IPCC WG2 Report is given in *Figure 2.5*.

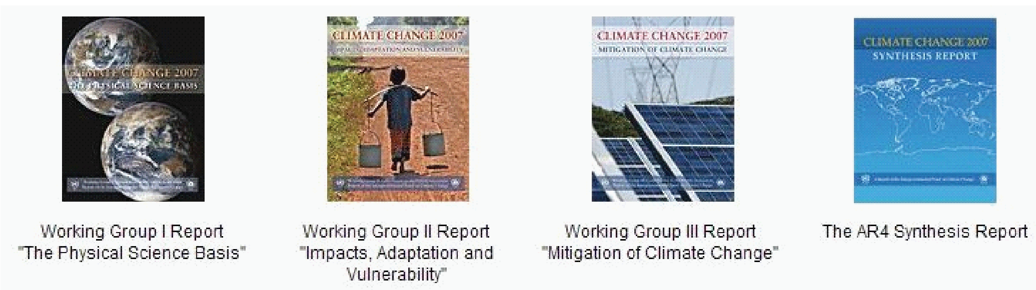

Figure 2.1. The Four Volumes of the IPCC Fourth Assessment Report (AR4) — "Climate Change 2007".

Synthesis Report Summary for Policymakers

Introduction

1. Observed changes in climate and their effects

2. Causes of change

3. Projected climate change and its impacts

4. Adaptation and mitigation options

5. The long-term perspective

Figure 2.2. Table of Content of the IPCC Synthesis Report Summary for Policy Makers.

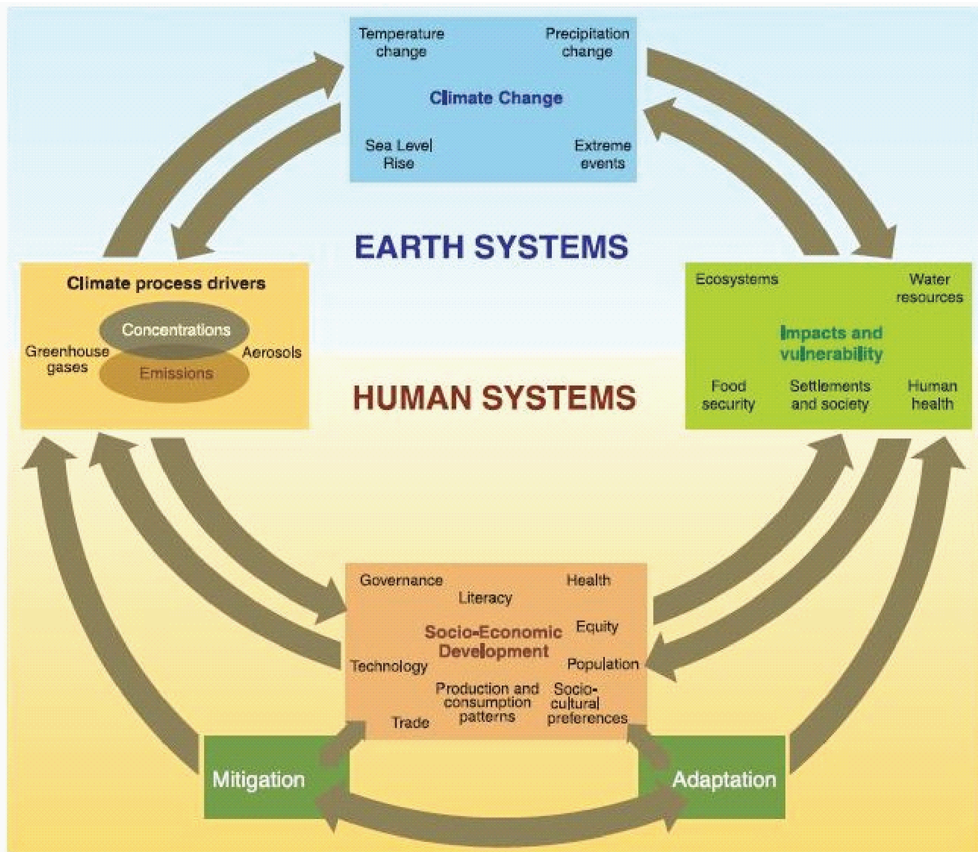

Figure 2.3. Schematic framework representing anthropogenic drivers, impacts of and responses to climate change, and their linkages.

2.1.1.4 <u>Climate Change 2007 — Mitigation of Climate Change</u>

The IPCC Working Group (WG) 3 Report presents an analysis of the costs, policies and technologies that could be used to limit and/or prevent emissions of greenhouse gases, along with a range of activities to remove these gases from the atmosphere. It recognizes that a portfolio of adaptation and mitigation actions is required to reduce the risks of climate change. It also has broadened the assessment to include the relationship between sustainable development and climate change mitigation.

The Table of Content of the IPCC WG3 Report is given in *Figure 2.6*.

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3. Observations: Atmospheric Surface and Climate Change
4. Observations: Changes in Snow, Ice and Frozen Ground
5. Observations: Ocean Climate Change and Sea Level
6. Palaeoclimate
7. Coupling Between Changes in the Climate System and Biogeochemistry
8. Climate Models and their Evaluation
9. Understanding and Attributing Climate Change
10. Global Climate Projections
11. Regional Climate Projections

Errata
Annex I: Glossary

Figure 2.4. Table of Content of IPCC WG1 Report on "Climate Change 2007 — The Physical Science Basis".

Contents

Foreword, Preface, and Introduction
Summary for Policymakers
Technical Summary

1. Assessment of observed changes and responses in natural and managed systems
2. New assessment methods and the characterisation of future conditions
3. Freshwater resources and their management
4. Ecosystem, their properties, goods and services
5. Food, fibre and forest products
6. Coastal systems and low-lying areas
7. Industry, settlement and society
8. Human health
9. Africa
10. Asia
11. Australia and New Zealand
12. Europe
13. Latin America
14. North America
15. Polar Regions (Arctic and Antarctic)
16. Small islands
17. Assessment of adaptation practices, options, constraints and capacity
18. Inter-relationships between adaptation and mitigation
19. Assessing key vulnerabilities and the risk from climate change
20. Perspectives on climate change and sustainability

Figure 2.5. Table of Content of IPCC WG2 Report on "Climate Change 2007 — Impacts, Adaptation and Vulnerability".

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8. Agriculture
9. Forestry
10. Waste management
11. Mitigation from a cross-sectoral perspective
12. Sustainable Development and mitigation
13. Policies, instruments, and co-operative arrangements

Errata
Annex I: Glossary

Figure 2.6. Table of Content of IPCC WG3 Report on "Climate Change 2007 — Mitigation of Climate Change".

2.1.2 *IPCC Technical Paper VI on Climate Change on Water (2008)*

2.1.2.1 Overview of the Technical Paper

The materials on water and climate change is scattered throughout the IPCC's Fourth Assessment and Synthesis Reports. It is useful to have in a compact and integrated publication all relevant information focused on water and climate change. Thus, the idea for this special IPCC publication dedicated to water and climate change was highlighted in the 19th IPCC Session held in Geneva in April 2002, when the Secretariat of the World Climate Programme — Water and the International Steering Committee of the Dialogue on Water and Climate requested that the IPCC prepares a Special Report on Water and Climate.

Thus, this *IPCC Technical Paper on Climate Change and Water (2008)* gives the distillation, prioritisation, synthesis and interpretation of all the materials on water and climate change that are scattered throughout the IPCC's Fourth Assessment and Synthesis Reports. It addresses the issue of freshwater only. Sea-level rise is dealt with in the Technical Paper only insofar as it can lead to impacts on freshwater in coastal areas and beyond.

The scope of the Technical Paper is to evaluate the impacts of climate change on hydrological processes and regimes, and on freshwater resources – their availability, quality, uses and management. It takes into account current and projected regional key vulnerabilities and prospects for adaptation. The objectives of this Technical Paper are summarized below:

(a) To improve our understanding of the links between both natural and anthropogenically induced climate change, its impacts, and adaptation and mitigation response options, on the one hand, and water-related issues, on the other; and

(b) To inform policymakers and stakeholders about the implications of climate change and climate change response options for water resources, as well as the implications for water resources of various climate change scenarios and climate change response options, including associated synergies and trade-offs.

This Technical Paper is addressed primarily to policymakers engaged in all areas relevant to freshwater resource management, climate change, strategic studies, spatial planning and socio-economic development. However, it is also addressed to the scientific community working in the area of water and climate change, and to a broader audience, including NGOs and the media.

The following is an outline of the contents in this Technical Paper, which is made up of eight sections:

- Section 1 gives the introduction to the paper.
- Section 2 is based primarily on the assessments of Working Group 1, and looks at the science of climate change, both observed and projected, as it relates to hydrological variables.
- Section 3 presents a general overview of observed and projected water-related impacts of climate change, and possible adaptation strategies, drawn principally from the Working Group 2 assessments.
- Section 4 then looks at systems and sectors in detail.
- Section 5 takes a regional approach.
- Section 6, is based on Working Group 3 assessments, and covers water related aspects of mitigation.
- Section 7 looks at the implications for policy and sustainable development
- Section 8 highlights the gaps in knowledge and gives suggestions for future work.

2.1.2.2 Executive Summary of the Technical Paper

The following are the 15 key points highlighted in the Executive Summary of this paper:

1. **Observed warming over several decades has been linked to changes in the large-scale hydrological cycle** such as: increasing atmospheric water vapour content; changing precipitation patterns, intensity and extremes; reduced snow

cover and widespread melting of ice; and changes in soil moisture and runoff. Precipitation changes show substantial spatial and inter-decadal variability. Over the 20th century, precipitation has mostly increased over land in high northern latitudes, while decreases have dominated from 10°S to 30°N since the 1970s. The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) has increased over most areas (likely [See Box 1.1]). Globally, the area of land classified as very dry has more than doubled since the 1970s (likely). There have been significant decreases in water storage in mountain glaciers and Northern Hemisphere snow cover. Shifts in the amplitude and timing of runoff in glacier- and snowmelt-fed rivers, and in ice-related phenomena in rivers and lakes, have been observed (high confidence).

2. **Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes (very likely)** and parts of the tropics, and decreases in some subtropical and lower mid-latitude regions (likely). Outside these areas, the sign and magnitude of projected changes varies between models, leading to substantial uncertainty in precipitation projections.[Projections considered are based on the range of non-mitigation scenarios developed by the IPCC Special Report on Emissions Scenarios (SRES).] Thus projections of future precipitation changes are more robust for some regions than for others. Projections become less consistent between models as spatial scales decrease.

3. **By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change** [This statement excludes changes in non-climatic factors, such as irrigation.] **at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics**. [These projections are based on an ensemble of climate models using the mid-range SRES A1B non-mitigation emissions scenario. Consideration of the range of climate responses across SRES scenarios in the mid-21st century suggests that this conclusion is applicable across a wider range of scenarios.] Many semi-arid and arid areas (e.g. the Mediterranean Basin, western USA, southern Africa and northeastern Brazil) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change (high confidence).

4. **Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas**. The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) will be very likely to increase over most areas during the 21st century, with consequences for the risk of rain-generated floods. At the same time, the proportion of land surface in extreme drought at any one time is projected to increase (likely), in addition to a tendency for drying in continental interiors during summer, especially in the sub-tropics, low and mid-latitudes.

5. **Water supplies stored in glaciers and snow cover are projected to decline in the course of the century**, thus reducing water availability during warm and dry periods (through a seasonal shift in streamflow, an increase in the ratio of winter to annual flows, and reductions in low flows) in regions supplied by melt water from major mountain ranges, where more than one-sixth of the world's population currently live (high confidence).

6. **Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution** – from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution, with possible negative impacts on ecosystems, human health, and water system reliability and operating costs (high confidence). In addition, sea-level rise is projected to extend areas of salinisation of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas.

7. **Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits (high confidence)**. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress. Areas in which runoff is projected to decline face a clear reduction in the value of the services provided by water resources. Increased annual runoff in some areas is projected to lead to increased total water supply. However, in many regions, this benefit is likely to be counterbalanced by the negative effects of increased precipitation variability and seasonal runoff shifts in water supply, water quality and flood risks (high confidence).

8. **Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilisation**. This is expected to lead to decreased food security and increased vulnerability of poor rural farmers, especially in the arid and semi-arid tropics and Asian and African megadeltas.

9. **Climate change affects the function and operation of existing water infrastructure – including hydropower, structural flood defences, drainage and irrigation systems – as well as water management practices**. Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation (very high confidence). Globally, water demand will grow in the coming decades, primarily due to population growth and increasing affluence; regionally, large changes in irrigation water demand as a result of climate change are expected (high confidence).

10. **Current water management practices may not be robust enough to cope with the impacts of climate change** on water supply reliability, flood risk, health,

agriculture, energy and aquatic ecosystems. In many locations, water management cannot satisfactorily cope even with current climate variability, so that large flood and drought damages occur. As a first step, improved incorporation of information about current climate variability into water-related management would assist adaptation to longer-term climate change impacts. Climatic and non-climatic factors, such as growth of population and damage potential, would exacerbate problems in the future (very high confidence).

11. **Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions**. The consequences of climate change may alter the reliability of current water management systems and water-related infrastructure. While quantitative projections of changes in precipitation, river flows and water levels at the river-basin scale are uncertain, it is very likely that hydrological characteristics will change in the future. Adaptation procedures and risk management practices that incorporate projected hydrological changes with related uncertainties are being developed in some countries and regions.

12. **Adaptation options designed to ensure water supply during average and drought conditions require integrated demand-side as well as supply-side strategies**. The former improve water-use efficiency, e.g. by recycling water. An expanded use of economic incentives, including metering and pricing, to encourage water conservation and development of water markets and implementation of virtual water trade, holds considerable promise for water savings and the reallocation of water to highly valued uses. Supply-side strategies generally involve increases in storage capacity, abstraction from water courses, and water transfers. Integrated water resources management provides an important framework to achieve adaptation measures across socio-economic, environmental and administrative systems. To be effective, integrated approaches must occur at the appropriate scales.

13. **Mitigation measures can reduce the magnitude of impacts of global warming on water resources, in turn reducing adaptation needs.** However, they can have considerable negative side effects, such as increased water requirements for afforestation/reforestation activities or bio-energy crops, if projects are not sustainably located, designed and managed. On the other hand, water management policy measures, e.g. hydrodams, can influence greenhouse gas emissions. Hydrodams are a source of renewable energy. Nevertheless, they produce greenhouse gas emissions themselves. The magnitude of these emissions depends on specific circumstance and mode of operation.

14. **Water resources management clearly impacts on many other policy areas**, e.g. energy, health, food security and nature conservation. Thus, the appraisal of adaptation and mitigation options needs to be conducted across multiple water-

dependent sectors. Low-income countries and regions are likely to remain vulnerable over the medium term, with fewer options than high income countries for adapting to climate change. Therefore, adaptation strategies should be designed in the context of development, environment and health policies.

15. **Several gaps in knowledge exist in terms of observations and research needs related to climate change and water**. Observational data and data access are prerequisites for adaptive management, yet many observational networks are shrinking. There is a need to improve understanding and modelling of climate changes related to the hydrological cycle at scales relevant to decision making. Information about the water related impacts of climate change is inadequate – especially with respect to water quality, aquatic ecosystems and groundwater – including their socio-economic dimensions. Finally, current tools to facilitate integrated appraisals of adaptation and mitigation options across multiple water-dependent sectors are inadequate.

2.1.3 *The Stern Review: Economics of Climate Change (2006)*

The Stern Review which came out in 2007 provides an economic perspective to the issue of climate change. Whilst the main thrust of this six part review which are set out below is to argue for strong early mitigation action, Part 2 (*The Impacts of Climate Change on Growth and Development*) and Part 5 (*Policy Responses for Adaptation*) have direct relevance to adaptation. Part 1, Chapter 1 concerns the Science of Climate Change which is based mainly on the findings of the *IPCC Third Assessment Report* and updates since then till the time the report was prepared.

The six parts of the Stern Review are:

- Part 1: Climate Change: Our approach
- Part 2: The impacts of climate change on growth and development
- Part 3: The economics of stabilisation
- Part 4: Policy responses for mitigation
- Part 5: Policy responses for adaptation; and
- Part 6: International collective action.

The sections on mitigation have indirect relevance as they are expected to shows results only in the long term through a reduction in the need to adapt in the future. For the purposes of this study, only the chapters directly relevant to adaptation are highlighted. The mitigation aspect is implicitly considered in the emissions scenario used in making future climate projections.

Overall, the analysis incorporates extreme weather events and impacts of threshold temperatures reaching 5–6% increases and assesses the impacts both from the market perspective as well as non- market factors. This approach was to provide a more comprehensive picture of the cost of impacts without any policy intervention, which was then compared to the cost of undertaking mitigation action.

The following summarises the information in the two parts of the Stern Review.

Part 2 is summarised in the following four chapters.

Chapter 3: How climate change will affect people around the world

This chapter explores how climate change will affect people around the world, including the potential implications for access to food, water stress, health and well being, and the environment. In the key messages (*Stern Part 2 Chap 3 pg 56*), warming inducing sudden shifts in regional monsoon weather patterns like the monsoons or the El Nino has been identified as having severe consequences for water availability and flooding in tropical regions. The chapter also assesses potential impacts for a range of temperature rise between 1–5 degrees celsius, assuming the IPCC population and GDP scenario for 2080 and adaptation at the individual or firm level but not economy wide scale with policy intervention (*Stern Part 2 Chap 3 pg 57*). The possible impact of an abrupt shift in the reliability of the Asian monsoon has been highlighted (*Stern Part 2 Chap 3, Box 3.5, pg 83*). The chapter also predicts that future average rainfall patterns will look more like an El Nino.

Chapter 4: Implications of climate change for development

This chapter considers the implications of climate change for developing countries. It explains why developing countries are so vulnerable to climate change — a volatile mix of geographic location, existing vulnerability and, linked to this, limited ability to deal with the pressures that climate change will create. It highlights the impact of climate change on economic growth prospects and implications for incomes and health and the fact that extreme weather events can and do affect growth rates in developing countries.

Chapter 5: Costs of climate change in developed countries

This chapter focuses on the implications for developed countries. Some regions will benefit from temperature rises of up to 1 to 2°C, but the balance of impacts will become increasingly negative as temperature rises.

Chapter 6: Economic modelling of climate change impacts

This chapter pulls together the existing modelling work that has been done to estimate the monetary costs of climate change, and also sets out the details of modelling work undertaken by the Review. The PAGE 2002 Integrated Assessment Model (IAM) was used. The range of loss is estimated to be between 5% (market loss only) to 20% (including non-market impacts, distributional impacts and dynamic feedback) of global per capita current consumption, now and forever.

Part V is summarised in the following three chapters.

<u>Chapter 18: Understanding the economics of adaptation</u>
This chapter provides an outline of key adaptation concepts and sets out an economic framework for adaptation. Box 18.1 describes adjustments that can be made to the parameters contributing to economic outputs in the short and long term. These parameters are identified as capital, variables and the environment. Box 18.2 provides a framework to assess adaptation cost and benefit using risk rankings. The risk rankings implicitly include uncertainties associated with future climate projections.

<u>Chapter 19: Adaptation in the developed world</u>
This chapter outlines the barriers and constraints to adaptation and recommendations on how the developed world can respond to this by providing information and a strong policy framework for individuals to respond to market signals.

<u>Chapter 20: The role of adaptation in sustainable development</u>
This chapter discusses how developing countries can adapt to climate change and highlights the lack of infrastructure, finances and access to public services as key constraints. The idea of investing in global public goods especially by the developed world is identified as one of the keys solutions.

2.1.4 *The Economics of Climate Change in South East Asia: A Regional Review (2009)*

The above "ADB SEA Review" is modelled after the Stern Review for South East Asia with the Asian Development Bank being the main co-ordinator of the study. This four part review stipulates its aims as follows:

- Contribute to the regional debate on economic costs and benefits of unilateral and regional actions on mitigation of, and adaptation to, climate change;
- Raise awareness among stakeholders (for example, government, civil society, academia, media, nongovernment organizations, private sector, and aid agencies) on the urgency of climate change challenges and their potential socioeconomic impact on the study countries; and
- Indirectly support government and private sector actions within the region that incorporate adaptation and mitigation into national development planning processes.

The four parts of the Review are:

- Part 1: Introduction
- Part 2: Climate Change, Its Impacts and Adaptation
- Part 3: Climate Change Mitigation; and
- Part 4: Policy Responses.

The study covers three main areas that serve as the basis for formulating climate change policies for Southeast Asia: impact assessment, adaptation analysis, and mitigation analysis. Impact assessment looks at how Southeast Asian countries have been and will be affected by climate change individually and collectively. Adaptation analysis then takes up the question of how they could individually and collectively best adapt to climate change and what adaptation options or strategies are needed to be incorporated into national sustainable development planning. The mitigation analysis assesses potential mitigation options and how the region can contribute to global GHG mitigation efforts.

The following provides highlights from the most relevant chapters from this Review. For the purposes of this Study, the Review will provide useful examples from countries around the region with which comparisons has been made. Furthermore, the climate projections for the region that are available in the Review has been compared to the ones available domestically to have better confidence in the domestic projections.

<u>Chapter 3: Climate Change and its Impacts: A review of Existing Studies</u>
This chapter notes that SEA's average temperature has increased at the rate of 0.1–0.3 per decade and sea level has risen 1–3 mm each year over the last 50 years. The region also experienced a downward trend in precipitation from 1960–2000. Extreme weather events in Southeast Asia have increased in the past several decades.

Five South East Asian countries, Thailand, the Philippines, Indonesia, Vietnam and Singapore were initially involved in the study. Information on the observed impacts of climate change was drawn from the five countries. For example, "Singapore faces extreme weather events such as high air temperatures and heavy rainfall, usually from November to January of each year when strong winds from the northeast and heavy cloud cover prevails. In Thailand, extreme events include prolonged flood and drought, landslides, and strong storm surges. These extreme events have become more frequent and more damaging. Storms have become more intense but so far not more frequent". It also notes that "sea levels have also risen in Southeast Asia in the last few decades, between 1 and 3 mm per year on average, marginally higher than the global average".

The Study highlights the following:

- Water stress has increased in Southeast Asia, particularly during El Niño years, causing damage to crops, shortages of drinking water, and a drop in electricity production.
- La Niña (associated with heavy rains) and tropical cyclones have caused massive flooding in major rivers in Southeast Asia; the events have become more frequent and have caused extensive loss in livelihoods, human life, and property.
- Projected maximum and minimum monthly flows in major river basins in Southeast Asia suggest increased flooding risk during the wet season and increased water shortages during the dry season by 2100.

- Areas under severe water stress are projected to increase in Southeast Asia, affecting millions, challenging the region's attainment of sustainable growth; and
- Heavy rains and tropical cyclones have caused massive landslides in already degraded forest areas, damaging livelihoods and taking lives.

Chapter 4: Modelling Climate Change and its Impacts
The A1F1 and B2 scenarios of the *IPCC Special Report on Emissions Scenario 2000 (SRES)* were used for three cases: the Business As Usual (BAU) or baseline case; stabilization at 550 ppm; and stabilization at 450 ppm. Furthermore, the Review considers human induced climate change and its consequences within three timelines: The Short Term (2020), Medium Term (2050) and Long Term (2100).

With regards to impacts on Water Resources, the Review makes the following finding: "Climate change is likely to worsen water stress in parts of the region, particularly Thailand and Viet Nam, in the coming decades; water resources in Indonesia, Thailand and Viet Nam are projected to be vulnerable.

Chapter 5: Modelling the Economy wide Impact of CC
The ADB SEA Review applies the same economic model as the Stern Review, the PAGE2002 IAM. The key finding is that "SEA is more vulnerable to climate change than the world as a whole". This modeling exercise does not include Singapore.

Chapter 6: CC Adaptation Options and Practices
This chapter highlights the initiatives that have been undertaken in the five countries covered by the Review. For water resources, the ADB SEA Review notes that "the priority is to scale up the existing good practices of water conservation and management, and apply more widely integrated water management, including flood control and prevention schemes, flood early warning systems, irrigation improvement, and demand-side management."

In general, the Review makes the following observations:

- The future climate poses challenges outside historical experience. Improving adaptive capacity must be an urgent priority for Southeast Asia.
- Adaptation decisions should be based on a sound economic foundation. Although uncertainty may make it difficult to fine-tune adaptation, there exist "win-win" measures that address climate change and are also good sustainable development practices.
- Government has a vital role to play in providing incentives and a policy framework for individuals and firms to adapt effectively to climate change and enhance their adaptive capacity; and
- Strengthening efforts requires mainstreaming climate change adaptation into development planning. This means that adaptation must be considered not only as a technical solution focused on natural systems, but more importantly, as an integral part of sustainable development and poverty reduction strategies.

With regard to water resources, examples of actions undertaken around the region in the countries under consideration were provided. They include the Bangkok Metropolitan Administration's initiative of established pumping stations in strategic areas of the city to regulate water in canals and rivers that tend to overflow during the rainy season and use of NEWater in Singapore.

2.1.5 *APWF Framework Document on Water and Climate Change Adaptation (Draft Nov. 2010)*

The Asia Pacific Water Forum (APWF) Steering Group on Water and Climate Change has produced a draft document (Nov. 2010) for leaders and policy-makers in the Asia-Pacific region to provide guidance to them on how to manage the water-related risks associated with climate change. The document builds upon the existing documents addressing the global challenges of climate change and development, including the Nairobi Guiding Principles. The document recommends a framework within which the priorities for action within Asia and the Pacific can be identified and implemented in a manner that acknowledges the region's uniqueness and diversity. The document also highlights that action is vital, as there is a high cost to inaction in the face of climate change.

The guidance takes the form of a set of five general principles that collectively address the challenges of climate change adaptation, as illustrated in *Figure 2.7* below. It provides the foundation for effective adaptation and mitigation efforts in the water sector. The five principles are summarized below together with the recommended actions to put them into practice.

Principle 1 — Usable knowledge

"We must support scientists and practitioners to work together and develop knowledge that leads to effective actions and increased public awareness."

There is still a "disconnect" between the knowledge generated by the scientific community and the specific needs of practitioners such as water managers in river basins and cities. There is a need to bridge this gap, to re-examine the basic planning methodology, and to reduce the gestation period from scientific finding to practical implementation. There is a specific need to customize projections of climate change to local conditions, particularly in developing countries. A more effective dialogue is required between scientists and communities of practitioners, both to improve the dissemination of scientific information as well as to learn from the experiences, knowledge and the needs of user communities.

Although there is strong evidence that climate change is occurring, there is still a gap between the generation of global projections and their effective use in adaptation strategies. The AR4 has clearly documented qualitative changes in extreme hydroclimatic events at global scale, but not quantitative changes at regional and river-basin scales. Due to the large uncertainty which is inherent in model projections of future climate and regional and local hydrology, projection results cannot be used directly for infrastructure design adaptation.

The recommended actions to put the above principle into practice are:

1. Develop data infrastructure and networking for sharing data, information and knowledge to support decision-making and to raise public awareness; and

2. Accelerate scientific efforts to improve the use of climate projections for countries, river basins and cities as well as to quantify and reduce the related uncertainty.

Principle 2 — No-regret investments

"We must identify and implement approaches that improve water security over a wide range of potential conditions, including current climate variability."

Risk management, involving communities and various organizations, should be adopted as the main adaptation policy. How to assess risk under uncertain future conditions is currently an unresolved issue, and practical methods should be developed based on projections of extreme events. While infrastructure is a vital element of adaptation measures, infrastructure

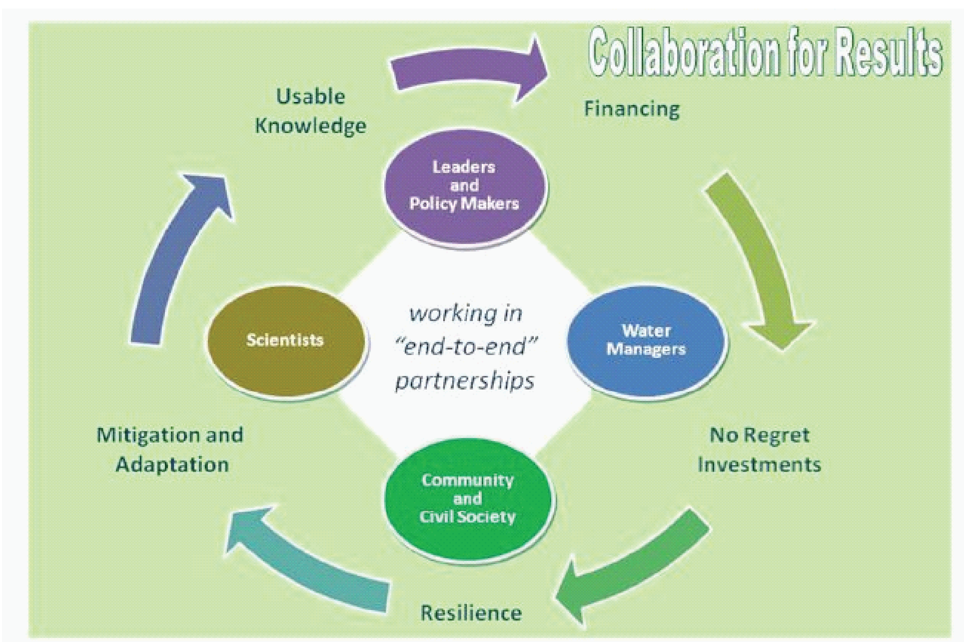


Figure 2.7. Working with the 5 principles in end-to-end partnerships is necessary.

planning methods must be fundamentally revised. As design of structural measures relies heavily on analysis of historical conditions (e.g. flood frequency analysis), climate change and uncertainty can undermine the performance of physical infrastructure, and high capital investment requirements create the risk of misallocation of capital if or when actual conditions fail to coincide with projections. Deciding on no-regret investments now, in sync with applying the other 4 principles, will ensure that socio-economic benefits will keep accruing over time as adaptation takes hold as illustrated in *Figure 2.8* below.

The recommended actions to put the above principle into practice are:

1. Plan for incremental adaptation actions in tandem with improving climate projections.
2. Use an appropriate mix of structural and non-structural measures.

<u>Principle 3 — Resilience</u>
"We must build societies' capacity to develop communities' resilience in the face of a changing climate."

While scientists continue their research, develop more accurate climate projections, and increase their understanding of the extent and consequences of climate challenges, rigorous policies, embodying sound strategies and pragmatic actions need to be devised

Figure 2.8. No-regret investments now will ensure socio-economic benefits later on.

to strengthen the resilience of these most vulnerable people. Resources must be made available to implement such activities at the local level, to support mutually agreed-upon policies.

These policies, accompanying strategies and action plans need to be well articulated and shared with all stakeholders. What are they? Are there examples of effective measures that have already been implemented and can be shared across the region, reducing the time required to devise and pilot new action plans at local levels? How can newly available knowledge be made accessible rapidly?

The recommended actions to put the above principle into practice are:

1. Strengthen the adaptation capacities of water managers, communities, and of society as a whole; and
2. Improve community-based water risk management capacities.

Principle 4 – Mitigation and adaptation
"We must adopt optimal combinations of measures."

(a) **Mitigation and adaptation must go hand-in-hand**
Given the uncertainties of climate change, a diverse set of measures, encompassing both mitigation and adaptation, is needed to deal effectively with it. As the set of climatic, hydrologic, social, cultural, economic and political circumstances varies across regions, these measures will also need to be customized to the local conditions.

(b) **Adaptation must be addressed in a broad development context**
Adaptation, in particular, must be addressed in a broad development context, recognizing climate change as an added challenge to reducing poverty, hunger, disease and environmental degradation. Hence, adaptation should not be seen as something "new and separate"; it must be considered an integral part of sustainable development. Synergies between climate change adaptation and the achievement of the Millennium Development Goals must be identified, and adaptation measures must be effectively integrated into the national economy and development and sector plans.

(c) **Integrated Water Resources Management is a suitable approach to adaptation**
Climate change, and increased climate variability, impact primarily through water and biological processes with implications for land use, including the coastal zone. Recognizing the fundamental importance of land and water linkages for livelihoods, food security, shelter, ecosystem services and economic growth, efficient and coordinated management of land and water resources is essential for building resilience to the impacts of climate change.

The importance of the IWRM approach to adaptation was recognized by the IPCC in the 3rd Assessment, where it is stated that ”it can be expected that the paradigm of Integrated Water Resources Management will be increasingly followed around the world... which will move water, as a resource and a habitat, into the centre of policy making. This is likely to decrease the vulnerability of freshwater systems to climate change.”

Managing water in an increasingly uncertain world, due to climate and other drivers of change, calls for risk management approaches. IWRM concepts, approaches and guidelines need to be further developed to address risks at all levels, from the community through the basin and national to the regional levels.

The recommended actions to put the above principle into practice are:

1. Promote Integrated Water Resources Management (IWRM) in river basins as the appropriate process for planning and investments; and
2. Promote synergies in the planning and implementation of adaptation and mitigation measures.

Principle 5 — Financing

“We must increase dedicated climate financing substantially.”

Estimates of adaptation funding needs cover an order of magnitude, and must be viewed as uncertain at best. In addition, the politics of adaptation finance are often contentious: developing countries argue that since they have contributed little to the emissions responsible for anthropogenic warming, they should not have to bear the costs of adaptation. They expect developed countries to provide grant financing as a matter of climate justice. On the donor side, it is not always clear if contributions to climate investment funds represent “new” resources, or if they are simply a re-labelling of previously committed development assistance. There are also relatively few good estimates of the specific needs and/or impacts by sector and by region.

There is also a mismatch in scales between the global and regional estimates cited above, and the more detailed, targeted estimates that will be required to guide national and local adaptation investment planning and policy-making. Our capacity to provide economic assessment of specific adaptation options is also currently constrained by deep uncertainty around the future conditions under which investments will be expected to perform. Uncertainty is not limited to climate and water systems, but extends, for example, to availability and prices of other key resources (including energy); and range of technology choices.

Currently, climate adaptation finance embodies a “top-down”, perspective emphasizing internationally negotiated agreements, protocols and funding vehicles. By contrast, “adaptation is local,” and effective strategies for adaptation finance cannot be formulated without the explicit input and participation of the communities most likely to be affected adversely by climate change. The right balance must be struck between centralised and decentralised solutions.

The recommended actions to put the above principle into practice are:

1. Conduct economic impact assessments for various adaptation options.
2. Mobilize significant investments today (e.g. 1% of GDP) to prevent greater damages later (e.g. 5%) as advised by the Stern report.

2.2 Review of Key National Documents

2.2.1 *The National Policy on Climate Change (2009)*

The National Policy on Climate Change (2009) is based on 5 principles and 10 strategic thrusts. A total of 43 key actions have been identified to achieve the goals of the 10 strategic thrusts in the Policy.

The objectives of the National Policy on Climate Change are:

(a) Mainstreaming climate change through wise management of resources and enhanced environmental conservation resulting in strengthened economic competitiveness and improved quality of life;

(b) Integration of responses into national policies, plans and programmes to strengthen the resilience of development from arising and potential impacts of climate change; and

(c) Strengthening of institutional and implementation capacity to better harness opportunities to reduce negative impacts of climate change.

The 5 Principles of the Policy are:

- **P1: Development on a Sustainable Path**
  Integrate climate change responses into national development plans to fulfil the country's aspiration for sustainable development.

- **P2: Conservation of Environment and Natural Resources**
  Strengthen implementation of climate change actions that contribute to environmental conservation and sustainable use of natural resources.

- **P3: Co-ordinated Implementation**
  Incorporate climate change considerations into implementation of development programmes at all levels.

- **P4: Effective Participation**
  Improve participation of stakeholders and major groups for effective implementation of climate change responses; and

- **P5: Common but Differentiated Responsibilities and Respective Capabilities**
  International involvement on climate change will be based on the principle of common but differentiated responsibilities and respective capabilities.

The 10 Strategic Thrusts of the Policy are:

- **ST1-P1**: Facilitate the harmonisation of existing policies to address climate change adaptation and mitigation in a balanced manner.

- **ST2-P1**: Institute measures to make development climate-resilient through low carbon economy to enhance global competitiveness and attain environmentally sustainable socio-economic growth.

- **ST3-P1**: Support climate-resilient development and investment including industrial development in pursuit of sustainable socio-economic growth.

- **ST4-P2**: Adopt balanced adaptation and mitigation measures to strengthen environmental conservation and promote sustainability of natural resources.

- **ST5-P2**: Consolidate the energy policy incorporating management practices that enhances renewable energy (RE) and energy efficiency (EE).

- **ST6-P3**: Institutionalise measures to integrate crosscutting issues in policies, plans, programmes and projects in order to increase resilience to climate change.

- **ST7-P3**: Support knowledge-based decision making through intensive climate related research and development and capacity building of human resources.

- **ST8-P4**: Improve collaboration through efficient communication and coordination among all stakeholders for effective implementation of climate change responses.

- **ST9-P4**: Increase awareness and community participation to promote behavioural responses to climate change; and

- **ST10-P5**: Strengthen involvement in international programmes on climate change based on the principle of common but differentiated responsibilities and respective capabilities.

2.2.2 *The National Policy on the Environment (2002)*

The National Policy on the Environment Policy (2002) is based on 8 principles and 7 strategic thrusts.

The objectives of the National Policy on the Environment are to achieve:

(a) A clean, safe, healthy and productive environment for the present and future generations.
(b) Conservation of the country's unique and diverse cultural and natural heritage with effective participation by all sectors of society; and
(c) Sustainable lifestyles and patterns of consumptions and production.

2.2.3 *The National Policy on Biological Diversity (1998)*

The National Policy on the Environment Policy (2002) is based on 11 principles and 15 strategic thrusts.

The objectives of the National Policy on Biological Diversity are:

(a) To optimise economic benefits from sustainable utilisation of the components of biological diversity;
(b) To ensure long-term food security for the nation;
(c) To maintain and improve environmental stability for proper functioning of ecological systems;
(d) To ensure preservation of the unique biological heritage of the nation for the benefit of present and future generations;
(e) To enhance scientific and technological knowledge, and educational, social, cultural and aesthetic values of biological diversity; and
(f) To emphasize biosafety considerations in the development and application of biotechnology;

The 11 Principles of the Policy are:

1. The conservation ethic, including the inherent right to existence of all living forms, is deeply rooted in the religious and cultural values of all Malaysians;
2. Biological diversity is a national heritage and it must be sustainably managed and wisely utilized today and conserved for future generations;
3. Biological resources are natural capital and their conservation is an investment that will yield benefits locally, nationally and globally for the present and future;
4. The benefits from sustainable management of biological diversity will accrue, directly or indirectly, to every sector of society;
5. The sustainable management of biological diversity is the responsibility of all sectors of society;

6. It is the duty of Government to formulate and implement the policy framework for sustainable management and utilisation of biological diversity in close cooperation with scientists, the business community and the public;
7. The role of local communities in the conservation, management and utilisation of biological diversity must be recognized and their rightful share of benefits should be ensured;
8. Issues in biological diversity transcend national boundaries and Malaysia must continue to exercise a proactive and constructive role in international activities;
9. The interdependence of nations on biological diversity and in the utilisation of its components for the well-being of mankind is recognized. International cooperation and collaboration is vital for fair and equitable sharing of biological resources, as well as access to and transfer of relevant technology;
10. Public awareness and education is essential for ensuring the conservation of biological diversity and the sustainable utilisation of its components; and
11. In the utilisation of biological diversity, including the development of biotechnology, the principles and practice of biosafety should be adhered to.

The 15 Strategic Thrusts of the Policy are:

- **ST1** — Improve the Scientific Knowledge Base
  Survey and document the biological diversity in Malaysia, and undertake studies to assess its direct and indirect values, and identify the potential threats to biological diversity loss, and how they may be countered.

- **ST2** — Enhance Sustainable Utilisation of the Components of Biological Diversity
  Identify and encourage the optimum use of the components of biological diversity, ensuring fair distribution of benefits to the nation and to local communities.

- **ST3** — Develop A Centre Of Excellence In Industrial Research In Tropical Biological Diversity
  Establish Malaysia as a centre of excellence in industrial research in tropical biological diversity.

- **ST4** — Strengthen The Institutional Framework For Biological Diversity Management
  Establish and reinforce the mechanisms for planning, administration and management of biological diversity.

- **ST5** — Strengthen And Integrate Conservation Programmes
  Increase efforts to strengthen and integrate conservation programmes.

- **ST6** — Integrate Biological Diversity Considerations Into Sectoral Planning Strategies

Ensure that all major sectoral planning and development activities incorporate considerations of biological diversity management.

- **ST7** — Enhance Skill, Capabilities And Competence
  Produce a pool of trained, informed and committed manpower in the field of biological diversity.

- **ST8** — Encourage Private Sector Participation
  Promote private sector participation in biological diversity conservation, exploration and sustainable utilisation.

- **ST9** — Review Legislation To Reflect Biological Diversity Needs
  Review and update existing legislation to reflect biological diversity needs and introduce new legislation where appropriate.

- **ST10** — Minimise Impacts Of Human Activities On Biological Diversity
  Take mitigating measures to reduce the adverse effects of human activities on biological diversity.

- **ST11** — Develop Policies, Regulations, Laws And Capacity Building On Biosafety
  Introduce measures for the incorporation of biosafety principles and concerns, especially in relation to genetic engineering, and the importation, creation and release of genetically modified organisms.

- **ST12** — Enhance Institutional And Public Awareness
  Promote and encourage the understanding and participation of the public and institutions for the effective conservation and protection of biological diversity.

- **ST13** — Promote International Cooperation And Collaboration
  Promote international cooperation and collaboration in order to enhance national efforts in biological diversity conservation and management.

- **ST14** — Exchange Of Information
  Promote and encourage the exchange of information on biological diversity at local and international levels; and

- **ST15** — Establish Funding Mechanisms
  Identify and establish appropriate funding mechanisms for biological diversity conservation and management.

2.2.4 *The Third National Agricultural Policy (1998 – 2010)*

The Third National Agricultural Policy (1998 – 2010) is based on 5 principles and 9 strategic thrusts. A total of 41 key actions have been identified to achieve the goals of the 9 strategic thrusts in the Policy.

The objectives of the Third National Agricultural Policy (NAP3) are:

(a) The maximisation of income through the optimal utilisation of resources in the sector. This includes maximising agriculture's contribution to national income and export earnings as well as maximising income of producers.

(b) Specifically, the objectives of the Policy are :

- (i) To enhance food security;
- (ii) To increase productivity and competitiveness of the sector;
- (iii) To deepen linkages with other sectors;
- (iv) To create new sources of growth for the sector; and
- (v) To conserve and utilise natural resources on a sustainablebasis.

The 5 Principles of the Policy are:

1. Meeting national food requirement
2. Enhancing competitiveness and profitability in agriculture and Forestry
3. Enhancing the integrated development of the food and industrial crop sub-sectors
4. Strengthening requisite economic foundation; and
5. Adopting sustainable development

The 9 Strategic Thrusts of the Policy are focused on the development of product groups and are as follows:

1. Food product group
2. Human resource development
3. Technology
4. Infrastructural development
5. Financing and incentives
6. Input Industries
7. Business support services
8. Institutions; and
9. Public-private sector collaborative mechanism

2.2.5 *The National Green Technology Policy (2009) (NGT)*

The National Green Technology Policy was officially launched on 24 July 2009 with the following policy statement:

> *"Green Technology shall be a driver to accelerate the national economy and promote sustainable development"*

The Policy objectives are as follows:

(a) To minimise growth of energy consumption while enhancing economic development;
(b) To facilitate the growth of the Green Technology industry and enhance its contribution to the national economy;
(c) To increase national capability and capacity for innovation in Green Technology development and enhance Malaysia's competitiveness in Green Technology in the global arena;
(d) To ensure sustainable development and conserve the environment for future generations; and
(e) To enhance public education and awareness on Green Technology and encourage its widespread use.

The policy is based on the following four pillars:

(i) Energy — Seek to attain energy independence and promote efficient utilization;
(ii) Environment — Conserve and minimize the impact on the environment;
(iii) Economy — Enhance the national economic development through the use of technology; and
(iv) Social — Improve the quality of life for all.

2.2.6 *The New Economic Model (2010) NEM*

The NEM is one of the four pillars of the National Transformation Programme introduced by the Prime Minister in March 2010 comprising the Economic Transformation Programme (ETP) to achieve Vision 2020. The other three pillars are 1 Malaysia (April 2009), Government Transformation Programme (GTP) (Jan 2010) and the 10th Malaysia Plan (June 2010) as shown in *Figure 2.9* below.

The NEM notes that while the "old growth model provided three decades of outstanding performance", it finds Malaysia is trapped in the "middle income trap" and that we are "not amongst the top performing economies." It states the following:

> *"Our economic growth has come at considerable environmental cost and has not benefited all segments of the population. The government must confront these realities and make tough decisions. We urgently need a radical change in our approach to economic development which will be sustainable over the long-term, will reach everyone in the country and will enable Malaysia to reach high income status. The NEM will be the catalyst to unleash Malaysia's growth potential. The ETP is designed to drive Malaysia forward from its current stagnant situation to be a high income economy which is both inclusive and sustainable."*
> **– [Why do we Need the NEM and What are its Goals?, Executive Summary, NEM, pgs 3–4).**

"The sustainability component of the NEM is meant to ensure that all of the proposed measures defined under the new model must be sustainable in both economic and environmental terms. Malaysia's dependence on natural resource consumption as the primary engine of growth is clearly not sustainable on either dimension. This is not to suggest that exploitation of natural resources should not be a key component of national production. But it does mean that under the new model, investment and policy decisions will only be made after full consideration of their long-term impact on the society, the economy as a whole, and of course the environment."
– [An Economically and Environmentally Enduring Solution, Executive Summary, NEM, pg 11].

The NEM report is set out in 7 chapters that provide a systematic rationale for the NEM and its proposals. The chapters are:

1. Why do we need the NEM and what are its goals?
2. Where are we?
3. What's happening around us?
4. Which advantages do we have?
5. Where do we want to be?
6. How do we get there?
7. The time for change is now — Malaysia deserves no less.

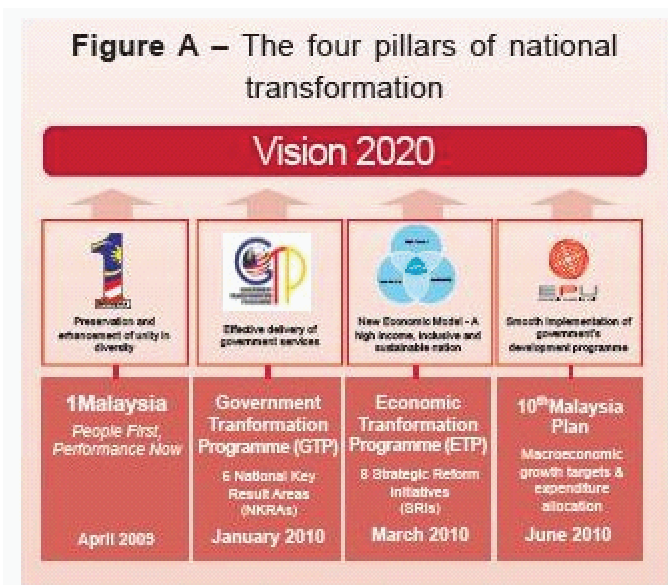


Figure 2.9. The Four Pillars of National Transformation of the New Economic Model (NEM).

In Chapter 3 on What's happening around us?, Section 3.3 entitled "Malaysia should lead the global green revolution" describes the abundance of natural resources we are endowed with giving us a strategic advantage. Although the economic advantage this provides is big, the greater benefit is articulated as follows:

> *"The major benefit of our green, high income, and inclusive strategy is that future generations of Malaysians (and world citizens) will continue to enjoy the clean air and water, and natural environment that they deserve and work so hard to preserve and enhance. Malaysians can feel proud that we are setting the pace in treasuring our heritage and delicate ecology for the mutual benefit of all mankind."* **[Chap 3, NEM, pg 70]**

Chapter 5 entitled "Where do we want to be?" notes that sustainability encompasses both economic and environmental aspects. With regard to environmental sustainability, it notes the following:

> *"Environmental sustainability will be achieved by rejecting the traditional approach to economic growth that has grossly neglected the environment. Although there has been a veneer of concern for the environment, past policies focused on delivering growth first, and dealing with the environment later. In the future, equal emphasis must be placed on both protection of the environment and economic growth. The conventional GDP measurement of economic growth does not take into account the costs to society arising from environmental degradation. The recent development of the 'Green GDP' concept will allow proper consideration of the impact of growth on the environment and the appropriate design of measures to address environmental concerns.*
>
> *The NEM seeks sustainable growth that meets the ongoing needs of the population without compromising future generations by effective stewardship and preservation of the natural environment and non-renewable resources. This new approach will be particularly relevant to the management of water, and oil and gas resources."* **[Chap 5, NEM, pg 93]**

In Chapter 6, How do new get there?, one of the eight cross cutting Strategic Reform Initiatives (SRIs) that the NEM proposes is Ensuring Sustainability of Growth (SRI 8). Within this context, it notes that:

> *"A green economy platform policy for development must be set by the government. In line with the government commitment in Copenhagen to reduce Malaysia's carbon footprint, a comprehensive energy policy is to be introduced. At the same time, greater efforts are needed to put in place pollution mitigation practices, enforce clean air and water standards, as well as maximize the stewardship of our scarce natural resources."* **[Chap 6, NEM, pg 147].**

Figure 2.10 below summarises the goals of the New Economic Model.

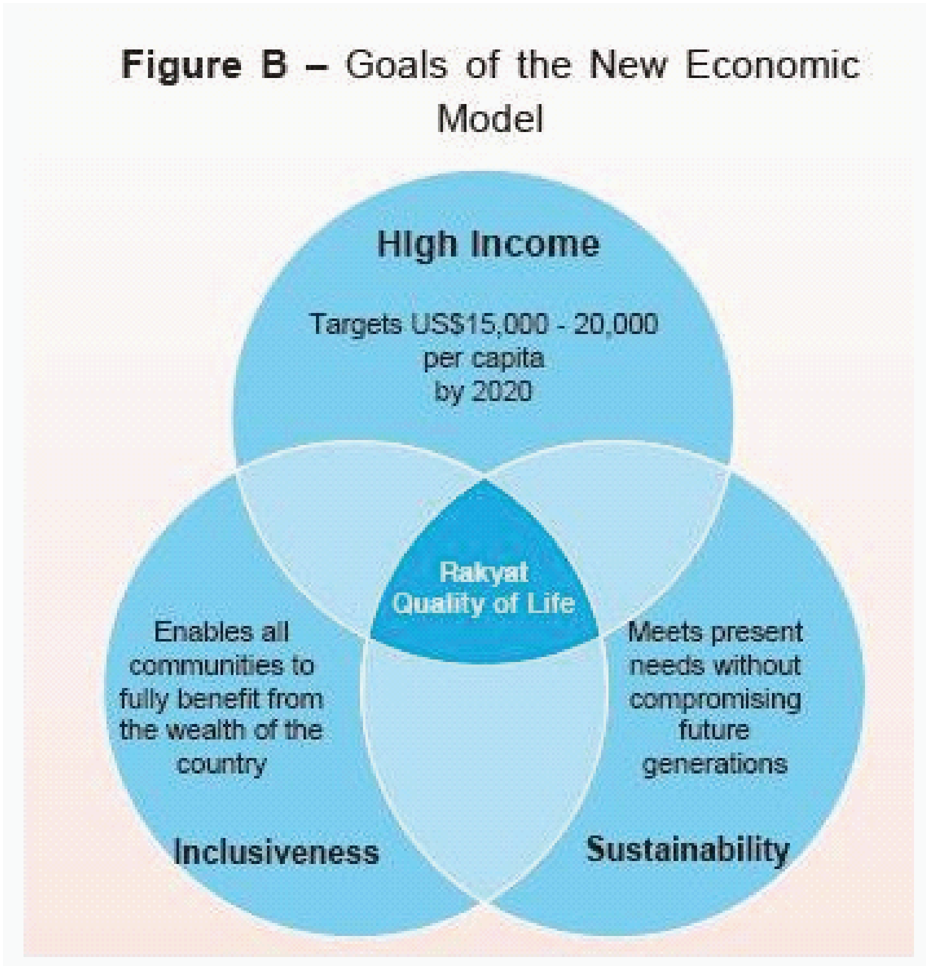


Figure 2.10. The Goals of the New Economic Model (NEM).

2.2.7 *The Tenth Malaysia Plan (2011–2015) (RMK10)*

The Tenth Malaysia Plan (RMK10) is Malaysia's National Development Plan for the period 2011 to 2015. Its focus is on ten big ideas as shown in *Figure 2.11*.

A systematic review of the contents in the RMK10 was carried out and the relevant points that refer to climate change or are relevant to the theme — adaptation to climate change were identified. The titles of the paragraphs and pages in the RMK10 report containing the relevant points are given below:

1. Idea No. 9 - Valuing our Environmental Endowments (page 26)
2. Looking Back: Achievements Under the Ninth Malaysia Plan (page 49)
3. Ensuring Effective Sourcing and Delivery of Energy (page 112)
4. Sarawak Corridor Renewable Energy (page 120)
5. Open Spaces and Green Corridors (page 257)
6. Waterfront Rejuvenation (page 257)
7. Strengthening Efforts to Deliver High Quality and Environmentally Sustainable Housing (page 279)
8. Managing Water Endowment and Supply (page 281)
9. Developing a Long-Term Strategy for Water Resource Management to Achieve Water Security (page 282)
10. Continuing Efforts to Restructure the Water Services Industry (page 283)
11. Protecting Rivers from Pollution (page 285)
12. Increasing and Diversifying Generation Capacity (page 287)
13. Restructuring the Electricity Supply Industry (page 287).

Figure 2.11. The Ten Big Ideas of the Tenth Malaysia Plan (RMK10).

14. Valuing the Nation's Environmental Endowments (page 297)
15. Developing a Climate Resilient Growth Strategy (page 300)
16. Climate Adaptation: Protecting the Nation from the Risks of Climate Change (page 300)
17. Climate Mitigation: Reducing Malaysia's Carbon Footprint (page 301)
18. Creating Stronger Incentives for Investments in Renewable Energy (page 302)
19. Promoting Energy Efficiency to Encourage Productive Use of Energy (page 303)
20. Improving Solid Waste Management (page 303)
21. Conserving Forests (page 305)
22. Reducing Emissions to Improve Air Quality (page 305)
23. Enhancing Forest and Wildlife Conservation Efforts (page 306)
24. Ensuring Equitable and Sustainable Utilisation of Resources (page 307)
25. Whole-of-Government Approach (page 314).

2.2.8 *The National Physical Plan (NPP)*

The Department of Town and Country Planning, Peninsular Malaysia developed and released the National Physical Plan for Peninsular Malaysia in 2005 (NPP). The NPP consists of the following 6 sections:

1. National Development Planning Framework
2. Goal, Objectives and Principles
3. Plan Context
4. Development Strategy
5. Policies; and
6. Implementation Mechanism.

The purposes of the National Physical Plan are:

- Enhancing the National Planning through spatial dimension in the country's economic policy.
- Coordination of sectoral agencies by introduction of the spatial policies
- Forming works for planning at the state and local level; and
- Formulation of the physical planning policies.

The eight themes in the National Physical Plan are as follows:

1. Shaping national spatial framework
2. Improvement of national economic competitiveness
3. Modernization of agricultural sector
4. Strengthen of tourism development
5. Management of human settlement
6. Conservation of wildlife and natural resources

7. Integration of all national transportation network; and
8. Installation of appropriate infrastructure.

A systematic review of the contents in the NPP was carried out and the relevant points that refer to climate change or are relevant to the theme - adaptation to climate change were identified. The titles of the sections in the NPP report containing the relevant points are given below:

1. Water Supply
2. Environmentally Sensitive Areas
3. Drainage
4. Sewerage
5. Hydropower
6. Major Granary Areas
7. Sensitive Coastal Ecosystems
8. Protection of Water Catchments
9. Water Resources Issues
10. Groundwater Resources; and
11. Flood Prone Areas.

2.2.9 *National Water Resources 2000 Study (NWRS 2000)*

The Government completed a National Water Resources Study in 2000 for Peninsular Malaysia. The Study made major recommendations for water resources projects for each states in Peninsular Malaysia based on water demand projections from 2000 to 2050. Based on the Study's water demand projections for Selangor the Study has recommended two sets of inter-basin water transfer tunnels projects (Southern and Northern Transfer Tunnels) from Pahang to Selangor to be built to meet the future water demand needs.

The Government has commenced construction work for the Southern Transfer Tunnel. However, a coalition of NGOs, known as the Coalition for Sustainable Water Management (CSWM), has since disputed the water demand projections in the NWRS 2000 Study used to justify the project. Also, the water demand projections of the NWRS 2000 Study is referenced in the Water Supply section in the National Physical Plan 2005 report and are used as the basis for the Plan. Since it is very important to get a good estimate of the future water demand the Government has commissioned a NWRS 2010 Study to update the NWRS 2000 Study in 2009.

The CSWM has been invited by the Selangor State Government to make a presentation of their findings to the State's law makers at the Quality Hotel at Shah Alam on 27 July 2010. The following are the key points in the CSWM presentation against the NWRS2000 water demand projections:

(a) Grossly inflated per capita water demand figures based on a flawed method used to estimate industrial water demand
(b) Economic growth data used to make water demand projections has been over optimistic
(c) Population growth data used to make water demand projections has been over optimistic
(d) Major changes in the development plans for Peninsular Malaysia since completion of NWRS2000 Study
(e) NWRS2000 Study overestimates of water demand compared to the results from NAHRIM's Preliminary Climate Change Impact studies.

2.2.10 *National Water Resources 2010 Study (NWRS 2010)*

The Government has commissioned a NWRS 2010 Study to update the NWRS 2000 Study in 2009. The NWRS 2010 Study is expected to be completed by the end of 2010. The overall objective of the Study is to formulate a National Water Resources Policy (NWRP) and a National Water Resources Law (NWRL), and to review the National Water Resources Study (2000–2050)/ (NWRS 2000):

1. The specific objectives of the Study are as follows:To prepare and formulate a comprehensive NWRP complete with strategies and measures in line with national and state policies to achieve sustainable water resources development and management in the country. The policy shall cover protection, conservation, enhancement, ensuring the availability, and promoting the assisting in the management and sustainable use of water resources for immediate, medium and long term needs.
2. To develop a water resources management framework with reference to existing organisational functions and setups.
3. To develop and formulate a comprehensive NWRL which can be adopted as a legislative framework in the planning, development and management, including enforcement, of water resources in the country in line with the NWRP.
4. To review the NWRS (2000–2050) and other relevant studies pertaining to water resources availability, water demands, water quality status and other relevant aspects as contain in existing studies such as Water Resources Study for Sabah, Sarawak and the Federal Territory of Labuan and the Water Resources Study for the Northern Region of Peninsular Malaysia (Perlis, Kedah and Pulau Pinang).
5. To review the feasibility, recommendations and implementation time frames of the water resources project proposed in the NWRS (2000–2050).
6. To propose additional water resources projects for all water use sectors; and
7. To review the existing water quality and quantity monitoring system and to propose improvements.

The two key governance outputs from the Study are as follows:

(a) National Water Resources Policy (NWRP). Introduction, Policy statement, vision, background, objectives, principles, relation between the policy and legislation, current and future action plans, strategies which include planning and development, demand management, conservation and catchment management, pollution and environmental control, flood, drought and climate change management, health, food and security on water resources, land use, water resources management framework, capacity building, information management and formulation of management protocol.

(b) National Water Resources Law (NWRL). That can be adopted as a legislative framework in the planning, development, management and enforcement of water resources in the country in line with the NWRP. The NWRL shall contain provisions for sustainable management of all the constituent aspects of water resources. It will contain appropriate provisions for the making of detailed regulations to deal with each and every particular constituent and its various aspects.

2.2.11 *NAHRIM's Preliminary Study on the Impacts of Climate Change on the Water Supply and Irrigation Schemes in Selected Areas (2009)*

NAHRIM completed a study in 2006 entitled "Impact of Climate Change on the Hydrologic Regime and Water Resources of Peninsular Malaysia". The study simulated the possible impacts of climate change on the future rainfall and water resources characteristics in Malaysia. Following the Study NAHRIM completed a preliminary study in July 2009 to assess the impacts of climate change on the irrigation and water supply sectors for selected areas in Peninsular Malaysia based on the projected rainfall and runoff characteristics from the 2006 Study.

The main objective of the 2009 Study is to assess the impacts of climate change on the irrigation and water supply for the following selected study areas:

- Muda Irrigation Scheme
- Kemubu Irrigation Scheme
- Barat Laut Selangor (BLS) Irrigation Scheme; and
- Klang Valley Water Supply System.

The study highlighted the fact that the simulated rainfall and runoff data are subject to a much higher level of uncertainties compared to the uncertainties in estimating the water supply and irrigation water demands for the selected study areas.

It must be emphasized that the conclusions from the Study are subject to the high uncertainties in the projected rainfall and runoffs arising from the climate simulation studies carried out in 2006.

2.2.12 *Malaysia's Second National Communication Report (2010) (NC2 Report)*

Malaysia ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 13 July 1994. As a developing nation Malaysia is classified under the category of Non–Annex 1 (N–A1) country. Under the UNFCCC's Article 12 all N–A1 parties must periodically prepare an inventory of Green House Gas (GHG) emissions and report on the implementation of the Convention. The term for the periodic report to the UNFCCC is "National Communications".

Malaysia has just completed the preparation of the NC2, which is now in the final stages of publication. One of the supporting documents of the NC2, entitled, "Programmes Assessing Vulnerability and Measures to Facilitate Adequate Adaptation to Climate Change" (V&A Synthesis Report) deals with the theme of adaptation to climate change. This document was prepared using information contained in the 7 sector reports and 2 V&A supporting reports. Chapter 4 of the NC2 devotes itself to Vulnerability and Adaptation Assessment.

The objective of this section is to provide a synthesis of water–related Vulnerability and Adaptation (V&A) issues as described in all the documents mentioned above. For each of the three broad thematic water-related areas (water bodies, water use and water management) the following information from the NC2 report has been extracted:

(a) Potential climate change impacts;
(b) Vulnerabilities to climate change of each component of these three broad thematic areas as well as related vulnerabilities in other sectors such as public health, agriculture, energy and transportation;
(c) Adaptation measures;
(d) Gaps in the analysis; and
(e) Recommendations to address these gaps.

Appendix 1 provides a summary table of the information presented in this section. The information presented in this section will be extracted and use in the analysis in the subsequent chapters. It forms the main source of information on the local status on water-related V&A.

The RegHCM-PM provides spatial projections for Peninsular Malaysia for the two future 10-year timeframes considered of 2025–2034 and 2041–2050 for different timescales including monthly rainfall. PRECIS projections include annual rainfall changes and seasonal variations for the whole of Malaysia until the end of the 21st century. Both these models are useful in identifying areas where climate impacts are likely to occur in the future. Some of the NC2 analysis has been based on the model projections made for specific areas such as the granary areas.

Although water is an all pervasive issue and climate impacts on water availability, accessibility and quality will affect almost every aspect from socio-economic activities, public health to physical land characteristics and ecosystem service delivery, the information collated below is limited to the direct vulnerabilities of other sectors due to climate change impacts on water as identified in the NC2. It therefore does not consider heat stressors for example on agriculture, livestock, biodiversity or human health apart from impacts arising from the resulting decrease in water supply, quality etc. Additionally, in keeping with the boundaries adopted in the IPCC Technical Paper VI on Climate Change on Water (2008), only impacts relating to fresh water are considered. Hence sea level rise considerations are limited to the impacts on coastal fresh water sources.

The final part of this section considers the mitigation indicator that Malaysia has adopted voluntarily to reduce emissions intensity of GDP by up to 40% of the 2005 levels by 2020 to identify potential water related impacts.

2.2.12.1 <u>Water Bodies</u>

The components of water bodies are rivers, lakes, aquifers, wetlands and coastal reaches. Of these, the NC2 analysis only considers impacts related to rivers and coastal reaches. One key gap is the lack of information on the impacts of climate change on other water bodies such as lakes, aquifer and wetlands. These should be studied and measures to adapt should be identified for these water bodies.

(a) <u>Rivers</u>
The changing annual rainfall and seasonal rainfall patterns will affect river flow and river water quality. Given the characteristics of Malaysian rivers which are generally small and short, flooding especially in low lying and coastal areas is likely during short intense rainfall or long, low intensity rainfall. During periods of low rainfall, river water quality is prone to deteriorate. Small forest streams are also breeding grounds for one of the malaria vectors. The manner in which climate change impacts on rivers could affect their role as a breeding ground for malaria vectors should be studied in order to avoid future reintroduction/occurrence of malaria or at least be prepared for such an event.

One major gap is the low number and frequency of hydrological and river flow data stations.

(b) <u>Coastal Reaches</u>
A lot of the climate change impacts in water bodies in coastal reaches will be the result of increased sea level rise (SLR) and increased wave action. This could result in erosion and eventually salt water intrusion. Ecosystems such as mangrove forests and mudflats and the biodiversity they support are susceptible to increases in brackish water areas. Coastal agricultural and aquaculture activities are also vulnerable to salt water intrusion. Public health could also be jeopardised

as increased areas of brackish water could increase the coastal malaria vector population.

Another impact to water bodies in coastal areas is reduced river flow during dry periods making river mouths vulnerable to sedimentation risks.

A pilot of the National Coastal Vulnerability Index (NCVI) study has been conducted in two areas, Tanjung Piai in Johore and Pantai Chenang in Langkawi. The study finds amongst other things that the global high worst case SLR scenario (10mm/year increase) will result in a loss of about 1,820 hectares of coastal land in Tangjung Piai and 148 hectares in Pantai Cenang by the end of the 21st century.

As one of the measures towards adaptation, not only for climate change impacts on coastal water bodies, but for impacts generally in coastal areas, the NCVI should be conducted throughout the country.

Another adaptation measure is to pass a Coastal Management Policy and ensure all coastline developments have Integrated Shoreline Management Plans (ISMP). The retreat, accommodate and protect approach should be adopted as necessary in an integrated manner.

R&D is also necessary to better understand long-term natural coastal evolution due to storm surges and wave patterns as these will also have an impact on water bodies in coastal reaches. Research on coastal reforestation has also been proposed to develop optimal planting methods and robust coastal forests as well as soft engineering (application of structural and biological concepts) to solve erosion and reduce erosive forces.

Gaps identified include the absence of long-term tidal records and changes in physical oceanographic patterns. Site-specific quantitative data and assessment is also lacking as is information on changes in storm patterns and frequency of storm events. These would be required for a more comprehensive nationwide analysis. Furthermore, the lack of a uniform understanding in various agencies dealing with SLR as well as the lack of enforcement powers for coastal development to adhere with guidelines are gaps that need to be addressed.

Some of the recommendations made to overcome these gaps include devising a system to monitor, detect and predict SLR and potential impacts as well as creating a centre of excellence for coastal issues.

Means to accelerate the formulation of ISMP and adherence to it should also be implemented including using legal instruments such as the Coastal

Development Control Law for consistency in the application of coastal development guidelines.

The NCVI study should be expanded to the East Coast: Pantai Sabak, Kelantan, Kuantan, Pahang, K. Terengganu, Terengganu; West Coast: Pelabuhan Klang, Selangor, P. Pinang, Batu Pahat, Johor; Sarawak: Bintulu, Miri, Kuching and Sabah: KK, Tawau, Sandakan. R&D on storm surges and wave patterns should be conducted along with developing long term wave measurement programmes along Malaysian coasts.

In terms of the NCVI it can be noted that some of the areas identified as being vulnerable to impacts like SLR would be coastal water bodies and the socio economic activities they help support. Focusing on such areas would help channel limited resources to the most critical areas and enable timely adaptation measures to be undertaken to reduce or eliminate the impact. This of course should be done in a holistic integrated manner. However in order to do so, a strong understanding of the impact on the specific water body would be necessary.

Following on from the NC2 findings, specific studies could be done in some particularly sensitive areas such as the coastal areas in Kuala Selangor supporting firefly colonies. Such an area would be especially vulnerable to dry periods which would affect river flow which in turn could result in salt water intrusion affecting the sensitive berembang trees which the fireflies rely on. The earlier measure to overcome water scarcity during future drought periods by constructing a dam upstream has already made the downstream coastal areas vulnerable. Climate change impacts resulting in extended dry periods could render the existing measures to overcome the reduction in river flow due to the dam construction useless.

Additionally the NC2 has not specifically looked at the impacts of climate change on fisheries. Coastal reaches such as wetlands and mangrove areas are habitats for juveniles and changes in water salinity may affect population and the sex ratio.

2.2.12.2 Water Use

The components of water use are irrigation, potable/water sanitation, industrial, hydropower, navigation, fisheries, ecosystem water needs. Of these, the NC2 analysis only considers consumptive water uses.

A key gap in the NC2 analysis is lack of consideration pertaining to non-consumptive water use such as for ecosystem water needs and recreational/tourism needs.

(a) Irrigation (Chap 4, Section 4.7(a)(i) Draft NC2)
Irrigation facilities and their efficacy can be impacted by excessive rainfall, reduced rainfall and extreme weather patterns. With excessive rainfall, failure to contain excess water is anticipated which could result in flooding and crop damage/loss of yield. Projections made by the RegHCM-PM model were used to identify vulnerabilities in three important granary areas, Muda Agriculture Development Authority (MADA), Kemubu Agriculture Development Authority (KADA) and the Barat Laut Selangor granary areas.

The projections indicate that the MADA granary area could face excess water for 76% of the 240 months studied while there are indications of extreme surplus of up to (+) 5,438 MCM in the KADA granary area. Insufficient rainfall is anticipated for 10 out of the 40 planting seasons considered at the MADA scheme possibly warranting the cancellation of paddy planting in some, or in the worst case scenario, all of the MADA area. Likewise, for the Barat Laut Selangor irrigation scheme where one of the deficit events is projected to be severe enough to disrupt planting in some parts. KADA is not expected to face severe deficits.

Some of the adaptation measures proposed are as follows: establishing an early warning system, rain water harvesting, soil water management and drainage improvement.

The gaps identified in the NC2 are twofold, first that the impacts have been considered in isolation and not in conjunction with impacts to other consumption and non-consumption uses of water. Second, the data used in the analysis has been taken from the National Water Resources Study (2000). The assumptions and information contained in this study is currently being revisited. A more updated analysis may provide a different picture of the constraints on water use.

The NC2 has not provided information on how much of the nation's rice needs are met by each of these granary areas as well as how much they are anticipated to provide in the future. Rice is a staple crop. It would be important to identify this in future analysis to understand the vulnerability of the nation's food security to projected climate change impacts in these and other rice production areas.

(b) Potable/Water Sanitation
Excessive rainfall leading to floods, reduced rainfall leading to droughts and extreme weather events can all affect the quality and quantity of water. Water pollution can result from overflows and damage to water supply infrastructure. Water supply can also be disrupted by droughts as was experienced in Selangor in the late part of the last decade.

The NAHRIM 2009 study indicates that based on the capacities of existing facilities (i.e. Klang Gates Dam, Batu Dam, Sg. Selangor Dam, Tinggi Dam and downstream catchment between Sg. Selangor Dam to Batang Berjuntai Intake Point, (excluding the Pahang-Selangor water transfer project), 28 (nearly 12%) out of the total 240 months are projected to face water supply deficit situations. These monthly water deficits range from (+)3 MCM to 214 MCM. The highest surplus could be as high as 2,137 MCM.

These estimates were based on demands from population that is increasing from nearly 5 million in 2010 to nearly 7 million in 2050. The estimates are also based on the assumption that per capita domestic consumption increases from 300 (2010) to 330 (2050) litres/capita/day and Non-Revenue Water (NRW) increases from 185 (2010) to 207 litres/capita/day (2050). Floods aspects are not considered and these may affect some of the facilities.

Health concerns can also arise such as an increase in the incidence of typhoid, cholera and diarrheal diseases.

The adaptation measures proposed include both demand and supply management. Demand management measures include encouraging water conservation and reduction of per capita water consumption through economic incentives and promoting rainwater harvesting. Supply management includes reducing the non revenue water (NRW) and regular maintenance of water treatment plans and distribution pipes.

Gaps are similar to those identified for the irrigation component.

(c) Industrial

Impacts on industrial water use are similar to those identified for irrigation and potable use. The vulnerabilities, proposed adaptation measures and gaps in the analysis are likewise similar.

Essentially for all these three water use areas, competition for limited water resources during droughts will be a concern. Hence an integrated water use management is required. This can be somewhat addressed through the implementation of IWRM with the proviso that climate change related stressors should be accounted for in its implementation.

During times of excess rain water or extreme weather, the integrity and efficacy of water supply infrastructure are at risk.

(d) Hydropower

Hydropower generation capacity will be impacted by reduced rainfall if there are insufficient amounts for generation.

One of the adaptation measures proposed is medium term and long term catchment management programmes for hydropower stations. Another is to promote the national implementation of grid connected rooftop solar panels to reduce disruption risks and ease hydropower capacity requirements.

(e) Navigation
Changes in river flows due to more extreme rainfall patterns as well as increased frequency of extreme weather such as storms can affect the navigability of water bodies such as rivers and lakes. This can result in reduced navigability of water bodies which are used as primary modes of transportation both of people and for trade and communication purposes in some parts of the country, especially in East Malaysia. Cargo transportation such as timber can also be affected with sedimentation at river mouths.

(f) Fisheries
This component has not been considered in NC2 apart from the potential impacts on coastal aquaculture activities as mentioned above.

Studies should be undertaken to better understand the impact to fresh water fisheries resulting from climate change impacts to water bodies. At the same time, a holistic approach should be taken to ensure that climate change vulnerabilities are not further aggravated by other stressors such as over fishing and pollution.

2.2.12.3 Water Management

The components of water management relate to water excesses (floods, increased rainfall and extreme weather), water scarcity (droughts), pollution of water supply and water bodies, physical changes to water bodies and competing use of water resources.

(a) Water excesses
With regard to this component, floods, increased rainfall and extreme weather are expected to occur more frequently and with greater intensity. Floods may occur in historically flood free areas. Soil saturation and nutrient leaching can also occur.

Water control structures like dams, barrages and bunds are vulnerable as they are likely to fail under these conditions given if their design specifications do not account for climate change impacts. For example, the NC2 reported that the Timah Tasoh dam had been upgraded recently. However the November 2010 floods resulted in breaching the dam alert levels requiring six sluice gates to be opened. State Agriculture Committee chairman Sabry Ahmad said Perlis would request RM300 million from the Federal Government to upgrade the dam to prevent floods. (nst.com.my, 05/11/2010 Situation improves in Perlis but not Kedah[1]). More recently, during the Perlis State Assembly, the Perlis Menteri Besar (Chief Minister) noted

[1]http://www.nst.com.my/nst/articles/12rece/Article#ixzz14nJ6wyOz

that the state is requesting an allocation of RM576.9 million from the Federal Government to further upgrade the Timah Tasoh Dam and flood bypass system to overcome the flooding problem especially in Kangar. In noting that the flood loss was estimated to be more than RM200 million (with the actual amount expected to be higher once all the loss reports are compiled), the upgrade works for the Timah Tasoh Dam is to increase its present capacity by 2 ½ times to 87 million m3. (NST, Wednesday, December 15, 2010, pg 26 Nation "MB: Good job in flood relief work").

Rainfed agriculture is also vulnerable. In terms of rice for example, a 15% increase in rainfall in the early growth stages could result in an 80% decrease in yield. Apart from food security being vulnerable, economic security is also vulnerable as yields of important crops to the economy like oil palm, rubber and cocoa will also be affected. These impacts will reduce the number of rubber tapping days and increase fungal incidence in cocoa. Additionally, if these anticipated impacts are not properly managed, soil erosion will be accelerated causing soil degradation and cause scouring of drainage structures affecting their efficacy in flood mitigation and sedimentation into rivers and reservoirs. Frequent and severe landslides are anticipated as is an increase in tree mortality.

All the impacts and vulnerabilities described above will naturally affect economic activities resulting from damage of power generation equipment, transmission pylons, roads, rail lines, bridges and fuel delivery systems. Public health is also vulnerable to these impacts with a possibility of increased breeding ground for malaria and dengue vectors and spread of water borne diseases.

Adaptation measures proposed include non-structural approaches such as improved rainfall and flood forecasting, implementing an effective disaster warning system and flood hazard mapping and reviewing flood management plans as part of a coordinated disaster prevention and management plan.

Design standards for flood risk management in all new structures such as water control, transportation, electrical, water and waste amenities should be reviewed and existing under designed structures should be retrofitted/reinforced.

For agriculture, R&D should be enhanced for flood resistant varieties while drainage should be designed to efficiently regulate water tables and prevent floods. Specific measures like low intensity tapping system and rain gutters for the rubber industry should be used in a more widespread manner.

In terms of public health, mapping of the malaria vector areas using remote sensing, providing wider access to malaria drugs and aedes proofing buildings through the review of building standards and guidelines to prevent/minimise rain water collection have been proposed.

Gaps identified include improving crop modeling projections with better local data on the projected magnitude of climate change, crop parameters and soil properties. R&D and funding are also necessary to establish baseline data on the effects of rainfall patterns on agricultural activities especially to ensure food security. Worker skills should be enhanced to be able to apply newer technologies such as low impact tapping.

Recommendations proposed include paying special attention to projections regarding maximum monthly rainfall as they can reveal the potential severity of floods and influence policy decisions to enhance management of available water. Additionally, it is recommended that research into innovative rainwater management to reduce floods, drought and other climate risks be undertaken.

The water management paradigm should also be changed from draining rainwater to collecting rainwater with multiple benefits (source of water, prevention of urban flooding, control on non-point source pollution, restoration of hydrological cycle, alleviation of urban heat islands, supplementing flows of urban streams, recreation/ tourism).

(b) <u>Scarcity</u>

Similar to the impacts of water excesses, water scarcity is also expected to be more frequent and severe and to occur in areas which were historically drought free. Agriculture and public health are vulnerable to these impacts.

Rainfed rice agriculture is equally vulnerable to a decrease in seasonal rainfall during the early growth stage with a 15% decrease likely resulting in a 80% reduction in yield. Crop quality will also be adversely affected. Yield reduction in cash crops such as oil palm (10% decrease in mean annual rainfall results in 30% decrease in yield), rubber (reduction below mean minimum and increase in temperature over 30oC results in 10% yield decrease) and cocoa is anticipated.

Public health risks include an increase in vector borne diseases as mosquito breeding grounds may increase with more pronounced wet and dry spells. Furthermore availability of water supply will also be reduced resulting in impacts already discussed under the water use section.

Adaptation measures that have been identified include enhancing water supply efficiency such as improving storage capacity and efficacy by removing sediments and eliminating losses from leakage and theft, enhancing existing dam capacity to store more water, encouraging rainwater harvesting for non potable uses, encouraging demand management in non potable water use and creating a decision support system that incorporates weather forecasting.

R&D should be enhanced to discover drought resistant/high water use efficiency (WUE) varieties. In particular, for rice, research on aerobic rice which consumes less water should be enhanced. Irrigation facilities may also need to be introduced in areas that were previously entirely rainfed. Public health measures are similar to those proposed for excess water management.

Here again special attention should be paid to monthly rainfall minimums to make appropriate policy decisions on managing available water.

(c) <u>Quality of water supply and water bodies</u>
Water supply quality will deteriorate with climate change impacts such as floods, droughts and extreme weather patterns. This in turn will adversely affect public health and cause diseases like cholera to spread easily. Improved sanitation and coverage of safe water supply is proposed to reduce this impact.

(d) <u>Physical changes to water bodies</u>
The NC2 briefly considers potential changes to sea water such as temperature rise, change in salinity and PH. However, no analysis is reported for changes to fresh water bodies.

(e) <u>Competing use of water resources</u>
As noted earlier in the water use section, the analysis in the NC2 was done on an isolated basis. The projected increase in frequency and severity of droughts however will result in enhanced competition for water resources with reduced availability and supplies not being able to meet the consumptive water use demands.

Adaptation measures proposed include implementing IWRM, rainwater harvesting, reducing NRW and better water demand management. The National Water Services Commission Act 2006 and Water Services Industry Act 2006 have been identified as promoting sustainable water use and better water management.

A major gap in this analysis is that non-consumptive water use such as for ecosystem services, power generation, recreation and tourism has not been included in considering competition for water resources.

A more holistic approach in formulating adaptation measures is recommended to avoid maladaptation. Such an approach will not only incorporate water resources needs for non-consumptive purposes, but would change the perspective by analysing the needs based on a spatial/regional or temporal dimension rather than a narrow sector based approach.

2.2.12.4 Overall Gaps and Recommendations regarding water resources analysis

The following are some overall gaps affecting all three thematic areas:

1. Gaps in technical understanding between different agencies result in a time lag in decision making. Furthermore, affected populations are still generally unaware and hence not being prepared to adapt to anticipated changes.
2. It was also found that there is a lack of data sharing amongst agencies, sectors and stakeholders probably due to insufficient means to do so.
3. It is also noted that there is a lack of incorporation of hydrological and climate variability into flood, water supply and other water related management.
4. There is also insufficient information on the reduction/alleviation of the numbers of flood or drought events by existing mitigatory measures such as the capacity enhancement of the Timah Tasoh dam or the construction of the SMART tunnel. Such information would be useful in working out the cost and benefit of undertaking adaptation measures to persuade policy and decision makers of the importance of undertaking appropriate adaptation measures.
5. Furthermore, although much of the analysis is qualitative, those which are quantitative are based on limited climate model projections for Malaysia.
6. There is also a low understanding on uncertainties and limitations of climate change projections and scenarios for effective communication to decision makers and end users. This is aggravated by the lack of procedures and risk management practices in incorporating projected climate and hydrological changes with related uncertainties from fine grid regional HCMs into sector analysis.

The following are some recommendations to address some of the above gaps:

1. Increase stakeholder and community involvement in water resources planning and management and undertake multi-disciplinary studies involving natural and social sciences to develop practical adaptation measures taking considerations of various stakeholders into account.
2. The number of GCM models and realizations and river based models with finer scale and temporal resolutions should be increased and the water resources study information should be updated.
3. Barriers to effective implementation which could take the form of economic, information or social barriers should be identified and overcome.

2.2.12.5 Mitigation measures

Malaysia voluntarily aspires to the scenario of reducing the GHG emission intensity of GDP by up to 40 percent in 2020 compared to 2005 as announced by the RT Hon Prime Minister in Copenhagen during COP 15 in 2009. The main sectors identified to achieve this are the energy and waste sectors. Enhancing forest management and conservation is also expected to contribute towards this.

With regards to energy, measures to reduce the consumption of fossil fuel include using renewable energy and becoming more energy efficient. With regards to renewable energy, implications on water resources would include water required for biofuel source cultivation. Any increase in existing acreage of oil palm to meet biofuel demand would add to water consumption in the agriculture sector.

On the other hand, waste management to reduce organic waste in landfills and thus reducing landfill methane release could help in reducing groundwater pollution due to leachate. Forest management and conservation too have implications for the water sector as this can better regulate water cycles.

Malaysia is presently preparing a detailed roadmap towards achieving this 40% target. A study on the Economics of Climate Change is also underway at EPU. These studies should include potential impacts on water resources as described above in their considerations. Any cost/benefit exercise should also include the cost or benefit to the water sector.

CHAPTER 3. CLIMATE CHANGE PROJECTIONS — OVERVIEW AND STATUS

This Chapter first provides a brief introduction to some key concepts and approaches in climate change modeling. This is then followed by the presentation of the observed climatic changes in Malaysia and also the available climate projections for Malaysia from various sources. The relevant outputs from the nine Atmospheric Ocean coupled GCM (AOGCM) models and the "Providing Regional Climates for Impacts Studies" (PRECIS) climate models used by the Meteorological Department of Malaysia and the Regional Hydro-Climate Model for Peninsular Malaysia (RegHCM-PM) used by the National Hydraulic Research Institute of Malaysia (NAHRIM) are presented.

Only the SRES A1B emission scenario is considered for the global climate simulation whereas the SRES A2, A1B and B2 emission scenarios are considered for the PRECIS model simulation. The IS92a scenario (IPCC 1992) is used in the RegHCM-PM model simulation.

This Chapter also gives the climate change projections for Southeast Asia and the global climate change projections for the region, as presented in the report prepared by the Asian Development Bank: "Economics of Climate Change in South East Asia: A Regional Review (2009)".

The Chapter concludes with a discussion on the comparison between the climate change model projections from both the Malaysian climate models and the regional and global projections presented in the ADB report. The statistical deviances between the models and potential reasons for the deviances are also highlighted.

3.1 Introduction to Climate Change Modelling

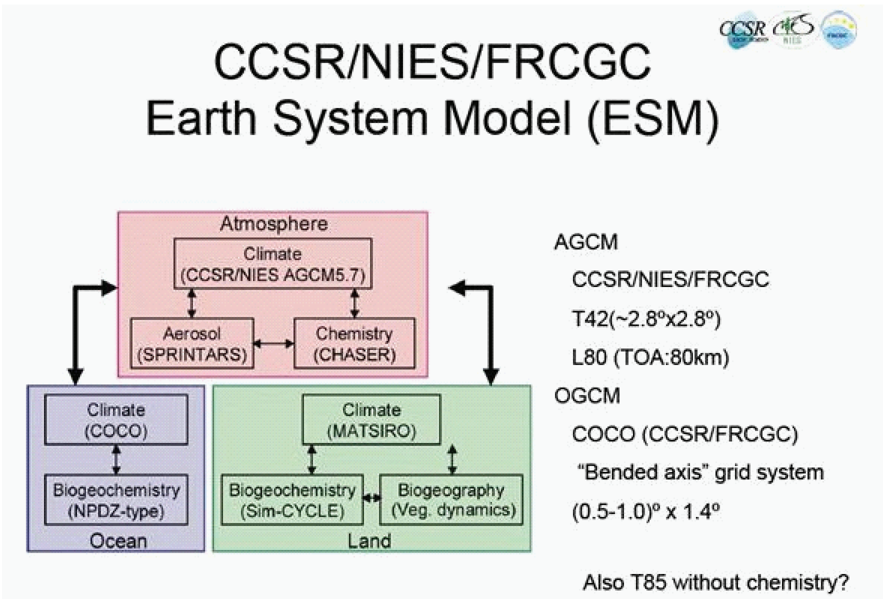
The following is a brief introduction to some key concepts and approaches in climate change modeling. They are:

(g) Atmospheric Global Circulation Models (AGCM) and Green House Gas (GHG) Emissions Scenarios
(h) The relationships between GHG emissions and water-related disasters
(i) Translating an AGCM Model's Outputs to Local Weather Patterns.

3.1.1 *Atmospheric Global Circulation Models (AGCM) and Green House Gas (GHG) Emissions Scenarios*

Figure 3.1 shows a schematic of the component interactions in a typical Atmospheric Global Circulation Model (AGCM) of the Earth System (Source: T. Koike, University of Tokyo). There are 3 major components in the model, corresponding to the atmosphere, ocean and land phase of the global system. Within each of the component the figure highlights that there are additional interactions with the aerosols, atmospheric chemistry, biogeochemistry and biogeography sub-systems.

By means of the AGCM climate scientists are able to make predictions of the likely changes in the global climate due to different greenhouse gas emission scenarios corresponding to different global population and economic development trends.



(Source: T. Koike, University of Tokyo).

Figure 3.1. A schematic of the component interactions in a typical Atmospheric Global Circulation Model (AGCM) of the Earth System.

The IPCC has defined a number of standard greenhouse gas emission scenarios for climate change model predictions. Figure 3.2 gives the four basic green house gas emissions scenarios that are published by the IPCC in its Special Report on Emissions Scenarios (SRES) in 2001.

3.1.2 *The relationships between GHG emissions and water-related disasters*

Due to the changes in the climate caused by the green house effect the global hydrological water balance will be affected. This will affect the local weather patterns of a region and results in changes to the normal temperature and rainfall hydrological regimes of a region. The changes in the local rainfall regimes will have major impacts on water resources.

Figure 3.3 shows an illustration (Source: T. Okazumi, MLITT, Japan) of the relationship between the impacts of climate change on the hydrological variables and water-related disasters. It highlights that the large volume of green house gases that are emitted into the Earth's atmosphere results in a "green house effect" which cause an increase in the global atmospheric temperature. The increase in the atmospheric temperature upsets the hydrological water balance which results in melting of glaciers, thermal expansion of sea water and change in the evapotranspiration regime. These changes results in more intense typhoons, increased precipitation and more frequent heavy rains and severe droughts.

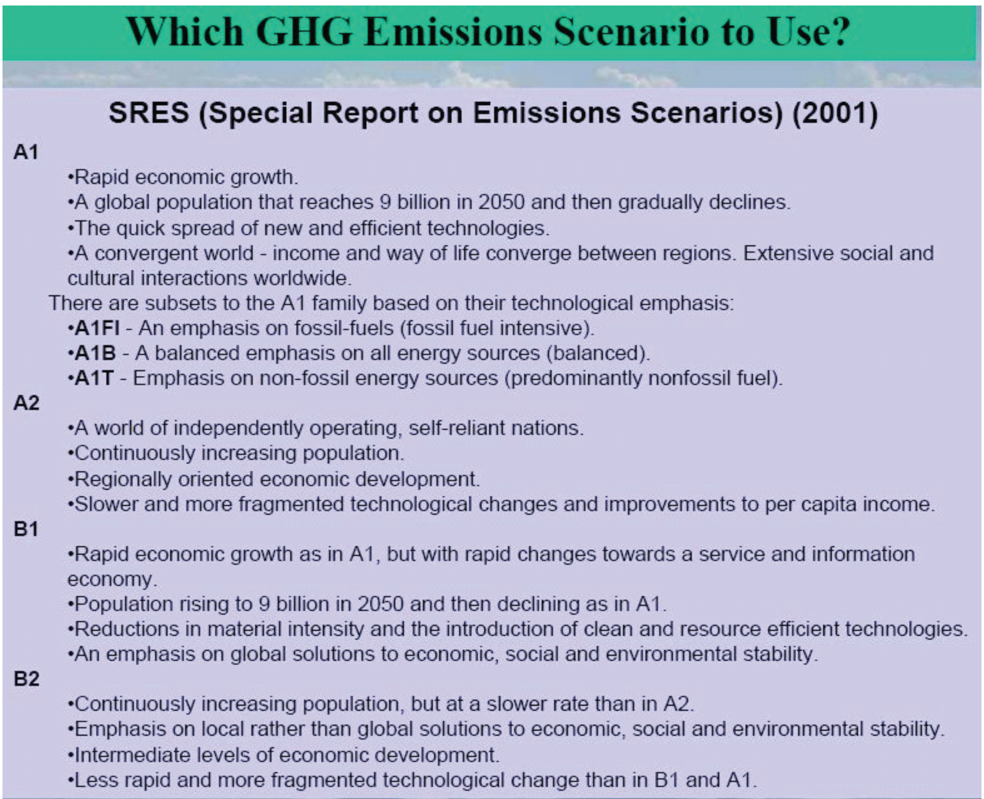


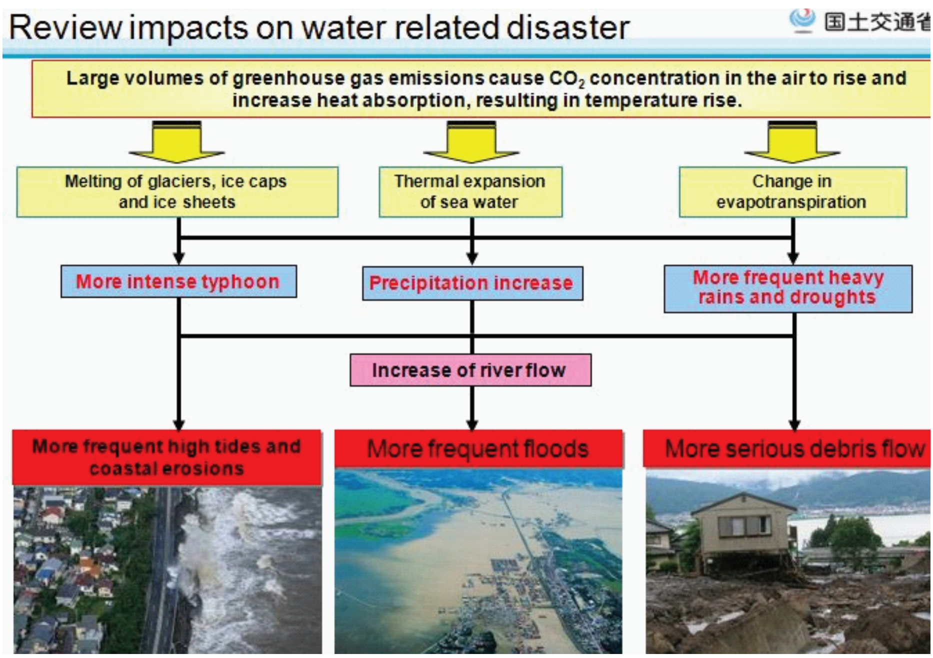
Figure 3.2. Which Green House Gas Emission Scenario to Use? – The IPCC Special Report on Emissions Scenarios (SRES) 2001.

3.1.3 *Translating an AGCM Model's Outputs to Local Weather Patterns*

In order to assess the impacts of climate change on the local weather pattern there is a need to translate the macro-level outputs from the global climate AGCM models to the micro-level local weather settings. *Figure 3.4* below (Source: T. Koike, University of Tokyo) illustrates how the outputs from a 180 km grid-size Ocean-Atmosphere model (AGCM) provides the boundary conditions for a 20 km high-resolution global atmospheric model. The outputs from the atmospheric model provides the boundary conditions for the 1–5km regional cloud resolving model that enables predictions of the local weather patterns within a 1–5km grid.

There are two basic approaches to convert or down-scale the results of the predicted local weather patterns to hydrological variables like rainfall and evaporation. They are:

- Statistical down-scaling
- Dynamic down-scaling.

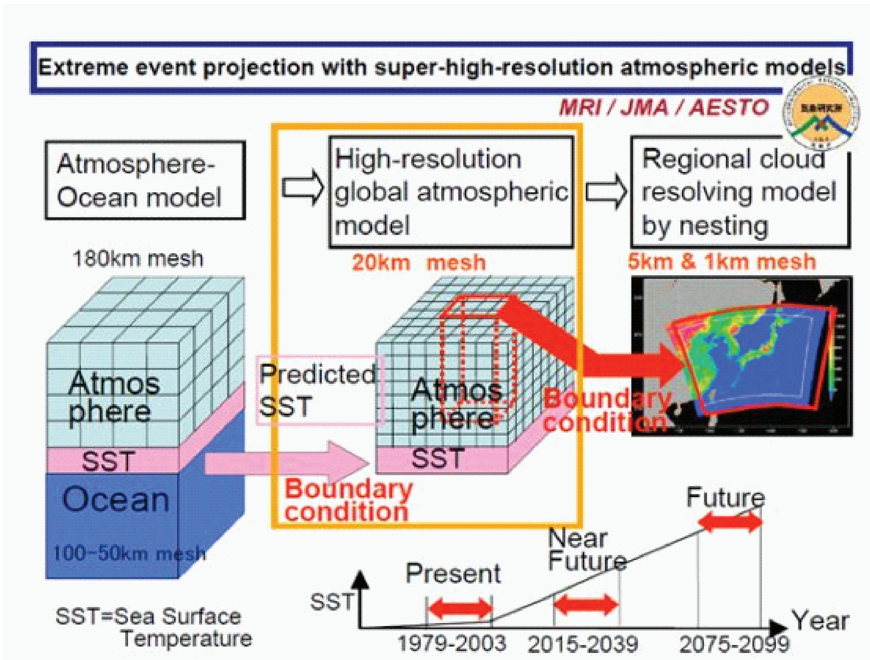


(Source: T. Okazumi, MLITT, Japan).

Figure 3.3. The relationships between GHG emissions and water-related disasters.

3.1.3.1 Statistical Down-scaling

In statistical down-scaling, statistical relationships are first developed among regional climate variables and large scale atmospheric state variables. They are then used to downscale AGCM results to regional scale. For example, *Figure 3.5* below shows how calibrated statistical relationships between the frequencies of past, observed heavy rainfall with observed meteorological parameters, such as water vapour, pressure, temperature, etc. are used to predict future rainfall with simulated meteorological parameters. The use of the calibrated statistical relationships enables the future rainfalls to be derived from the simulated, meteorological parameters of the future climate scenarios. (Source: T. Koike, University of Tokyo).

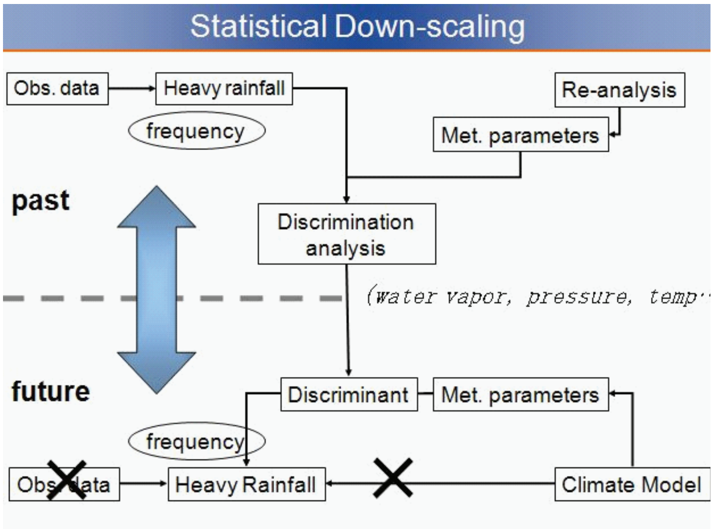


(Source: T. Koike, University of Tokyo).

Figure 3.4. Translating the outputs from an AGCM to a regional cloud resolving model that enables predictions of local weather patterns.

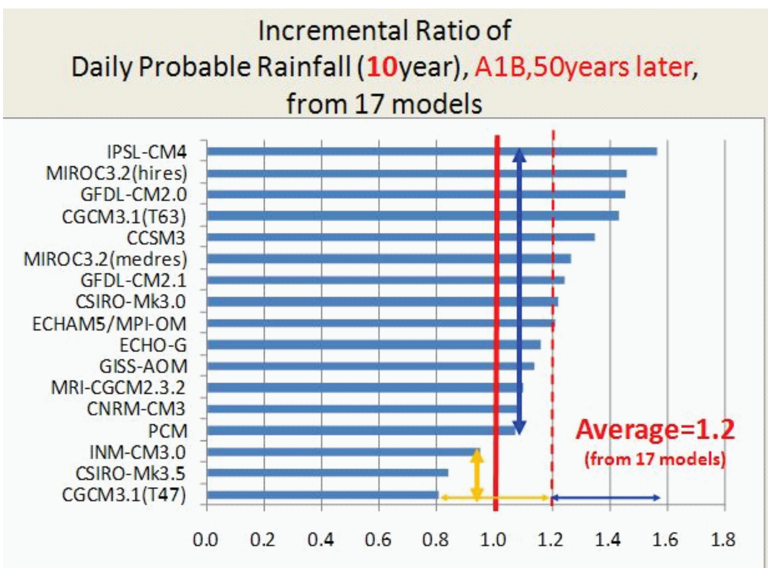
3.1.3.2 Dynamic Down-scaling

In dynamic down-scaling the results from an AGCM are used as the initial and boundary conditions for simulations of regional atmospheric/hydrologic models which are nested into the AGCM. The advantages of dynamic down-scaling are that it can quantify the impacts of evolving land conditions, and evolving atmospheric boundary conditions explicitly in regional scale hydro-climate simulations at very fine grid resolutions. It can also simulate climate (precipitation, air temperature, radiation, etc.) at hourly or finer time intervals in order to provide sufficiently refined climate data for the simulation of floods and environmental conditions.



(Source: T. Koike, University of Tokyo).

Figure 3.5. Statistical Down-scaling: Using calibrated statistical relationships between frequencies of past heavy rainfalls with observed meteorological parameters, to predict future rainfall with simulated meteorological parameters.



(Source: T. Koike, University of Tokyo).

Figure 3.6. Comparison of results from 17 models for daily rainfall for the A1B Green House Gas emission scenarios indicating the wide range in the models' predictions.

However, due to the variety and limitations of the "physically-based hydrological models" that are used for the simulations and the uncertainty in model calibration the results of model predictions from dynamic down-scaled models can vary widely. Figure 3.6 below shows the comparison of the model results from 17 models for daily rainfall for the A1B Green House Gas emission scenarios. It can be seen that the results vary within quite a wide range. (Source: T. Koike, University of Tokyo)

3.2 Climate Change Model Projections for Malaysia

The observed and climate change model projections for Malaysia are presented in this section under the following headings:

(a) Past Climate Trends in Malaysia (MMD)
(b) Climate Change Projection Scenarios from Nine AOGCMs (MMD)
(c) Climate Change Projection Scenarios from PRECIS Model (MMD)
(d) Climate Change Projection Scenarios from RegHCM-PM Model (NAHRIM).

3.2.1 *Past Climate Trends in Malaysia (Section 2.2, pg 8 CC Scenarios, Jan 2009, MMD)*

The climate of Malaysia is tropical and humid. It is very much influenced by the mountainous topography and complex land-sea interactions. Intraseasonal and interdecadal fluctuations such as the El Niño Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) and Madden-Julian Oscillation (MJO) are known to significantly influence the interannual climate variability of Malaysia. Increase in tropical storms in the South China Sea have contributed to more extreme events of rainfall and gusting in both East and West Malaysia. Annual trend analysis of both temperature and rainfall has been carried out by analyzing both the temperature and rainfall data for Malaysia over the last 40 years (1968–2007).

3.2.1.1 <u>Temperature (Section 2.2.1, pg 8, CC Scenarios, Jan 2009, MMD)</u>

The Kuching, Kota Kinabalu, Kuantan and Petaling Jaya meteorological stations were selected to represent Sarawak, Sabah, East Peninsular Malaysia and West Peninsular Malaysia respectively. All the four stations indicate an increasing temperature trend and indicate consistent significant temporal variation in annual mean temperatures for all the regions.

For most stations, new surface temperature maximum were recorded in 1972, 1982 and 1997. From 1970 to 2004, strong El Nino events were recorded in 1972, 1982, 1987, 1991 and 1997. During these 5 years, all the four stations recorded significant annual temperature maximum.

Higher temperature increases are recorded in Peninsular Malaysia compared to East Malaysia when comparing the long term means obtained for 1961–1990 and 1998–2007.

An average temperature increase of 0.5°C to 1.5°C is recorded in Peninsular Malaysia and 0.5°C to 1.0°C in East Malaysia. Western Peninsular Malaysia experiences more significant rise in temperature when compared to other regions in Malaysia. Among the four seasons, SON records the highest temperature increase for Peninsular Malaysia, followed by DJF. Nevertheless, for East Malaysia, temperature increase for all the seasons are about similar.

3.2.1.2 Rainfall Analysis (Section 2.2.2, pg 12, CC Scenarios, Jan 2009, MMD)

The spatial variability of rainfall lacks the regularity that is generally found with temperature. Therefore the standardized rainfall anamoly averaged for Peninsular Malaysia and East Malaysia is used to analyse the rainfall pattern for Malaysia. Meteorological stations data from 1951–2005 was used for this purpose.

The frequency of relatively drier years has increased for Peninsular Malaysia and East Malaysia as of 1970. Most of the El Niño events as of 1970 have resulted in relatively drier years for Peninsular Malaysia and East Malaysia. Most of the severe dry spells in East Malaysia have been recorded during the El Niño events. Though the three driest years for Peninsular Malaysia (1963, 1997 and 2002) were recorded during El Niño events, the substantial frequency of relatively dry years in Peninsular Malaysia not accounted for by El Niño event indicates that El Niño event on its own is not the primary rainfall regulatory mechanism for Peninsular Malaysia. Most La Niña events have resulted in wet years for Peninsular Malaysia with the exception of 1998 and 1955.

In Peninsular Malaysia, dry years observed from 1975–2005 are more frequent and intense compared to those of 1951–1975 (See *Figure 8*, pg 13 in report).

Neither an increasing nor decreasing trend for rainfall was found for East Malaysia during the observed 50 years period (see *Figure 9*, pg 14 in report). Nevertheless the intensity and frequency of the dry years as of 1970 have increased when compared to those of the earlier period. Though the dry years are more frequent than the wet years, the intensity of rainfall increase during the wet years is comparable to those of the decrease in rainfall during the dry years. The La Niña phenomenon is responsible for the three wettest years recorded (1984, 1988 and 1999) for East Malaysia. Most of the relatively severe dry spells in East Malaysia were recorded during the El Niño events except 1978, 1990 and 1992.

With regard to seasonal precipitation patterns a trends comparison was conducted between 1998–2007 trends compared to those in 1961–1990. A decreasing seasonal rainfall trend was found for PM while EM showed an increasing trend. (see *Figures 10*, pg 16 and 11, pg 17 in report).

3.2.1.3 Winter Monsoon Circulation (Section 3.2, pg 30, CC Scenarios, Jan 2009, MMD)

Winter Monsoon (DJF) averaged 850hPa wind for the nine selected AOGCMs climatology (1961–1990) (See *Figure 29* in report) and the ensemble of the nine AOGCM climatology (1961–1990) (see *Figure 30* in report).

3.2.1.4 The Northeast Monsoon of 2006/2007 and 2007/2008

The northeast monsoon of 2006/2007 and 2007/2008 brought a lot of rainfall and floods to Malaysia and Indonesia. The rainfall during the northeast monsoon of 2006/2007 was the worst ever recorded over southern Peninsular Malaysia. The 2007/2008 northeast monsoon, however, brought heavy rainfall over different localized areas. *Section 3.5, pg 35, CC Scenarios, Jan 2009*, MMD, provides a description of the features which contributed to these heavy rainfall episodes.

3.2.1.5 Summary

Please see Appendix 2 – "Observed and Projected Change in Climate for Malaysia", for a summary of all the observations.

3.2.2 *Climate Change Projections by MMD (Chap 3, pg 18, CC Scenarios, Jan 2009, MMD)*

The past and current observed data and models projection of future climates show a picture of a warming future climate along with other variability and extremes. The world is very concerned of the frequency and magnitude of extreme events in the future. In the recent years the occurrence of extreme weather events in Malaysia has increased. The winter monsoon of 2006/2007 and 2007/2008 brought in heavy rainfall and caused severe floods in Malaysia. The heavy rainfall during the winter monsoon of 2006/2007 was the worst ever recorded over southern Peninsular Malaysia. Other extreme events such as flash floods, strong winds and waterspouts have become more frequent over the recent years. The socio-economic impacts of these extreme events have been a cause for concern for the country.

3.2.2.1 Climate Change Scenarios from Nine AOGCMs

Temperature and rainfall analysis for Malaysia was done using nine Atmosphere-Ocean General Circulation Models (AOGCM) as given in *Table 3.1* below, while the impact of global warming on the monsoons over Malaysia was studied using 12 AOGCMs. (*Section 3.1, pg 19, CC Scenarios, Jan 2009, MMD*).

The model control period is selected as the average of 1990–1999 of the 20C3M run and compared against the SRES-A1B scenario for the period 2020 – 2029, 2050 – 2059 and

2090 – 2099. The parameters analysed were the changes in precipitation and temperature over the region 90˚E – 130˚E, 5˚S – 15˚N. In addition to the above analysis, a 5-year running mean was used to show the change in precipitation in comparison to the baseline period of 1961–1990 for Peninsular Malaysia, Sarawak and Sabah for the SRES A1B scenario (areas selected for this study are as shown in *Figure 3.7*). An ensemble projection for temperature and precipitation of the nine AOGCMs were plotted for the period 2000 – 2100 for the SRES A1B scenario.

TABLE 3.1. NAME, INSTITUTION, GENERAL REFERENCE AND RESOLUTION OF AOGCM MODELS

Model	Institution	Resolution
CNCM3	Meteo-France	2.8˚ x 2.8˚
MRCGCM	Meteorological Research Institute, Japan	T42 (≈2.8˚x 2.8˚)
FGOALS	Institute of Atmospheric Physics, China	T42 (≈2.8˚x 2.8˚)
GFCM20	NOAA/GFDL, USA	2.5˚ x 2.0˚
HADCM3	Hadley Centre, UK	3.75˚x 2.5˚
MIHR	JAMSTEC, Japan	T42 (≈2.8˚x 2.8˚)
MPEH5	Max Plank Institute, Germany	T63 (≈1.8˚x 1.8˚)
NCPCM	NCAR, USA	2.8˚ x 2.8˚
CSMK3	CSIRO Atmospheric Research	2.8˚ x 2.8˚
CGMR	Canadian Centre for Climate Modeling & Analysis	T47 (≈3.75˚x 3.75˚)
MIMR	University Of Tokyo	3.75˚x2.5˚

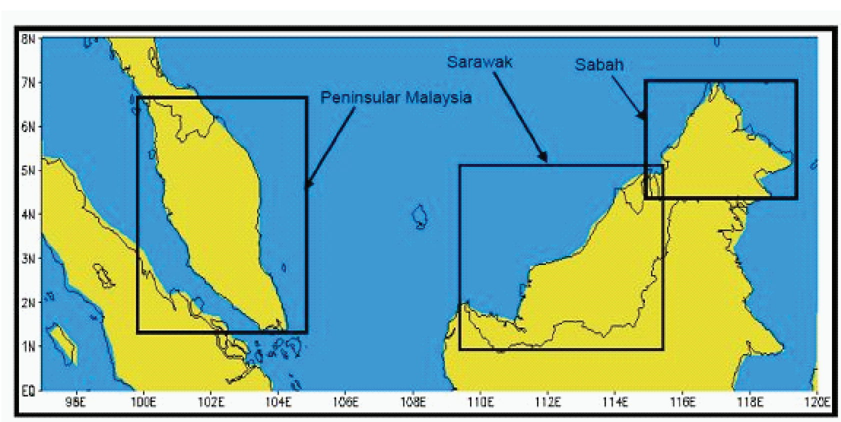


Figure 3.7. Selected Domains over the Malaysian Region.

(a) Temperature

Outputs generated by the AOGCMs show that all the models projected an increase in temperature for Peninsular Malaysia (see *Figure 13* in report), Sabah (see *Figure 14* in report) and Sarawak (see *Figure 15* in report) but the degree of temperature increase varies from model to model. An ensemble mean of the entire nine AOGCM models indicate an increasing temperature trend for the 3 domains, Peninsular Malaysia (see *Figure 16* in report), Sabah (see *Figure 17* in report) and Sarawak (see *Figure 18* in report).

Projected temperature changes for the early (2020–2029), middle (2050–2059) and late (2090–2099) part of the 21st century relative to the last decade of the 20th century (1990–1999) are also provided as shown in *Figures 19, 20* and *21*, respectively, in the report.

(b) Rainfall

There is no clear trend shown by all of the selected models due to the high variability in the precipitation-modulating factor. The 10-year running mean precipitation projections for Peninsular Malaysia, Sabah and Sarawak are as shown in *Figures 22, 23* and *24*, respectively, in the report.

Projected rainfall changes for the early (2020–2029), middle (2050–2059) and late (2090–2099) part of the 21st century relative to the last decade of the 20th century (1990–1999) are also provided as shown in *Figures 25, 26* and *27*, respectively, in the report.

The ensemble rainfall projection for the nine AOGCM for the 21st century exhibit an increase in precipitation over the West Coast states and a decrease over the East Coast states of Peninsular Malaysia (see *Figure 28(b)* in the report). For East Malaysia, the AOGCM models have projected the rainfall over western Sarawak to increase significantly by the end of the 21st century.

(c) Winter Monsoon Intensity (Section 3.4, pg 33, CC Scenarios, Jan 2009, MMD)

The interannual variations are found to be closely connected to the sea surface temperature (SST) anomaly in both the western and eastern tropical Pacific. The results suggest that the processes associated with the SST anomaly over the tropical Pacific mainly influence the strength of the winter monsoon (DJF). The winter monsoon generally becomes weak when there is a positive SST anomaly in the tropical eastern Pacific (El Niño), and it becomes strong when there is a negative SST anomaly (La Niña).

The projected 850hPa wind circulation pattern anomaly and the negative trends in the ensemble projection of the Winter Monsoon Index (2001–2099) (see *Figure 34* in the report) show the overall weakening of the winter monsoon.

3.3.2.2 Regional Climate Simulation using PRECIS (Section 4.1, pg 37, CC Scenarios, Jan 2009, MMD)

Global Circulation Models (GCM) lack the regional detail that impact assessments on climate change require. A Regional Climate Model (RCM) adds small-scale detailed information of future climate change to the large-scale projections of a GCM. They use coarse resolution information from a GCM and then develop temporally and spatially fine scale information. Generally oceans are not modelled in RCMs as this will result in increase of costing and yet will make little difference to projections over land that most impact assessment reports require. Nevertheless the ocean component is already modelled and coupled with the GCM as an Ocean Atmospheric Coupled Global Circulation Model (AOGCM).

The minimum resolution generally used by a RCM is around 50 km. Lateral atmospheric boundary conditions are obtained from GCMs. The main advantage of a RCM is that it can provide high-resolution information on a large physically consistent set of climate variables and therefore better representation of extreme events.

The Providing Regional Climates for Impacts Studies (PRECIS) Regional Climate Model had been used to simulate future climate projections for the South-East Asian region using the HadCM3 AOGCM lateral boundary data. SRES A1B scenario was used and regional simulations were done for the periods from 1960 to 2100. The simulation results for 1961 to 1990 are used as the baseline. Results from 2001 to 2099 generate climate change scenarios of the future climate.

SRES A2 and B2 simulations were also done using the PRECIS RCM. LBC for the A2 and B2 simulations were obtained from atmospheric only GCM (AGCM), the HadAM3P. The HadAM3P AGCMs for both A2 and B2 were run for the specific period or time-slice from 2070 to 2100.

Comparing the baseline (1961–1990) simulation output with the observed data for the period above, the RCM simulation was validated. Temperature and rainfall observational data was obtained from the Climate Research Unit of the University of East Anglia, United Kingdom. Resolution of the observed dataset is 60 km, which is comparable to regional simulation output of 50 km resolution.

Though there is difference in values obtained for both rainfall and temperature between the baseline simulation and the observation, nevertheless the monthly variation trend of the temperature and monthly distribution of rainfall are consistent. (see *Figure 36* in report)

(a) Temperature

Annual average surface temperature increase consistent with the GCM signal was obtained for Peninsular Malaysia, Sabah and Sarawak. Nevertheless regional modelling did simulate a deviation from the GCM in regard to projected temperatures for the period of 2080 to 2089. A significant reduction of 0.4ºC to 0.5ºC in RCM projected annual average surface temperature was obtained for all the three sub regions during the 2080 to 2089 decade.

Generally higher temperatures are simulated for East Malaysia compared to Peninsular Malaysia. Higher temperature increase during the last decade is obtained for Sarawak compared to Peninsular Malaysia and Sabah.

The rate of temperature increase during the 30-year period from 2059 to 2090 is generally double the rate of increase simulated for earlier 20-year period from 2029 to 2050. Highest temperature increasing rate during the 60-year period from 2029 to 2090 is simulated for the Eastern Sarawak region (1.4ºC to 3.8ºC) compared to the lowest increase rate simulated for Central Peninsular Malaysia (1.5ºC to 3.2ºC).

Higher detailed regional analysis of PRECIS temperature simulations driven by the HadCM3 AOGCM, for three decades representing the first quarter (2020 – 2029), middle (2050 – 2059) and end of the century (2090–2099) relative to 1990–1999 period are summarised in *Table 3.2* and shown in *Figure 3.8* below.

TABLE 3.2 – ANNUAL MEAN TEMPERATURE CHANGES (DEGREES C) RELATIVE TO 1990–1999 PERIODS

Region	2020-2029	2050-2059	2090-2099
North-West PM	1.3	1.9	3.1
North-East PM	1.1	1.7	2.9
Central PM	1.5	2.0	3.2
Southern PM	1.4	1.9	3.2
East Sabah	1.0	1.7	2.8
West Sabah	1.2	1.9	3.0
East Sarawak	1.4	2.0	3.8
West Sarawak	1.2	2.0	3.4

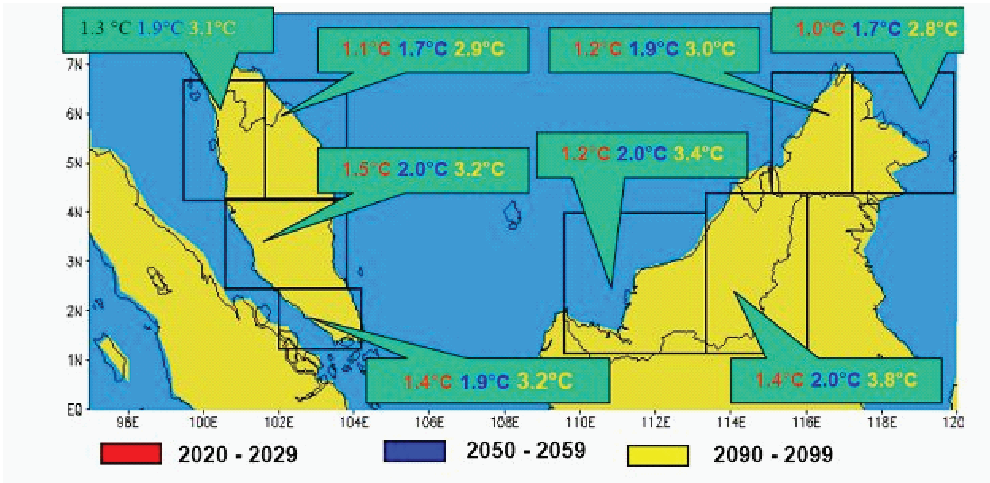


Figure 3.8. Annual Mean Temperature Anomaly Relative to 1990 – 1999.

(b) Rainfall

Seasonal rainfall trends are projected in Figures 48–51 in the report from 2001–2099 for DJF, MAM, JJA, SON. The DJF seasons for a 50-year span from 2035 to 2085 are relatively very dry for all regions. During the last third of the simulation period (2065 – 2099), an upward trend of MAM seasonal rainfall seems to be established for all three regions.

The regional rainfall response to the A2, A1B and B2 scenarios are shown in *Figure 3.9* for Peninsular Malaysia, *Figure 3.10* for Sabah and *Figure 3.11* for Sarawak. The 5-year running mean for the A2 and B2 annual rainfall has been simulated for the period from 2072 to 2097. Generally for all the three regions, less annual rainfall seems to be indicated for the B2 scenario compared to the A2 scenario. From around 2082 to 2093, very evidently an upward trend of annual rainfall is simulated for the A1B scenario, but a downward trend for both the A2 and B2 scenarios. Reduction in annual rainfall simulated in the A2 and B2 scenarios is more severe in Sabah and Sarawak compared to Peninsular Malaysia.

In terms of annual rainfall, a negative annual rainfall trend is far more evident in Sabah compared to Peninsular Malaysia and Sarawak. The significant increase in annual temperature simulated for 2028, 2048, 2061 and 2079 is consistent with the corresponding significant reduction in annual average rainfall projected for the same four years mentioned above. This consistent significant reduction of rainfall together with significant increase in temperature is generally exhibited during El Niño events. In the case of the four years mentioned above, Peninsular Malaysia, Sabah and Sarawak are all affected, which is a signature of a strong

El Niño. The impact of El Niño and La Niña events are more significant in East Malaysia compared to Peninsular Malaysia. Nevertheless all three regions seem to experience increased rainfall towards the end of the century (2080 onwards), especially Peninsular Malaysia and Sarawak.

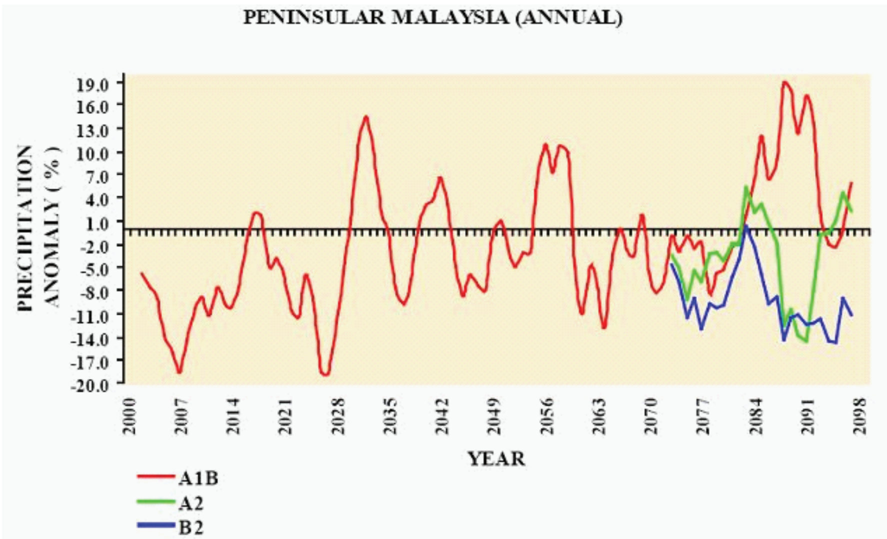


Figure 3.9. PRECIS Annual Rainfall Anomaly Simulation for Peninsular Malaysia driven by HadCM3 A1B, HadAM3P A2 and B2.

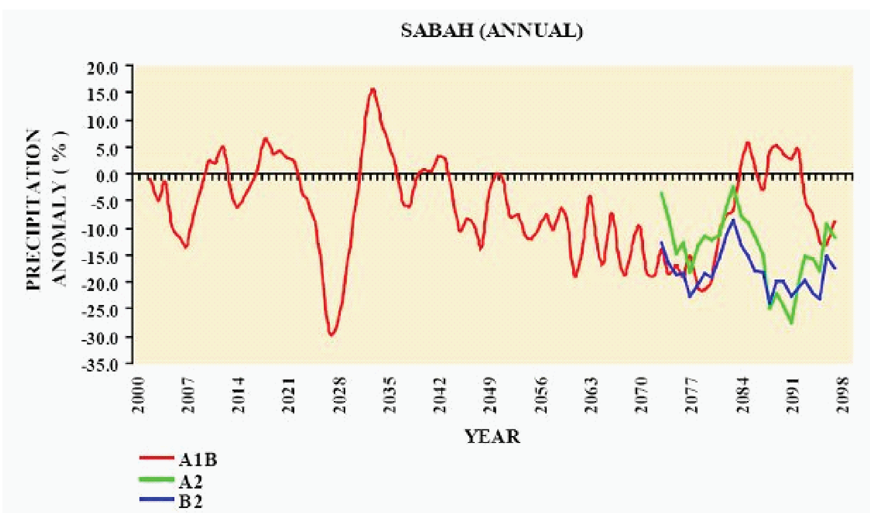


Figure 3.10. PRECIS Annual Rainfall Anomaly Simulation for Sabah driven by HadCM3 A1B, HadAM3P A2 and B2.

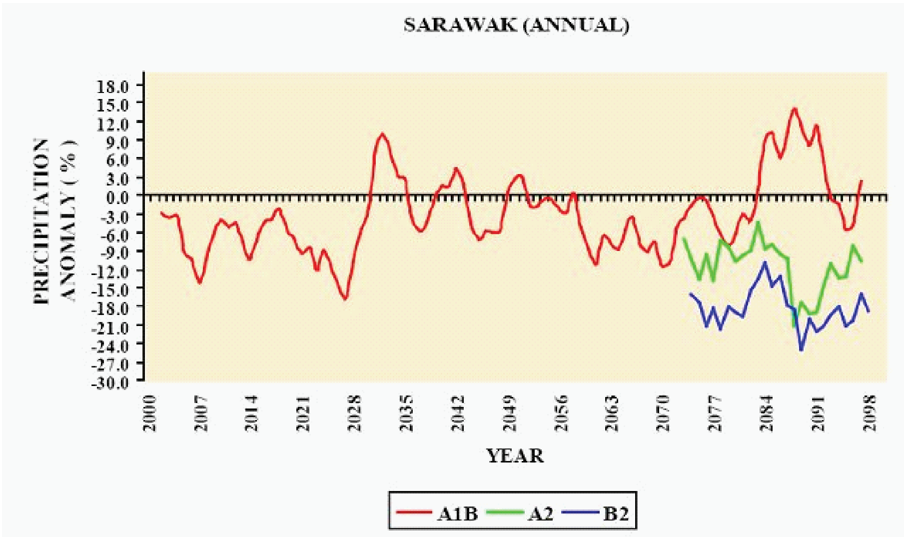


Figure 3.11. PRECIS Annual Rainfall Anomaly Simulation for Sarawak driven by HadCM3 A1B, HadAM3P A2 and B2.

Significant periods of increased annual rainfall are simulated during 2030 to 2031, 2055 to 2058 and 2084 to 2091. Of these three periods, all three regions experience significant increase during 2030 to 2031. This bears the signature of a strong La Niña like event accompanying the supposedly simulated strong El Niño like event of 2028. During the two remaining simulated wet periods, only Peninsular Malaysia experiences significant annual rainfall increase during 2055 to 2058 and all regions experience significant annual increase in rainfall during 2084 to 2091. For the last 20 years of the simulated seasonal rainfall, increasing seasonal rainfall trend is obtained clearly for Sarawak and Peninsular Malaysia compared to Sabah for all the four seasons. The extremely significant reduction of rainfall during 2028 and the accompanying significant increase in 2030 t0 2031 mentioned above is captured clearly during all seasons except for SON.

Higher detailed regional analysis of PRECIS rainfallnjmnm simulations driven by the HadCM3 AOGCM, for three decades representing the first quarter (2020 – 2029), middle (2050 – 2059) and end of the century (2090 – 2099) relative to 1990 – 1999 are summarised in *Table 3.3* and shown in *Figure 3.12* below.

3.3.2.3 Summary

Please see *Appendix 2* – "Observed and Projected Change in Climate for Malaysia", for a summary of the projections.

TABLE 3.3. ANNUAL RAINFALL CHANGES (%) RELATIVE TO 1990–1999

Region	2020-2029	2050-2059	2090-2099
North-West PM	- 11.3	6.4	11.9
North-East PM	- 18.7	- 6.0	4.1
Central PM	- 10.2	2.3	14.1
Southern PM	- 14.6	- 0.2	15.2
East Sabah	- 17.5	- 12.8	- 3.6
West Sabah	- 8.9	- 1.2	0.3
East Sarawak	- 9.1	- 1.3	6.2
West Sarawak	- 8.8	3.8	14.6

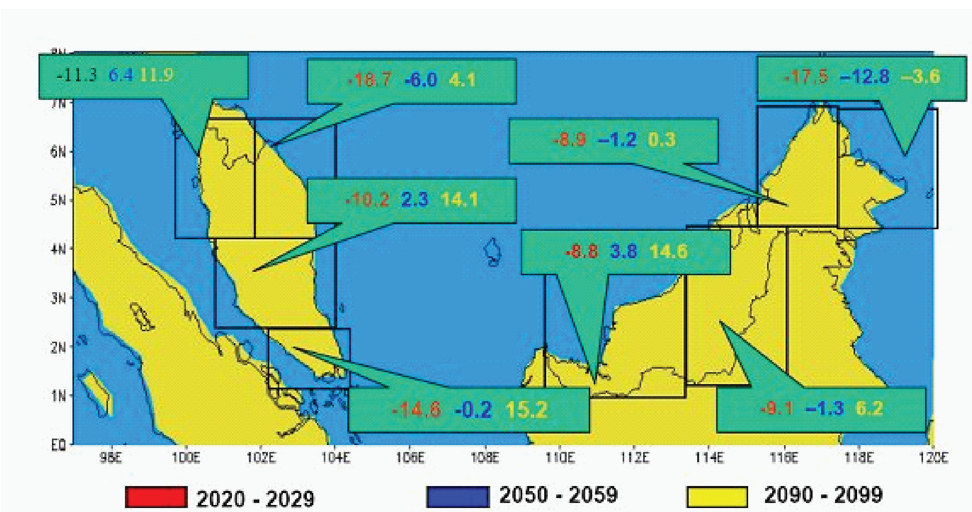


Figure 3.12. Annual mean rainfall anomaly (%) relative to 1990 – 1999.

3.2.3 Climate Change Projections by NAHRIM with RegHCM-PM

3.2.3.1 The RegHCM-PM Model

A regional hydroclimate model of Peninsular Malaysia (RegHCM-PM) was developed in order to downscale the climate change simulations of the Canadian Center for Climate Modeling and Analysis general circulation model (CGCM1) at coarse spatial resolution (410km grid resolution) to the region of Peninsular Malaysia at fine spatial resolution (9km grid resolution) for a quantitative assessment of the possible change of climate on the hydrology and water resources of Peninsular Malaysia. It is known that more refined topographic & land characteristics at regional and watershed scales have profound impact on regional climate. Furthermore, land use patterns/changes impact regional climate conditions. Thus, the climate change data at such coarse spatial resolution cannot be used directly for evaluating the climate change at regional and watershed scales for Peninsular Malaysia. Therefore, downscaling of the coarse scale GCM data to regional scale and watershed scale of Peninsular Malaysia is required for the studies of the potential long-term climate and hydrologic impacts of global warming on the hydrologic regime and water resources of Peninsular Malaysia. The Regional Hydro-climate Model of Peninsular Malaysia (RegHCM-PM) includes a mesoscale atmospheric model component and a regional land hydrology model component, similar to the original IRSHAM for Japan.

A validation of the combined CGCM1/RegHCM-PM approach to the modeling of the hydroclimate of Peninsular Malaysia was performed by comparing the hydroclimate simulations of the combined model against their historically observed counterparts during the 1984 – 1993 period over the subregions/watersheds and selected river stations of Peninsular Malaysia. These comparison results demonstrate that the RegHCM-PM (forced by the historical CGCM1-simulated data) can produce reasonable simulations of the historical hydro-climatic trends over Peninsular Malaysia at the scales of watersheds and subregions of the Peninsula. Also, the simulated hydro-climatic variables (air temperature, precipitation, river flow) are of the same order of magnitude and show similar seasonal trends as their observed counterparts.

The GCM datasets that have been used in this study are the climate change simulation datasets, corresponding to the increasing greenhouse gas (GHG) concentrations and changes in sulfate aerosol (A) loadings (GHG+A) of IPCC IS92a Scenario Run (IPCC 1992), simulated by the First Generation Coupled General Circulation Model (CGCM1) of the Canadian Center for Climate Modeling and Analysis (CCCma).

The oceanic component of the coupled model CGCM1 is a version of the GFDL modular ocean model MOM at a spatial resolution of 1.8° lat × 1.8° degree long. Therefore, for each 3.7° lat × 3.7° long grid box of the atmospheric component of CGCM1 there are four oceanic grid boxes. Because many important oceanic processes occur at fine scale (e.g. flows through Malacca strait, Gibraltar strait, etc.) higher resolution in the oceanic component is desirable.

The atmospheric model component of the RegHCM-PM is the MM5 (the Fifth Generation Mesoscale Model) from NCAR (National Center for Atmospheric Research) instead of the original mesoscale atmospheric component of IRSHAM because, unlike the original IRSHAM's atmospheric component which is hydrostatic, MM5 is a non hydrostatic model which can be downscaled even to 0.5 km spatial resolution, which makes it very desirable for downscaling climate study results to the scale of watersheds, and be able to capture the impact of steep topography of Peninsular Malaysia at watershed scale (spatial resolutions < 10 km) on the local climatic conditions.

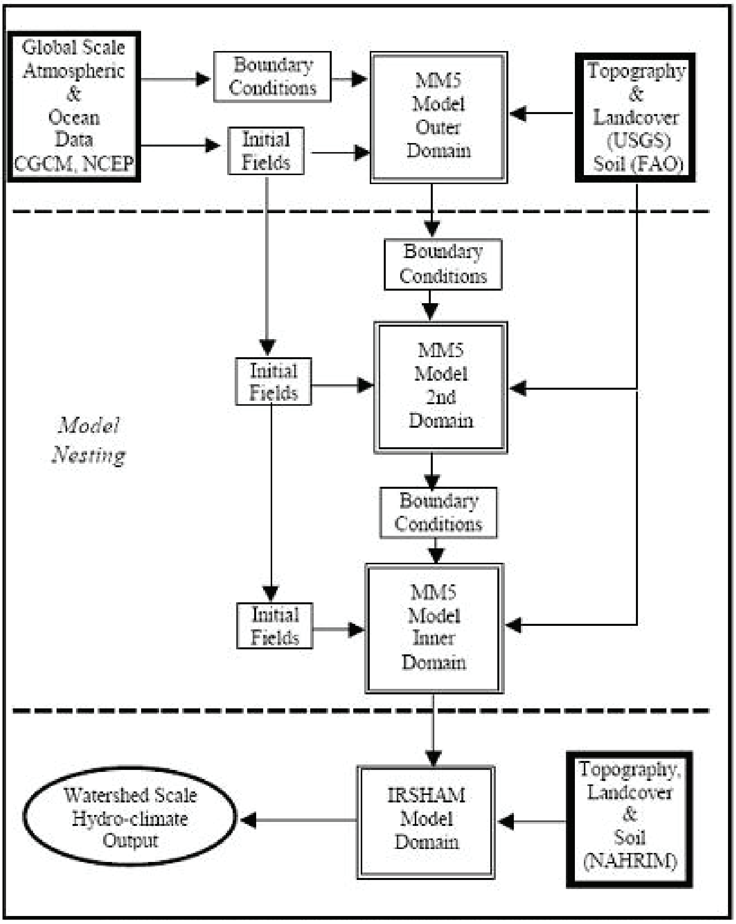
The land hydrology component of the RegHCM-PM model is still IRSHAM's hydrologic component since IRSHAM's land hydrology model component is the only fully physically-based regional land hydrology model which is based on upscaled hydrologic conservation equations.

The RegHCM-PM was run first with its initial and boundary conditions provided from the global scale atmospheric data at an outer domain, covering the whole Peninsular Malaysia region and the surrounding areas, and to be called "outer domain". Then, the second domain of RegHCM-PM was nested inside the outer domain and RegHCM-PM was run over the inner domain with its initial conditions coming from global scale atmospheric data, interpolated at 9 km, while its boundary conditions were provided from the simulation results of the second domain RegHCM-PM simulations. The simulations of inner domain RegHCM-PM with these initial and boundary conditions provide comprehensive atmospheric data (precipitation, air temperature, radiation, wind, relative humidity, evapotranspiration) at 9 km spatial grid resolution at 1 hr time intervals, as shown in the data flow chart of the RegHCM-PM in *Figure 3.13*. Finally, the water balances over the Peninsular Malaysia under a given climate change scenario are assessed by means of this hydro-climate model.

For more details on the various components of the RegHCM-PM model and its validation, please refer to the "*Study of the Impact of Climate Change on the Hydrologic Regime and Water Resources of Peninsular Malaysia*" (NAHRIM, 2006) and *Regional Hydroclimate Model of Malaysia* paper by Chen *et al*.

3.2.3.2 <u>Future Climate</u>

The impact of change in the climate during the two ten-year future periods 2025–2034 and 2041–2050 on the atmospheric conditions and hydrologic regime of Malaysian Peninsula is assessed. The future simulation of the hydroclimate over Peninsular Malaysia during 2025–2034 and 2041–2050 periods is compared against the CGCM1/RegHCM-PM simulated historical hydro-climate over Peninsular Malaysia during 1984 – 1993 in order to quantify the potential changes in atmospheric and hydrologic conditions over the region.



NCEP: stands for United States National Center for Environmental Prediction;
USGS: United States Geological Survey;
FAO: Food and Agriculture Organization of the United Nations;
CGCM: Canadian General Circulation Model
NAHRIM: National Hydraulics Research Institute of Malaysia

Figure 3.13. Data Flow Chart of RegHCM of Peninsular Malaysia (RegHCM-PM).

3.2.3.3 Summary

Table 3.4 gives a summary of the results from the RegHCM-PM for some key hydrological variables for two future ten-year eriods of 2025–2034 and 2041–2050.

A comparison of 32 GCMs during the Atmospheric Model Inter-comparison Project (AMIP) showed that none of the current GCMs can simulate well the monsoon conditions or rainfall over Southeast Asia.

For more details on the projections, please refer to the "Study of the Impact of Climate Change on the Hydrologic Regime and Water Resources of Peninsular Malaysia" (NAHRIM, 2006) and NC2 Combined Climate Projection Report (2010).

Please see *Appendix 2 – "Observed and Projected Change in Climate for Malaysia*", for a summary of the projections.

TABLE 3.4. SUMMARY OF THE RESULTS FROM THE REGHCM-PM FOR SOME KEY HYDROLOGICAL VARIABLES FOR TWO FUTURE TEN-YEAR PERIODS OF 2025–2034 AND 2041–2050

		PROJECTED (for the period 2025-2034 and 2041 - 2050 relative to 1984-1993)
(1)	**Averaged Annual Air Temperature**	+1.5°C
(2)	**Averaged Annual Rainfall**	+10% (Kelantan, Terengganu & Pahang) -5% (Selangor & Johor)
(3)	**River Flow (Monthly)**	+11% to +43% (Flood Flows) -31% to -93% (Low Flows)
(4)	**Evapotranspiration**	No significant changes
(5)	**Soil Water**	Seasonal oscillation for monthly storage

3.3 Climate Change Model Projections for Southeast Asia

The ADB report on "The Economics of Climate Change in South East Asia: A Regional Review" has compiled the results of climate observations in five South East Asian countries - Thailand, the Phillippines, Indonesia, Vietnam and Singapore. Also, climate change simulation results for the region were reported for the A1F1 and B2 scenarios of the IPCC Special Report on Emissions Scenario 2000 (SRES) for three cases: the Business As Usual (BAU) or baseline case; stabilization at 550 ppm; and stabilization at 450 ppm. The results also consider human induced climate change and its consequences within three timelines: The Short Term (2020), Medium Term (2050) and Long Term (2100). The following is a summary of the relevant results from the ADB report.

3.3.1 *Observed Changes in Climate*

Climate change is already affecting the region. The IPCC (2007) reports an increasing trend in mean surface air temperature in Southeast Asia during the past several decades, with a 0.1–0.3°C increase per decade recorded between 1951 and 2000. Rainfall has been trending down and sea levels up (at the rate of 1–3 millimeters per year), and the frequency of extreme weather events has increased: heat waves are more frequent (an increase in the number of hot days and warm nights and decrease in the number of cold days and cold nights since 1950); heavy precipitation events rose significantly from 1900 to 2005; and the number of tropical cyclones was higher during 1990– 2003.

Tables 3.5 and *3.6* show the extracted tables from the ADB report for the observed changes in temperature and precipitation for the five countries in Southeast Asia, respectively.

TABLE 3.5. OBSERVED TEMPERATURE CHANGES IN SOUTHEAST ASIA[a]

Table 3.1. Observed Temperature Changes in Southeast Asia

	Temperature change (°C)	Source
Indonesia	Increase of 1.04–1.40°C per century	Rataq (2007)
Philippines	Increase of 1.4°C per century	IPCC (2007)
Singapore	Increasing by about 0.3°C per decade as observed between 1987–2007	Ho (2008)
Thailand	Increase of 1.04–1.80°C per century	Jesdapipat (2008)
Viet Nam	Increase of 1.0°C per century	Cuong (2008)

Source: Compiled by ADB study team.

[a](Extracted from *Table 3.1* in ADB Report)

TABLE 3.6 – OBSERVED CHANGE IN PRECIPITATION IN SOUTHEAST ASIA[a]

Table 3.3. Observed Change in Precipitation in Southeast Asia

	Change in precipitation	Reference
Indonesia	Decrease in annual rainfall during recent decades in some areas	Aldrian (2007)
Philippines	Increase in annual rainfall and in the number of rainy days	Anglo (2006)
Singapore	Decrease in annual rainfall in the past three decades	Ho (2008)
Thailand	Decreasing annual rainfall for the last five decades	Jesdapipat (2008)
Viet Nam	Decrease in monthly rainfall in July-August and increase in September to November	Cuong (2008)

Source: Compiled by ADB study team.

[a] (Extracted from *Table 3.3* in ADB Report)

Sea levels have also risen in Southeast Asia in the last few decades, between 1 and 3 mm per year on average, marginally higher than the global average.

An analysis of the data for the past 13 years of tide levels at Tanjong Pagar, Singapore shows an average tide level of 3.3 meters and no observable trend toward higher mean sea levels so far. Because Singapore is a small country, this measurement at one location may be taken as representative of the whole country.

3.3.2 *Climate Change Projections*

Under a high emissions scenario (that is, A1FI), developed in IPCC (2000), by the end of this century temperatures could be more than 4°C above 1980–1999 levels, ranging from 2.5–6°C (*Box 3.1*). This trend could be seriously amplified in different regions of the world. According to IPCC (2007) projections, the mean surface air temperature in Southeast Asia would increase between 0.75–0.87°C by 2039, 1.32–2.01°C by 2069, and 1.96–3.77°C by 2100, depending on which business-as-usual (BAU) baseline scenario is assumed (*Table 3.2*). While in most parts of Asia the greatest warming occurs from December to February, future warming in Southeast Asia is projected to occur throughout the year.

There is a tendency for warming to be stronger over mainland Southeast Asia and the larger land masses of the archipelago.

Tables 3.7 and *3.8* show the extracted tables from the ADB report for the projected changes in the global average surface warming and sea level rise in 2100, and change in mean surface air temperature for Southeast Asia under A1F1 and B1 SRES scenarios, respectively.

TABLE 3.7. PROJECTED GLOBAL AVERAGE SURFACE WARMING AND SEA LEVEL RISE IN 2100[a]

Table 3.7. Projected Global Average Surface Warming and Sea Level Rise in 2100

Case	Termperature change (°C) (in 2090–2099 relative to 1980–1999) [a]		Sea level rise (meter) (in 2090–2099 relative to 1980–1999)
	Best estimate	Likely range	Model-based range excluding future rapid dynamic changes in ice flow
At constant year 2000 GHG concentration [b]	0.6	0.3–0.9	–
B1 scenario	1.8	1.1–2.9	0.18–0.38
A1T scenario	2.4	1.4–3.8	0.20–0.45
B2 scenario	2.4	1.4–3.8	0.20–0.43
A1B scenario	2.8	1.7–4.4	0.21–0.48
A2 scenario	3.4	2.0–5.4	0.23–0.51
A1FI scenario	4.0	2.4–6.4	0.26–0.59

– = not available.
a These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity, and a large number of Atmosphere-Ocean Global Circulation Models (AOGCMs).
b Year 2000 constant composition is derived from AOGCMs only.
Source: IPCC (2007).

[a](Extracted from *Table 3.7* in ADB Report)

TABLE 3.8. PROJECTED CHANGE IN MEAN SURFACE AIR TEMPERATURE FOR SOUTHEAST ASIA UNDER A1F1 AND B1 SRES SCENARIOS [a]

Table 3.2. Projected Change in Mean Surface Air Temperature for Southeast Asia under A1FI and B1 (with respect to baseline period of 1961–1990), °C

Season	2010–2039		2040–2069		2070–2099	
	A1FI	B1	A1FI	B1	A1FI	B1
December to February	0.86	0.72	2.25	1.32	3.92	2.02
March to May	0.92	0.80	2.32	1.34	3.83	2.04
June to August	0.83	0.74	2.13	1.30	3.61	1.87
September to November	0.85	0.75	1.32	1.32	3.72	1.90
Mean	0.87	0.75	2.01	1.32	3.77	1.96

Source: IPCC (2007).

[a] (Extracted from *Table 3.2* in ADB Report)

The ADB report projected that temperature in Indonesia will increase 2.1ºC and 3.4ºC by 2100 under the B2 and A2 scenarios, respectively. It is also reported that there will be a projected temperature increase of 1.2–3.9ºC in the Philippines by 2080, using all the IPCC emission scenarios. The temperature rise in Singapore by the end of this century, according to IPCC (2007), is likely to be similar to the projected global mean temperature rise of 2.5ºC with a range of 1.7–4.4ºC. Thailand's temperature, based on the climate data generated by a global circulation model, is projected to increase 2–4ºC by the end of this century. Most regions in Viet Nam are projected to experience an increase in temperature of 2–4ºC by 2100.

By 2050, Southeast Asia's precipitation will increase 1% under A1FI and 2.25% under B1 (See *Table 3.9* below), with the strongest rise starting in December and ending in May (*Table 3.4*). Localized climatic change patterns are likely to show significant variation from the regional average due to the very complex topography and maritime influences within Southeast Asia. The strongest increase in rainfall will follow the inter-tropical convergence zone, which could occur between December and May in some parts. Away from the inter-tropical convergence zone, precipitation will decrease. Broadly, the projected precipitation pattern is that the wet season will become wetter and the dry season drier.

TABLE 3.9. PROJECTED CHANGES IN PRECIPITATION FOR SOUTHEAST ASIA UNDER A1F1 AND B1 SRES SCENARIOS [a]

Table 3.4. Projected Change in Precipitation for Southeast Asia under A1FI and B1 (with respect to baseline period 1961–1990), %

Season	2010–2039		2040–2069		2070–2099	
	A1FI	B1	A1FI	B1	A1FI	B1
December–February	-1	1	2	4	6	4
March–May	0	0	3	3	12	5
June–August	-1	0	0	1	7	1
September–November	-2	0	-1	1	7	2
Mean	-1.00	0.25	1.00	2.25	8.00	3.00

Source: IPCC (2007).

[a] (Extracted from *Table 3.4* ADB Report)

3.3.3 *Key Conclusions*

Figure 3.14 presents the key conclusions from the ADB report on the climate change projections for Southeast Asia.

3.4 Comparisons of the Climate Projections Outputs

Comparing the data and information gathered from the MMD climate change scenarios, NAHRIM's RegHCM-PM modeling, and ADB Economics of Climate Change for SEA study (which uses IPCC AR 4 projections), the following observations are made. These observations were made, despite the fact that different emissions scenarios have been used, different baselines and different time scales were considered. Therefore, the observations are intended only to give a broad indication of how our national climate projections compare with the projections for Southeast Asia.

With regard to the emissions scenarios, *Figure 3.15* below from the ADB study describes the different emission scenarios used in IPCC 2007 for the projections of global surface warming. Of this, the studies above have applied the A1B, A2, B2 and A1F1 scenarios. An earlier IPCC scenario called IS92a (IPCC 1992) was used in the RegHCM-PM model. Both the MMD and ADB studies have used the B2 scenario as one of the scenarios considered.

Key Messages

Climate change modeling carried out under this study using an integrated assessment model confirms many of the findings documented in existing studies and provides new estimates of climate change and its likely impact in coming decades, with a particular focus on Indonesia, Philippines, Thailand, and Viet Nam.

Climate patterns in Southeast Asia are likely to change significantly, with impact on the environment and economies expected to be more severe than the world average. The actual extent of climate change and impact depends on the assumed future emission scenarios, and on the level of global mitigation action.

The region's mean temperature by 2100 is projected to increase 2.5°C under B2—a medium emissions scenario—and 4.8°C under A1FI—a high emissions scenario—from 1990, without global mitigation. With stabilization under A1FI, from 1990, temperature will only increase 2.3°C at 550 parts per million (ppm) and 1.8°C at 450 ppm.

Increasingly drier weather conditions are projected to afflict Indonesia, Thailand, and Viet Nam over the next 2–3 decades although this trend is projected to reverse by mid-century.

Global mean sea level is projected to rise 70 cm by the end of this century relative to the 1990 level under A1FI, and Southeast Asia is to follow this global trend, threatening economic activity and population in coastal areas and islands.

Climate change is likely to worsen water stress in parts of the region, particularly Thailand and Viet Nam, in coming decades; water resources in Indonesia, Thailand and Viet Nam are projected to be most vulnerable.

Under A1FI, rice yield potential in the four countries is projected to decline about 50% by 2100 on average, relative to 1990, without adaptation or technical improvements. Part of the decline could be offset by productivity improvements and adaptation.

Figure 3.14. Key conclusions from the ADB report on the climate change projections for Southeast Asia.

In terms of findings, rainfall patterns are influenced greatly by local topographical and other factors. Hence, findings from comparing data in these different studies may not be indicative of much given the spatial variance.

Finally, it can be seen that future modeling exercises involve uncertainty management as evident from the very different projections provided by the different AOGCM models.

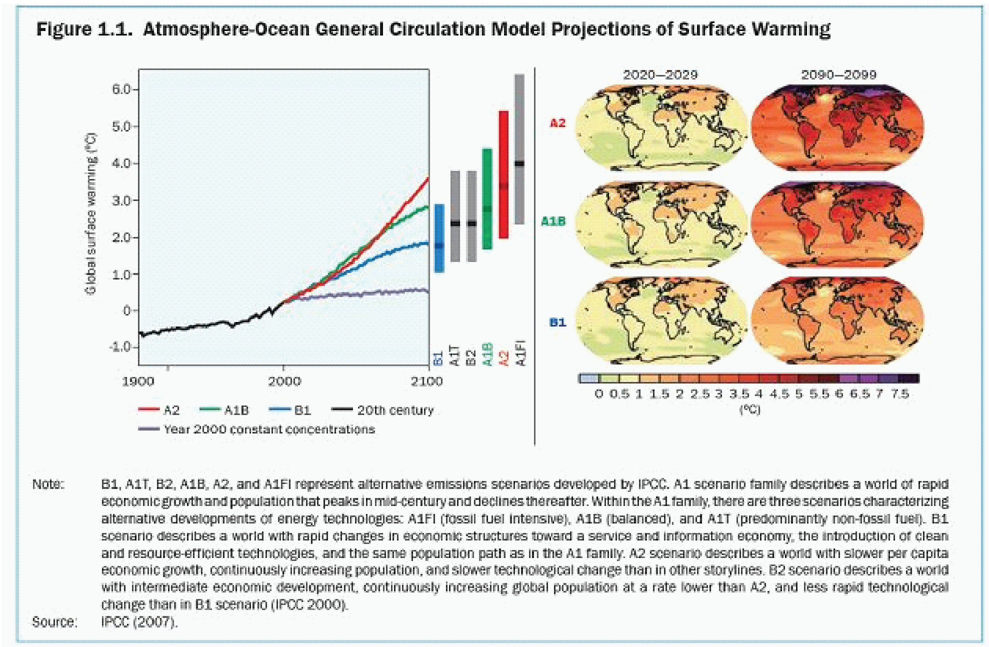


Figure 3.15. Atmosphere-Ocean General Circulation Model Projections of Surface Warming (Extracted from Figure 1.1 *in ADB report).*

3.4.1 *Temperature*

Table 3.10 shows the comparisons of the PRECIS and RegHCM models' temperature projections for Malaysia with the IPCC (2007) projections for Southeast Asia as reported in the ADB Report.

It can be seen that generally, the PRECIS model's projections for the early part of the century is higher for Malaysia compared to the projections for SEA. For mid and late century, the PRECIS model's projections using the A1B scenario appear to correspond with the A1F1 (worst case scenario) projections for SEA. The RegHCM-PM model's projections appear to depict a slower rate of temperature rise compared to the PRECIS model's projections for Peninsular Malaysia and are comparable to the mid-century B1 projections for SEA.

3.4.2 *Rainfall*

Table 3.11 shows the comparisons of the PRECIS and RegHCM models' rainfall projections for Malaysia with the IPCC (2007) projections for Southeast Asia as reported in the ADB Report.

TABLE 3.10 COMPARISONS OF PRECIS AND REGHCM MODELS' TEMPERATURE PROJECTIONS FOR MALAYSIA WITH THE IPCC (2007) PROJECTIONS FOR SOUTHEAST ASIA AS REPORTED IN THE ADB REPORT

Model	Scenario	Early 21st Century (°C)	Mid 21st Century (°C)	Late 21st Century (°C)
PRECIS (Malaysia)	A1B	1.0-1.5	2	2.8-3.8
PRECIS (PM)	A1B	1.1-1.5	1.7-2.0	2.9-3.2
PRECIS (EM)	A1B	1.0-1.4	1.7-2.0	2.8-3.8
RegHCM-PM	IS92a		1-1.5	
Global A1B (Best estimate)		N/A	N/A	1.7-4.4 (2.8)
IPCC (SEA) From ADB study	B1	0.75	1.32	1.96
IPCC (SEA) From ADB study	A1F1	0.87	2.01	3.77

TABLE 3.11. COMPARISONS OF PRECIS AND REGHCM MODELS' RAINFALL PROJECTIONS FOR MALAYSIA WITH THE IPCC (2007) PROJECTIONS FOR SOUTHEAST ASIA AS REPORTED IN THE ADB REPORT

Model	Scenario	Early 21st Century (%)	Mid 21st Century (%)	Late 21st Century (%)
PRECIS (Malaysia)	A1B	(-)18.7 to (-)8.8	(-) 12.8 to (+) 6.4	(-) 3.6 to (+) 15.2
PRECIS (PM)	A1B	(-)18.7 to (-)10.2	(-) 6 to (+) 6.4 %	(+) 4.1 to (+) 15.2 %
PRECIS (EM)	A1B	(-)17.0 to (-)8.8	(-) 12.8 to (+) 3.8	(-) 3.6 to (+) 14.6
RegHCM-PM	IS92a		(-) 5 to (+)10	
Global A1B (Best estimate)		N/A	N/A	N/A
IPCC (SEA) From ADB study	B1	(+) 0.25	(+) 2.25	(+) 3
IPCC (SEA) From ADB study	A1F1	(-) 1	(+) 1	(+) 8

It can be seen that generally, the PRECIS model's projections indicate a higher rate of decrease in the early part of the century than the A1FI projection which shows a lower negative trend. The B1 projection for SEA shows an increasing trend. Both the PRECIS and RegHCM-PM models' projections show a trend range of negative to positive for Malaysia for mid century (and late century for PRECIS) while the SEA projections for both scenarios show positive trends. The PRECIS and RegHCM-PM models' projections also correspondingly show a negative to positive trend range for Peninsular Malaysia. It is likely that the more refined features required for hydro-climate modeling of the PRECIS and RegHCM-PM modeling has captured more precise information for Malaysia regarding rainfall.

3.4.3 *Conclusions*

While it is evident from the above that there is inherent uncertainty in climate change projections, nevertheless the exercise of downscaling as well as analyzing future climate projections helps to focus attention on key sectors and/or regions that would be potentially most impacted. A system to manage the inherent uncertainties to best utilize the information gained from these projections should be formulated and disseminated to all key stakeholders.

CHAPTER 4. OVERVIEW OF CLIMATE CHANGE IMPACT, VULNERABILITY AND ADAPTATION FOR THE WATER SECTOR

This Chapter provides an overview discussion of the key concepts and messages relating to climate change impacts, vulnerability and adaptation, with particular emphasis on water-related issues. The aim of this Chapter is to provide the reader with a concise appreciation of the key messages contained in two key reports — (a) "The Stern Review: Economics of Climate Change" and (b) "Economics of Climate Change in South East Asia: A Regional Review" by ADB. The information contained in this Chapter has been extracted and synthesized from the two reports.

4.1 Overview of Climate Change Impacts and Vulnerability (Stern Review report)

4.1.1 *Key message on impacts and vulnerability*

Climate change will affect people's lives, the environment and the prospects for economic growth and development in different parts of the world. All three dimensions are fundamental to understanding how climate change will affect our future. These effects will not be felt evenly across the globe. Although some parts of the world would benefit from modest rises in temperature, at higher temperature increases, most countries will suffer heavily and global growth will be affected adversely.

For some of the poorest countries there is a real risk of being pushed into a downwards spiral of increasing vulnerability and poverty. Average global temperature increases of only 1–2°C (above pre-industrial levels) could commit 15–40 percent of species to extinction. As temperatures rise above 2–3°C, as will very probably happen in the latter part of this century, so the risk of abrupt and large-scale damage increases, and the costs associated with climate change — across the three dimensions of mortality, ecosystems and income – are likely to rise more steeply. In mathematical terms, the global damage function is convex. No region would be left untouched by changes of this magnitude, though developing countries would be affected especially adversely.

Modelling work undertaken by the Review suggests that the risks and costs of climate change over the next two centuries could be equivalent to an average reduction in global per capita consumption of at least 5%, now and forever. The estimated damages would be much higher if non-market impacts, the possibility of greater climate sensitivity, and distributional issues were taken into account.

Figure 4.1 below summarises the key messages from the Chapter on impacts and vulnerability of climate change in the Stern Review report.

Key Messages

Climate change threatens the basic elements of life for people around the world – access to water, food, health, and use of land and the environment. On current trends, average global temperatures could rise by 2 - 3°C within the next fifty years or so,[1] leading to many severe impacts, often mediated by water, including more frequent droughts and floods (Table 3.1).

- **Melting glaciers** will increase flood risk during the wet season and strongly reduce dry-season water supplies to one-sixth of the world's population, predominantly in the Indian sub-continent, parts of China, and the Andes in South America.
- **Declining crop yields**, especially in Africa, are likely to leave hundreds of millions without the ability to produce or purchase sufficient food - particularly if the carbon fertilisation effect is weaker than previously thought, as some recent studies suggest. At mid to high latitudes, crop yields may increase for moderate temperature rises (2 – 3°C), but then decline with greater amounts of warming.
- **Ocean acidification**, a direct result of rising carbon dioxide levels, will have major effects on marine ecosystems, with possible adverse consequences on fish stocks.
- **Rising sea levels** will result in tens to hundreds of millions more people flooded each year with a warming of 3 or 4°C. There will be serious risks and increasing pressures for coastal protection in South East Asia (Bangladesh and Vietnam), small islands in the Caribbean and the Pacific, and large coastal cities, such as Tokyo, Shanghai, Hong Kong, Mumbai, Calcutta, Karachi, Buenos Aires, St Petersburg, New York, Miami and London.
- Climate change will increase worldwide deaths from **malnutrition and heat stress**. Vector-borne diseases such as malaria and dengue fever could become more widespread if effective control measures are not in place. In higher latitudes, cold-related deaths will decrease.
- By the middle of the century, 200 million more people may become **permanently displaced** due to rising sea levels, heavier floods, and more intense droughts, according to one estimate.
- **Ecosystems** will be particularly vulnerable to climate change, with one study estimating that around 15 – 40% of species face extinction with 2°C of warming. Strong drying over the Amazon, as predicted by some climate models, would result in dieback of the forest with the highest biodiversity on the planet.

The consequences of climate change will become disproportionately more damaging with increased warming. Higher temperatures will increase the chance of triggering abrupt and large-scale changes that lead to regional disruption, migration and conflict.

- Warming may induce **sudden shifts in regional weather patterns** like the monsoons or the El Niño. Such changes would have severe consequences for water availability and flooding in tropical regions and threaten the livelihoods of billions.
- **Melting or collapse of ice sheets** would raise sea levels and eventually threaten at least 4 million Km^2 of land, which today is home to 5% of the world's population.

Figure 4.1. Key Messages on Climate Change Impacts (Stern Review report).

4.1.2 *Overview of water-related impacts and vulnerability*

People will feel the impact of climate change most strongly through changes in the distribution of water around the world and its seasonal and annual variability. Water is an essential resource for all life and a requirement for good health and sanitation. It is a critical input for almost all production and essential for sustainable growth and poverty reduction.

The location of water around the world is a critical determinant of livelihoods. Globally, around 70% of all freshwater supply is used for irrigating crops and providing food.

About 22% is used for manufacturing and energy (cooling power stations and producing hydro-electric power), while only 8% is used directly by households and businesses for drinking, sanitation, and recreation.

Climate change will alter patterns of water availability by intensifying the water cycle. Droughts and floods will become more severe in many areas. There will be more rain at high latitudes, less rain in thedry subtropics, and uncertain but probably substantial changes in tropical areas. Hotter land surface temperatures induce more powerful evaporation and hence more intense rainfall, with increased risk of flash flooding.

Differences in water availability between regions will become increasingly pronounced. Areas that are already relatively dry, such as the Mediterranean basin and parts of Southern Africa and South America, are likely to experience further decreases in water availability, for example several (but not all) climate models predict up to 30% decrease in annual runoff in these regions for a 2°C global temperature rise and 40 – 50% for 4°C. In contrast, South Asia and parts of Northern Europe and Russia are likely to experience increases in water availability (runoff), for example a 10 – 20% increase for a 2°C temperature rise and slightly greater increases for 4°C, according to several climate models.

These changes in the annual volume of water each region receives mask another critical element of climate change – its impact on year-to-year and seasonal variability. An increase in annual river flows is not necessarily beneficial, particularly in highly seasonal climates, because:

(a) There may not be sufficient storage to hold the extra water for use during the dry season; and
(b) Rivers may flood more frequently.

In dry regions, where runoff one-year-in-ten can be less than 20% of the average annual amount, understanding the impacts of climate change on variability of water supplies is perhaps even more crucial.

One recent study from the Hadley Centre predicts that the proportion of land area experiencing severe droughts at any one time will increase from around 10% today to 40% for a warming of 3 to 4°C, and the proportion of land area experiencing extreme droughts will increase from 3% to 30%. In Southern Europe, serious droughts may occur every 10 years with a 3°C rise in global temperatures instead of every 100 years if today's climate persisted.

4.1.3 *The Meaning of Water Stress*

As the water cycle intensifies, billions of people will lose or gain water. Some risk becoming newly or further water stressed, while others see increases in water availability. Seasonal and annual variability in water supply will determine the consequences for people through floods or droughts.

Around one-third of today's global population live in countries experiencing moderate to high water stress, and 1.1 billion people lack access to safe water. *Figure 4.2* shows *Box 3.3* extracted from the Stern Review report explaining the meaning of water stress. Water stress is a useful indicator of water availability but does not necessarily reflect access to safe water. Even without climate change, population growth by itself may result in several billion more people living in areas of more limited water availability.

The effects of rising temperatures against a background of a growing population are likely to cause changes in the water status of billions of people. According to one study, temperature rises of 2°C will result in 1– 4 billion people experiencing growing water shortages, predominantly in Africa, the Middle East, Southern Europe, and parts of South and Central America. At the same time, 1 – 5 billion people, mostly in South and East Asia, may receive more water. However, much of the extra water will come during the wet season and will only be useful for alleviating shortages in the dry season if storage could be created (at a cost). The additional water could also give rise to more serious flooding during the wet season.

4.2 Role, Perspective, Limits and Barriers to Climate Change Adaptation (Stern Review report)

4.2.1 *The Role of Adaptation to Climate Change*

Adaptation is a vital part of a response to the challenge of climate change. It is the only way to deal with the unavoidable impacts of climate change to which the world is already committed, and additionally offers an opportunity to adjust economic activity in vulnerable sectors and support sustainable development.

A broad definition of adaptation, following the IPCC, is:

> *"any adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."*

The objective of adaptation is to reduce vulnerability to climatic change and variability, thereby reducing their negative impacts, as illustrated and described in *Figure 4.3* below. It should also enhance the capability to capture any benefits of climate change. Hence adaptation, together with mitigation, is an important response strategy. Without early and strong mitigation, the costs of adaptation will rise, and countries' and individuals' ability to adapt effectively will be constrained.

Box 3.3 Meaning of water stress metrics

Water is essential for human existence and all other forms of life. Over half of the world's drinking water is taken directly from rivers or reservoirs (natural or man-made), and the rest from groundwater. Water supply is determined by runoff – the amount of water that flows over the land surface. Typically this water flows in channels such as streams and rivers, but may also flow over the land surface directly.

Water stress is a useful indicator of water availability but does not necessarily reflect access to safe water. The availability of water resources in a watershed can be calculated by dividing long-term average annual runoff (or "renewable resource") by the number of people living in the watershed.[27] A country experiences *water scarcity (or "severe water stress")* when supply is below 1000 m^3 per person per year and *absolute scarcity (or "extreme water stress")* when supply is below 500m^3 per person per year. The thresholds are based loosely on average annual estimates of water requirements in the household, agricultural, industrial and energy sectors, and the needs of the environment.

For comparative purposes, the basic water requirement for personal human needs, excluding that used directly for growing food, is around 50 Litres (L) per person per day or 18.25 m^3 per person per year which includes allowances for drinking (2 - 5 L per person per day), sanitation (20 L per person per day), bathing (15 L per person per day), and food preparation (10 L per person per day). This does *not* include any allowance for growing food, industrial uses or the environment, which constitute the bulk of the use (see next point).[28]

The threshold for water scarcity is considerably higher than the basic water requirement for three reasons:

- Much of the water available to communities is used for purposes other than direct human consumption. Globally, the largest user of water is irrigated agriculture, representing 70% of present freshwater withdrawals. Industry accounts for 22% through manufacturing and cooling of thermoelectric power generation, although much of this is returned to the water system but at higher temperature. Domestic, municipal and service industry use accounts for just 8% of global water use. The proportions of water used in each sector can vary considerably by country. For example in Europe, water used for domestic, municipal and service industries is a very high proportion of total demand. Agriculture in large parts of Asia and Africa is rain-fed and does not rely on irrigation and storage infrastructure.
- Not all river flows are available for use (some flows occur during floods, and some is used by ecosystems). On average, approximately 30% of river flows occur as non-captured flood flows, and freshwater ecosystem use ranges between 20 and 50% of average flows. Taken together, 50 - 80% of average flow is unavailable to humans, meaning that a threshold of 1000 m^3 per person per year of average flows translates into 200 to 500 m^3/person/year *available* flows.
- The 1000 m^3 per person per year is an annual average and does not reflect year-to-year variability. In dry regions, runoff one-year-in-ten can be less than one-fifth the average, so that less than 200 m^3 would be available per person even before other uses are taken into account.

Water availability per person is only one indicator of potential exposure to stress. Some "stressed" watersheds will have effective management systems and water pricing in place to provide adequate supplies (e.g. through storage), while other watersheds with more than 1000 m^3 per person per year may experience severe water shortages because of lack of access to water.

Source: Prepared with assistance from Prof Nigel Arnell, Tyndall Centre and University of Southampton

Figure 4.2. Meaning of Water Stress Metrics (Stern Review report).

Adaptation can operate at two broad levels:

(a) **Building adaptive capacity** — creating the information and conditions (regulatory, institutional, managerial) that are needed to support adaptation. Measures to build adaptive capacity range from understanding the potential impacts of climate change, and the options for adaptation (i.e. undertaking impact studies and identifying vulnerabilities), to piloting specific actions and accumulating the resources necessary to implement actions.

(b) **Delivering adaptation actions** — taking steps that will help to reduce vulnerability to climate risks or to exploit opportunities. Examples include: planting different crops and altering the timing of crop planting; and investing in physical infrastructure to protect against specific climate risks, such as flood defences or new reservoirs.

4.2.2 *Adaptation Perspective*

(a) *Some adaptation will occur autonomously, as individuals respond to changes in the physical, market or other circumstances in which they find themselves. Other aspects will require greater foresight and planning, e.g. major infrastructure decisions.*

Adaptation is different from mitigation because:

(i) it will in most cases provide local benefits, and
(ii) these benefits will typically be realised without long lag times. As such, many actions will be taken 'naturally' by private actors such as individuals, households and businesses in response to actual or expected climate change, without the active intervention of policy. This is known as '**autonomous' adaptation**. In contrast, **policy-driven adaptation** can be defined as the result of a deliberate policy decision.

Autonomous adaptation is undertaken in the main by the private sector (and in unmanaged natural ecosystems), while policy-driven adaptation is associated with public agencies - either in that they set policies to encourage and inform adaptation or they take direct action themselves, such as public investment. Table 4.1 gives practical examples of autonomous and policy-driven adaptations for both short and long time frames.

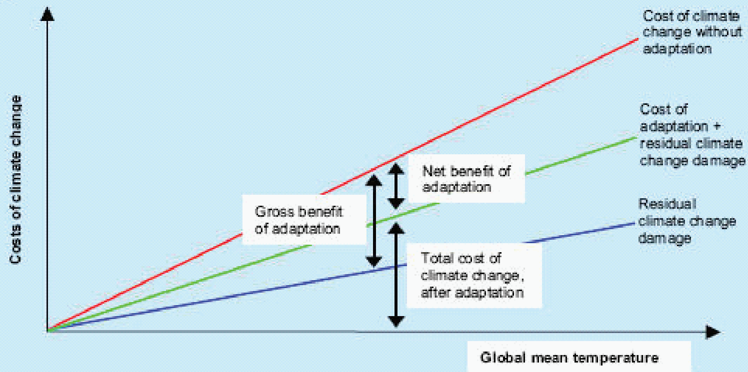
There are likely to be exceptions to this broad-brush rule, but it is useful in identifying the role of policy. The extent to which society can rely on autonomous adaptation to reduce the costs of climate change essentially defines the need for further policy. Costs may be lower in some cases if action is planned and coordinated, such as a single water-harvesting reservoir for a whole river catchment rather than only relying on individual household water harvesting.

The distinction between short-run and long-run adaptation is linked to the appropriate pace and flexibility of adaptation options. In the short run, the decision maker's response to climate change and variability is constrained by a fixed capital stock (e.g. physical infrastructure), so that the principal options available are restricted to variable inputs to production.

Figure 18.1 The role of adaptation in reducing climate change damages

Adaptation will reduce the negative impacts of climate change (and increase the positive impacts), but there will almost always be residual damage, often very large. The gross benefit of adaptation is the damage avoided. The net benefit of adaptation is the damage avoided, less the cost of adaptation.

The residual cost of climate damage plus the cost of adaptation is the cost of climate change, after adaptation.



For the sake of simplicity, the relationships between rising temperatures and the different costs of climate change/adaptation are shown as linear. In reality, Part II and Chapter 13 demonstrated that the costs of climate change are likely to accelerate with increasing temperature, while the net benefit of adaptation is likely to fall relative to the cost of climate change.

Figure 4.3. The role of adaptation in reducing climate change damages (Stern Review report).

TABLE 4.1. PRACTICAL EXAMPLES OF AUTONOMOUS AND POLICY-DRIVEN ADAPTATIONS FOR BOTH SHORT AND LONG TIME FRAMES

Table 18.1 Examples of adaptation in practice

Type of response to climate change	Autonomous	Policy-driven
Short-run	▪ Making short-run adjustments, e.g. changing crop planting dates ▪ Spreading the loss, e.g. pooling risk through insurance	▪ Developing greater understanding of climate risks, e.g. researching risks and carrying out a vulnerability assessment ▪ Improving emergency response, e.g. early-warning systems
Long-run	▪ Investing in climate resilience if future effects relatively well understood and benefits easy to capture fully, e.g. localised irrigation on farms	▪ Investing to create or modify major infrastructure, e.g. larger reservoir storage, increased drainage capacity, higher sea-walls ▪ Avoiding the impacts, e.g. land use planning to restrict development in floodplains or in areas of increasing aridity.

For example, a farmer can switch crops and postpone or bring forward planting dates in response to forecasts about the forthcoming growing season. On the other hand, major investments in irrigation infrastructure cannot be made reactively on such a timescale. Evaluating such investments requires expectations to be formed on costs and benefits over several decades, which places a challenging requirement on climate and weather forecasting. If the climate changes faster than expected, infrastructure could become obsolete before its planned design-life or require a costly retrofit to increase resilience.

(b) *Adaptation will occur in practice in response to particular climate events and in the context of other socio-economic changes.*

Responding to changed climate and weather (for example the appearance of stronger and more frequent floods or storms) is often an important first step for adaptation. Enhancing these responses to prepare for future impacts is the second step — for example, by using drought-resistant crops or improving flood defences. Many decisions to adapt will be made autonomously, within existing communities, markets and regulatory frameworks. This has important consequences for the way economists understand and appraise adaptation policy.

First, much adaptation will be triggered by the way climate change is experienced. Climate variability and in particular extreme weather, such as summer heat waves or storms, are likely to constitute important signals, alongside the dissemination of knowledge and information. Since adaptive capacity is related to income and capabilities, the most vulnerable in society will experience the same negative climate impacts more acutely.

Second, many adaptation decisions involve a measure of habit and custom, especially smaller decisions made by, for example, individuals, households and small businesses on short time-scales and with small amounts of resources. This effect may limit the extent to which such adaptations will be orientated towards maximising net benefits in an economic and social sense, since 'custom' may have been based on responding to past climate patterns.

(c) *Decisions about the timing and amount of adaptation require that costs and benefits are compared.*

An appraisal of any particular method of adaptation should compare the benefits — which are the avoided damages of climate change — with the costs appropriately discounted over time. The adaptation route that is chosen should be the one that yields the highest net benefit, having taken account of the risks and uncertainties surrounding climate change.

(d) *More quantitative information on the costs and benefits of economy-wide adaptation is required. For some specific sectors — such as coastal defences and agriculture — some studies indicate that efficient adaptation could reduce climate damages substantially.*

Adaptation is an important component of integrated assessment models that estimate the economy-wide cost of climate change at the regional and global levels. However, these models are currently of limited use in quantifying the costs and benefits of adaptation, because the assumptions made about adaptation are largely implicit. Adaptation costs and benefits are rarely reported separately.

However, for some sectors that are especially vulnerable to climate change, illustrative studies have been undertaken. Many assumptions must be made to project costs and benefits over long periods of time. Assumptions about population and economic growth are especially important for evaluating the benefits of adaptation expressed in terms of avoided damage.

For coastal protection, the avoided damages of climate change can be calculated from the value of land, infrastructure, activities and so on protected by sea walls, while the cost of sea walls can be calculated by scaling up from engineering estimates of construction costs. Coastal protection should – in theory – occur up to the point where the cost of the next unit of protection is just equal to the benefit.

In general, these studies suggest that high levels of protection may be economically efficient and reduce the costs of land loss substantially. According to one recently analysis, the effectiveness of adaptation declines with higher amounts of sea level rise. This analysis found that for 0.5 m of sea level rise damage costs were reduced by 80 – 90% with enhanced coastal protection than without, while the costs were only reduced by 10 – 70% for 1 m of sea level rise.

In agriculture, adaptation responses could be even more diverse, ranging from low-cost farm-level actions — such as choice of crop variety, changes in the planting date, and local irrigation — to economy-wide adjustments — including availability of new cultivars, large-scale expansion of irrigation in areas previously only rain-fed, widespread fertiliser application, regional/national shifts in planting date. Some studies suggest that relatively simple and low-cost adaptive measures, such as change in planting date and increased irrigation, could reduce yield losses by at least 30 – 60% compared with no adaptation. But adaptation gains will be realised only by individuals or economies with the capacity to undertake such adjustments. The costs of implementing adaptation, particularly the transition and learning costs associated with changes in farming regime, have not been clearly evaluated.

4.2.3 *Barriers and Limits to Adaptation*

In many cases, market forces are unlikely to lead to efficient adaptation.

Broadly, there are three reasons for this:

(a) Uncertainty and imperfect information;
(b) Missing and misaligned markets, including public goods; and
(c) Financial constraints, particularly those faced by the poor.

Policies can reduce these problems. But policy-makers themselves face imperfect information and have their own organisational challenges. Difficult policy choices may not always be tackled head-on.

(a) Uncertainty and imperfect information

Alongside an increase in global temperatures, climate change will bring increases in regional temperatures, changes in patterns of rainfall, rising sea levels, and increases in extreme events (heatwaves, droughts, floods, storms). High-quality information on future climate change at the regional scale is important for a market-based mechanism that drives successful adaptation responses. In particular, information is required for markets operate efficiently. Without a robust and reliable understanding about the likely consequences of climate change, it is difficult individuals — or firms — to weigh up the costs and benefits of investing in adaptation.

Uncertainty in climate change projections could therefore act as a significant impediment to adaptation. The uncertainty will never be completely resolved, but should become more constrained as our understanding of the system improves.

As this understanding improves and develops, there may also be a role for markets in providing information to individuals. For example, better developed insurance markets would help to create clear price signals — for example through differentiated insurance premia - about the risks associated with climate change. Thus premia associated with buildings in high flood risk areas might be expected to be higher than those on buildings in less vulnerable locations.

(b) Missing and misaligned markets, including public goods

Autonomous adaptation is more likely when the benefits will accrue solely — or predominantly — to those investing in adaptation. For sectors that are characterised by short planning horizons — and where there is less uncertainty about the potential impacts of climate change - successful adaptive responses may therefore be driven by autonomous decisions.

However, effective adaptation of long-term investment patterns (such as climate-proofing buildings and defensive infrastructure) could prove challenging for private markets, especially with uncertain information. Decisions that leave a long-lasting legacy require private agents to weigh the uncertain future benefits of adaptation against its more certain current costs.

Even if the benefits of adaptation can be realised over a relatively short time-horizon, unless those paying the costs can fully reap the benefits, then there will be a barrier to adaptation. For example, there will be little financial incentive for developers to increase resilience of new buildings unless property buyers discriminate between properties on the basis of vulnerability to future climate.

Some adaptive responses not only provide private benefits to those who have paid for them, they also provide benefits — or positive spillovers — to the wider economy. In such circumstances, the private sector is unlikely to invest in adaptation up to the socially desirable level because they are unable to capture the full benefits of the investment. In some cases, there may be little – or no – private adaptation because the necessary adaptative response is effectively a 'public good' in the technical economic sense.

Public goods occur where those who fail to pay for something cannot be excluded from enjoying its benefits, and where one person's consumption of a good does not diminish the amount available for others. In the case of climate change, relevant pubic goods include research to improve our understanding of climate change and its likely impacts, coastal protection and emergency disaster planning.

(c) <u>Financial constraints and distributional impacts</u>
Upfront investment in adaptive capacity and adaptation actions will be financially constrained for those on low incomes. In many developing countries, financial resources in general are already extremely limited, and poverty already limits the ability to cope with and recover from climate shocks – particularly when combined with other stresses.

Equally, across all countries, it will be the poorest in society that have the least capacity to adapt. Thus, the impacts of climate change could exacerbate existing inequalities by limiting the ability of poor people to afford insurance cover or to pay for defensive actions. Social safety nets that function in emergencies could be of great importance here: for example cash or food for work schemes, such as those involved in employment guarantee schemes in India, can play a very important role in droughts.

Even with an appropriate policy framework, adaptation will be constrained both by uncertainty and technical limits to adaptation.

An inherent difficulty for long-term adaptation decisions is uncertainty, due to limitations in our scientific knowledge of a highly complex climate system and the likely impacts of perturbing it. Even as scientific understanding improves, there will always remain some residual uncertainty, as the size of impacts also depend on global efforts to control greenhouse gas emissions.

Effective adaptation will involve decisions that are robust to a range of plausible climate futures and are flexible so they can be modified relatively easily. But there will always be a cost to hedging bets in this way, compared to the expert 'optimal' adaptation strategy that is revealed only with the benefit of hindsight.

There are clear limits to adaptation in natural ecosystems. Even small changes in climate may be disruptive for some ecosystems (e.g. coral reefs, mangrove swamps) and will be exacerbated by existing stresses, such as pollution. Beyond certain thresholds, natural systems may be unable to adapt at all, such as mountainous habitats where the species have nowhere to migrate.

But even for human society, there are technical limits to the ability to adapt to abrupt and large-scale climate change, such as a rapid onset of monsoon failure in parts of South Asia. Sudden or severe impacts triggered by warming could test the adaptive limits of human systems. Very high temperatures alone could become lethal, while lack of water will undermine people's ability to survive in a particular area, such as regions that depend on glacier meltwater. Rising sea levels will severely challenge the survival of low-lying countries and regions such as the Maldives or the Pacific Islands, and could result in the abandonment of some highly populated coastal regions, including several European cities.

4.3 Key Messages on Adaptation to Climate Change from Stern Review and ADB Review Reports

4.3.1 *Key message on adaptation to climate change (Stern Review report)*

Climate is a pervasive factor in social and economic development — one so universally present and so deeply ingrained that it is barely noticed until things go wrong. People are adapted to the distinct climate of the place where they live. This is most obvious in productive sectors such as agriculture, where the choice of crops and the mode of cultivation have been finely tailored over decades, even centuries, to the prevailing climate. But the same is true for other economic sectors that are obviously weather-dependent, such as forestry, water resources, and recreation. It is also evident in how people live their daily lives, for instance in working practices.

Adaptation will be crucial in reducing vulnerability to climate change and is the only way to cope with the impacts that are inevitable over the next few decades. In regions that may benefit from small amounts of warming, adaptation will help to reap the rewards. It provides an impetus to adjust economic activity in vulnerable sectors and to support sustainable development, especially in developing countries. But it is not an easy option, and it can only reduce, not remove, the impacts. There will be some residual cost – either the impacts themselves or the cost of adapting. Without early and strong mitigation, the costs of adaptation rise sharply.

Figure 4.4 below summarises the key messages from the Chapter on adaptation to climate change in the Stern Review report.

4.3.2 *Key message on adaptation to climate change and adaptive capacity building for Southeast Asian countries (ADB Review report)*

4.3.2.1 Key message on adaptation to climate change

Figure 4.5 summarises the key messages from the Chapter on adaptation to climate change in the ADB Review report.

4.3.2.2 Adaptive capacity building for Southeast Asia

Building adaptive capacity involves creating the information and conditions—regulatory, institutional, managerial, and financial—needed to support adaptation actions. While building a country's adaptive capacity requires the effort of all segments of society, the government has a particularly important role to play. This includes:

(i) Putting in place an effective policy and institutional framework,
(ii) Filling information and knowledge gaps,
(iii) Creating the right incentives, and
(iv) Allocating adequate public resources for adaptation.

The following are some recommendations for Southeast Asian countries to implement to build-up their adaptive capacity to climate change.

(a) *The future climate poses challenges outside historical experience. Improving adaptive capacity must be an urgent priority for Southeast Asia.*

While Southeast Asia has a long record of dealing with weather-related incidents, future climate change and its variability are expected to increase the frequency of extreme events and intensify impacts in ways that are outside the realm of historical experience. The region's vulnerability to climate change has necessitated the development of adaptation practices to cope with climate impacts.

Key Messages

Adaptation is crucial to deal with the unavoidable impacts of climate change to which the world is already committed. It will be especially important in developing countries that will be hit hardest and soonest by climate change.

Adaptation can mute the impacts, but cannot by itself solve the problem of climate change. Adaptation will be important to limit the negative impacts of climate change. However, even with adaptation there will be residual costs. For example, if farmers switch to more climate resistant but lower yielding crops.

There are limits to what adaptation can achieve. As the magnitude and speed of unabated climate change increase, the relative effectiveness of adaptation will diminish. In natural systems, there are clear limits to the speed with which species and ecosystems can migrate or adjust. For human societies, there are also limits – for example, if sea level rise leaves some nation states uninhabitable.

Without strong and early mitigation, the physical limits to – and costs of – adaptation will grow rapidly. This will be especially so in developing countries, and underlines the need to press ahead with mitigation.

Adaptation will in most cases provide local benefits, realised without long lag times, in contrast to mitigation. Therefore some adaptation will occur autonomously, as individuals respond to market or environmental changes. Much will take place at the local level. Autonomous adaptation may also prove very costly for the poorest in society.

But adaptation is complex and many constraints have to be overcome. Governments have a role to play in making adaptation happen, starting now, providing both policy guidelines and economic and institutional support to the private sector and civil society. Other aspects of adaptation, such as major infrastructure decisions, will require greater foresight and planning, while some, such as knowledge and technology, will be of global benefit.

Studies in climate-sensitive sectors point to many adaptation options that will provide benefits in excess of cost. But quantitative information on the costs and benefits of economy-wide adaptation is currently limited.

Figure 4.4. Key Messages on Adaptation to Climate Change (Stern Review report).

These include reactive/responsive measures such as changing the pattern and timing of the cropping system, emergency response to disasters, and migration; as well as proactive/anticipatory adaptation like crop and livelihood diversification, climate forecasting, community-based disaster risk reduction, famine early warning systems, insurance, water storage, supplementary irrigation, and so forth.

Enhancing adaptive capacity has been high on the development agenda in Southeast Asia. Although uncertainty remains about the extent of climate change impacts in the region, there is sufficient information and knowledge available to implement adaptation activities now.

Table 4.2 summarizes the major adaptation options that are available and have been practiced in developing countries.

Key Messages

The future climate poses challenges outside historical experience. Building and improving adaptive capacity and taking technical and non-technical adaptation actions in key climate-sensitive sectors must be an urgent priority for Southeast Asia.

There exist "win-win" measures that address climate change and are also good sustainable development practices. Government has a vital role to play in providing incentives and an effective policy framework for individuals and firms to adapt to climate change and to enhance their adaptive capacity.

Southeast Asian countries have made significant efforts to build adaptive capacity. There remains a need for enhancing policy and planning coordination across ministries and different levels of government for climate change adaptation. There is also a need for adopting a more holistic approach to building the adaptive capacity of vulnerable groups and localities and their resilience to shocks, including developing their capability to diversify local economies, livelihoods, and coping strategies.

Southeast Asian countries have also made encouraging efforts in taking adaptation actions in key sectors including water resources, agriculture, forestry, coastal and marine resources, and health. But most implemented to date have been reactive not proactive, autonomous not well-planned, and developed to address climate variability not change.

In water resources, the priority is to scale up existing good practices of water conservation and management, and apply more widely integrated water management, including flood control and prevention schemes, flood early warning systems, irrigation improvement, and demand-side management.

In the agriculture sector, the priority is to strengthen local adaptive capacity by providing public goods and services, such as better climate information, research and development on heat-resistant crop varieties and other techniques, early warning systems, and efficient irrigation systems; and explore innovative risk-sharing instruments such as index-based insurance schemes.

In the forestry sector, the priority is to enhance early warning systems and awareness-raising programs to better prepare for potentially more frequent forest fires as a result of climate change; and implement aggressive public-private partnerships for reforestation and afforestation.

In the coastal and marine resources sector, the priority is to implement integrated coastal zone management plans, including mangrove conservation and plantation.

In the health sector, the priority is to expand or establish early warning systems for disease outbreaks, health surveillance, awareness-raising campaigns, and infectious disease control programs.

In the Infrastructure sector, the priority is to introduce "climate proofing" of transport-related investments and infrastructure.

Figure 4.5. Key Messages on Adaptation to Climate Change in Southeast Asia (ADB Review report).

(b) *Adaptation decisions should be based on a sound economic foundation. Although uncertainty may make it difficult to fine-tune adaptation, there exist "win-win" measures that address climate change and are also good sustainable development practices.*

Planning for coping with the observed and anticipated impacts of climate change requires decisions based on sound economic considerations. It is necessary to know what adaptation would cost, and to what extent it would help avoid climate change damage. However, studies on adaptation costs and benefits for Southeast Asia are still limited—this is an area for further research.

The long-term nature of climate change makes timing crucial to adaptation decisions. Despite the uncertainties, one of the best adaptation measures available would be to extend ongoing efforts toward sustainable development, as these are

TABLE 4.2. SUMMARY OF MAJOR ADAPTATION OPTIONS FOR VARIOUS SECTORS (ADB REVIEW REPORT)

Table 6.1. Adaptation Options

	Reactive/Responsive	Proactive/Anticipatory
Water Resources	• Protection of groundwater resources • Improved management and maintenance of existing water supply systems • Protection of water catchment areas • Improved water supply • Groundwater and rainwater harvesting and desalination	• Better use of recycled water • Conservation of water catchment areas • Improved system of water management • Water policy reform including pricing and irrigation policies • Development of flood controls and drought monitoring
Agriculture	• Erosion control • Dam construction for irrigation • Changes in fertilizer use and application • Introduction of new crops • Soil fertility maintenance • Changes in planting and harvesting times • Switch to different cultivars • Educational and outreach programs on conservation and management of soil and water	• Development of tolerant/resistant crops (to drought, salt, insect/pests) • Research and development • Soil-water management • Diversification and intensification of food and plantation crops • Policy measures, tax incentives/subsidies, free market • Development of early warning systems
Forestry	• Improvement of management systems including control of deforestation, reforestation, and afforestation • Promoting agroforestry to improve forest goods and services • Development/improvement of national forest fire management plans • Improvement of carbon storage in forests	• Creation of parks/reserves, protected areas and biodiversity corridors • Identification/development of species resistant to climate change • Better assessment of the vulnerability of ecosystems • Monitoring of species • Development and maintenance of seed banks • Including socio-economic factors in management policy
Coastal and Marine Resources	• Protection of economic infrastructure • Public awareness to enhance protection of coastal and marine ecosystems • Building sea walls and beach reinforcement • Protection and conservation of coral reefs, mangroves, sea grass, and littoral vegetation	• Integrated coastal zone management • Better coastal planning and zoning • Development of legislation for coastal protection • Research and monitoring of coasts and coastal ecosystems
Health	• Public health management reform • Improved housing and living conditions • Improved emergency response	• Development of early warning system • Better and/or improved disease/vector surveillance and monitoring • Improvement of environmental quality • Changes in urban and housing design

Source: Adapted from UNFCCC (2007).

adaptations that are justifiable even without climate change. Better health care, access to safe drinking water, better sanitary conditions, and improved standards of education and infrastructure are "win-win" measures that, while useful in their own right, will also enhance the region's adaptive capacity.

(c) *Government has a vital role to play in providing incentives and a policy framework for individuals and firms to adapt effectively to climate change and enhance their adaptive capacity.*

Adaptation decisions are largely decentralized, unlike mitigation, which requires global cooperation. Some adaptations will have local public good characteristics and as such may be provided by the state, also called policy-driven adaptation. However, a majority of decisions will be taken by private agents, individuals, households, and firms with local benefits, known as autonomous adaptation. Because adaptation is a decentralized process, there is the question of how incentives can be provided to support it through private agents.

The literature on climate change has so far paid relatively little attention to the role of market and regulatory mechanisms in scaling up and enhancing the efficiency of adaptation efforts. This is a critical gap, because most adaptations are undertaken by private actors, and the scope of the adaptation will likely be far greater than the government budgets available to address it.

(d) *Southeast Asian countries have made encouraging efforts to build adaptive capacity, but much more is needed.*

Strengthening efforts requires mainstreaming climate change adaptation into development planning. This means that adaptation must be considered not only as a technical solution focused on natural systems, but more importantly, as an integral part of sustainable development and poverty reduction strategies. Among the immediate priorities for Southeast Asian countries in mainstreaming climate change adaptation identified by the ADB Review study are:

7. Step up efforts to raise public awareness of climate change and its impact, with a view to building consensus for public action and engaging all stakeholders including households, businesses, government agencies, nongovernment organizations, civil society, and development partners in combating climate change.

8. Undertake more research to better understand (i) climate change and its impact at the local level; (ii) cost-effective technical solutions that focus on natural systems (water resources, agriculture production, forestry, coastal and marine resources, and others); and (iii) sound adaptation strategies beyond technical

solutions (migration, social protection mechanisms, livelihoods of small-scale farmers and fishermen, and governance of adaptation at all levels).

9. Step up efforts in information and knowledge dissemination.

10. Put in place or enhance multi-ministerial coordination and planning mechanisms to promote multi-sector approaches to climate change adaptation, including linking climate change adaptation with disaster risk management. Given that climate change is an issue that cuts across all parts of government, it requires the attention of not just the ministries of the environment and the key agencies. Climate policy should be led by heads of state and the economics and finance ministries.

11. Put in place or enhance central government-local authority coordination, planning, and funding mechanisms to encourage local and autonomous adaptation actions, and to strengthen local capacity to plan and take adaptation initiatives.

12. Adopt a more holistic approach to building vulnerable groups' and localities' adaptive capacity and resilience to shocks beyond technical solutions, including developing their capacity to diversify local economies, livelihoods, and coping strategies.

At a more fundamental level, a country's adaptive capacity depends on its economic, social, and human development, which is closely related to levels of income, inequality, poverty, literacy, and regional disparity; capacity and governance of public institutions and public finance; availability or adequacy of public services including education, health, social protection and social safety nets; capacity of economic diversification especially at local levels. In all these aspects, there is wide variation across Southeast Asia and significant gaps between Southeast Asia and the developed world. Eliminating these gaps by keeping growth strong and making development sustainable and inclusive will go a long way toward improving the region's adaptive capacity.

CHAPTER 5. CURRENT STATUS, GAPS AND RECOMMENDATIONS

This chapter gives a summary of the current status of water management in the country to address the impacts of climate change on water for the following seven thematic areas. It also highlights the gaps and gives the recommendations to address them:

a) Governance and Institutional Capacity
b) Climate Change Projections and R&D Capacity
c) Information Management Capacity
d) Stakeholder Awareness and Participation
e) Water Bodies Management Capacity
f) Water Use Management Capacity; and
g) Water Management Capacity.

In particular, it highlights the gaps and recommendations identified by the various NC2 working groups that contributed to the most recent and comprehensive domestic document on the issue of climate change and adaptation, i.e. the NC2 report. Apart from the gaps already identified in the NC2, this chapter also highlights other gaps and gives recommendations based on a comparison of the information contained in the international documents reviewed, as well as those proposed in the NC2.

With regard to the international documents, it is to be noted that while most identified common issues to be addressed, the recommendations provided were mainly general. The FAO study entitled "Coping with a Changing Climate: Considerations for Adaptation and Mitigation in Agriculture" (FAO study) however contained more practical suggestions that can be implemented to overcome some of the gaps identified. Hence many of the recommendations on these four general categories, and indeed the gaps identified therein, are summarized from the FAO study.

5.1 Governance and Institutional Capacity

5.1.1 *Current Status*

As can be seen, climate change water related impacts affects a broad range of sectors and activities and poses a special issue concerning governance and institutional capacity. Traditionally, sectors involved in climate change analysis are governed individually and specific Ministries and agencies with specific sector related mandates have been established to do so.

The ADB Review on Economics of Climate Change study recommends the following:

> *"Put in place or enhance multi-ministerial coordination and planning mechanisms to promote multi-sector approaches to climate change adaptation, including linking*

climate change adaptation with disaster risk management. Given that climate change is an issue that cuts across all parts of government, it requires the attention of not just the ministries of the environment and the key agencies. Climate policy should be led by heads of state and the economics and finance ministries." [Please refer to Chap 4, Section 4.3.2.2 (d)(4)].

In Malaysia, climate change has generally been considered to be an environment issue and is anchored presently by the Ministry of Natural Resources and Environment (NRE). Prior to the establishment of NRE in 2004, climate change was under the purview of the then Ministry of Science, Technology and Environment.

A National Committee on Climate Change was established in 1994 after Malaysia became a signatory party to the UNFCCC. This national committee was chaired by the anchor Ministry and comprised of members from various ministries. However with the rising escalation of attention and concern regarding climate change both at the global and domestic level, a Cabinet Committee on Climate Change was established in 2008 which has been more recently succeeded by a Green Technology and Climate Change Council (GTCCC) which held its first meeting in 2010. Both the Cabinet Committee and Council are chaired by the Prime Minister with members from numerous ministries. The NRE is a joint secretary of the GTCCC along with the Ministry of Energy, Green Technology and Water.

It can be seen that Malaysia has evolved its institutional framework on climate change to that recommended in the ADB study through the establishment of the GTCCC.

In addition to this, a National Water Council also exists which is chaired by the Deputy Prime Minister and comprised of all the State Chief Ministers. This would be the appropriate avenue to discuss and determine water related issues nationwide and climate change water related measures can be implemented in a uniform manner using this vehicle.

5.1.2 *Gaps and Recommendations*

5.1.2.1 A decision-making framework and process on water and climate change adaptation

While the framework exists, with the recent formation of the GTCCC, and given the fact that climate change is a factor that has recently become an important national consideration, **a decision-making framework and process relating to climate change and water still needs to be developed**. This was highlighted in the NC2 wherein the lack of procedures and risk management practices in incorporating projected climate and hydrological changes with related uncertainties from fine grid regional HCMs into sector analysis was identified as a gap.

Furthermore, as highlighted in an FAO study[2]:

> *"many of the environmental changes that are occurring and those that are likely to occur in the future as a result of climate change are incremental and "slow onset," but they are cumulative. Policy-makers must improve the ways they choose to deal with such creeping changes in the environment". In addition to that the rate of change may be faster than projected by modeling exercises, hence policy-makers must be able to monitor and react to this effectively. The FAO study finds that "the problem is that because the physical and ecological mechanisms involved in these processes continually seem to translate to shorter and shorter timeframes for what once were distantly projected impacts, these accelerated environmental changes will continue to create a major dilemma in thinking about and acting on these impacts,* ***since both the physical and ecological rates of change will occur far faster than the rates at which institutional bureaucracies are designed to cope effectively"****.*

A further problem as identified in the FAO Study is that because the focus of the past decades has been on adapting and mitigating to future impacts, the concept of prevention seems to have been abandoned. A related issue is that often, impacts of mitigation measures are not accounted for in adaptation planning be they positive or negative and likewise, contributions or otherwise of adaptation measures towards reducing emissions are also not considered.

It is recommended that proposals contained in the FAO study be considered to formulate a framework to cope with the challenges of decision-making relating to climate change and water issues. This is equally applicable to general climate change related decision making which require an equally holistic approach. These include:

1. Scenario planning
2. Adopting a "resilient adaptation" approach.
3. Undertaking a SWOC/T analysis of proposed adaptation strategies;
4. Applying Commoner's Four Laws of Ecology[3] in considering any adaptation strategy; and
5. Prioritising adaptation action to be implemented

The FAO study describes these approaches as follows in the context of food security. They are equally applicable in the context of water security and minor changes have been made to the original text in the FAO study to reflect this.

The following is a brief summary of the recommended FAO approach to develop the decision-making framework and process:

[2]Coping with a Changing Climate: considerations for adaptation and mitigation in agriculture
[3]Taken from Commoner's book entitled "The Closing Circle" (1971)

1. Scenario Planning
   The creation of scenarios is a popular approach to attempt to gain a glimpse of the future, at least the near-term future. Scenarios can help decision makers create contingency plans for possible futures based on past experience. Surprises are to be expected, of course, even though the form they will take may not be known, but scenarios, overall, can be quite useful for hypothesizing about a wide range of potential impacts of a changing climate. Because of their relatively short shelf-life and because societies are constantly changing, however, scenarios need to be revisited, critically reviewed and updated periodically at regular intervals.

2. Resilient Adaptation
   The IPCC (2007a) defines "resilience" as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change. Resiliency can also be defined by a capacity to cope successfully in the face of significant future risk.

   "Resilient Adaptation" is a hybrid concept that merges the best of the suggested practices of resilience and of adaptation in the face of potential hazards and threats from climate change. It includes a safety net or way out of strategies that may, after a while, prove to have been mal-adaptations. It also includes a recovery mechanism that has a degree of flexibility in the face of uncertain future, scientific model-based findings notwithstanding. The concept of resilient adaptation is borrowed from the field of psychotherapy. The editor of a book on the topic suggested "resiliency is operationally defined…as a dynamic developmental process reflecting evidence of positive adaptation despite significant life adversity" (Luthar, 2003).

3. SWOC/T analysis
   SWOC/T assessments are used to evaluate the Strengths, Weaknesses, Opportunities and Constraints (or Threats) of an organization, process or plan. They can also be used as educational tools to assess the prospects and potential pitfalls of strategic responses a government might pursue to counter the adverse impacts of climate change or to derive value from the transformations in the environment that a change in climate might cause.

   In an open forum, a SWOC/T approach can also help tease out those not-so-obvious aspects of a policy response to climate change's influences on a country's food security (or water security in this case). In addition, exposing weaknesses can be useful in a government's preparations for or avoidance of the adverse side effects of a strategy's implementation. In the same vein, identifying both obvious and not-so-obvious constraints is the first step in identifying pathways to remove or overcome them.

   It must be remembered however that although SWOC/T assessments can be valuable learning tools, they will not in and of themselves yield designs for strategic plans to cope with climate change's impacts including those on water security. Such strategic plans will be formulated by relevant agencies.

4. <u>Commoner's Four Laws of Ecology</u>
   It is important that policy-makers at all levels of government keep in mind each of these "laws," as they search for, identify, develop and implement adaptation strategies for coping with the impacts of climate change on water security. They serve as reminders of the important role of ecosystems not only in the health and well-being of societies but also on the health and wellbeing of other ecosystems on which those ecosystems depend. These four laws should be borne in mind in applying the SWOC/T analysis to adaptation strategies and can also serve as educational and instructive guidelines to policy.

   - <u>1st Law … Everything is Connected to Everything Else</u>.
     "The system is stabilized by its dynamic self-compensating properties; these same properties, if overstressed, can lead to a dramatic collapse" (p. 35).

   - <u>2nd Law … Everything Must Go Somewhere</u>.
     "One of the chief reasons for the present environmental crisis is that great amounts of materials have been extracted from the earth, converted into new forms, and discharged into the environment without taking into account that everything has to go somewhere" (p. 37).

   - <u>3rd Law … Nature Knows Best</u>.
     "The third law of ecology holds that any major man-made change in a natural system is likely to be detrimental to that system" (p. 37).

   - <u>4th Law … There Is No Such Thing as a Free Lunch</u>.
     "In ecology, as in economics, the law is intended to warn that every gain is won at some loss" (p. 42).

5. <u>Prioritising</u>
   Adaptation action should be taken sequentially addressing the most immediate risks first. A framework of criteria should be developed to rank actions according to their response ability in addressing climate change vulnerabilities. In addition, actions should be planned sequentially according to short, medium and long term timelines.

5.1.2.2 <u>Adherence to existing national polices/plans</u>

As noted earlier, there are many existing policies and plans that pertain to climate change and water issues in the country. While they are all national policies, generally however, only the Ministry formulating the policy/plan takes ownership over its implementation.

With regard to a cross cutting issue like climate change and water however, such policies/ plans require broader participation for full implementation. **A gap that presently exists is the lack of coordination to ensure that decisions adhere to existing policies or plans such as the National Physical Plan which provide overarching guidance on land issues for the nation or the National Climate Change Policy which steers climate action in the country**.

The GTCCC and the National Water Council provide adequate platforms through which holistic actions and decisions can be made regarding climate change generally, and those relating to water issues specifically. The multi-sectoral composition of the GTCCC should ensure that relevant policies and plans are considered in making decisions. **It is nevertheless recommended that a checklist of relevant policies and plans be compiled to ensure they are considered in the decision making process**.

A process to review new policies/plans to identify their relevance to the climate change decision making process should also be formulated. This is to ensure that relevant future policies/plans are also considered in the decision making process.

In summary it is recommended that:

(a) A comprehensive checklist of relevant policies/plans be prepared summarizing key sections for quick reference by decision makers; and

(b) A process be formulated to ensure that this checklist is regularly updated with newer policies/plans.

5.2 Climate Change Projections and R&D Capacity

5.2.1 *Climate Change Projections*

5.2.1.1 <u>Current Status</u>

Chapter 3 provides an update on the current status of climate change projections in Malaysia. Two models are used to produce detailed climate change projections for Malaysia. They are the PRECIS model used by the Meteorological Department of Malaysia (MMD) and the RegHCM-PM model used by NAHRIM.

Both the PRECIS and RegHCM-PM models' projections show a trend range of negative to positive for Malaysia for mid century (and late century for PRECIS) for the SRES A1F1 and B1 scenarios, while a comparison with the climate change projections for the SEA region, as reported in the ADB Review report, for both scenarios show positive trends. The PRECIS and RegHCM-PM models' projections also correspondingly show a negative to positive trend range for Peninsular Malaysia.

It is likely that the more refined features required for hydro-climate modeling of the PRECIS and RegHCM-PM modeling has captured more precise information for Malaysia regarding rainfall. Nevertheless, the significant uncertainty in the current climate change projections is an area of concern that needs to be addressed.

5.2.1.2 Gaps and Recommendations

In general future vulnerability analysis depends on the dual aspects of availability of reliable climate projections and appropriate baseline data.

The gaps identified with regard to climate change projections in the NC2 are:

(a) inherent uncertainty in downscaled projections especially for Malaysia given the limited number of models used;
(b) a low understanding of uncertainties and limitations of climate change projections and scenarios for effective communication to decision makers and end users;
(c) lack of procedures and risk management practices in incorporating projected climate and hydrological changes with related uncertainties from fine grid regional HCMs into sector analysis;
(d) lack of application of the projection results in sector vulnerability analysis; and
(e) Lack of data in various aspects.

The recommendations to address the above are as follows:

1. Reduce the Uncertainty in Climate Change Projections
   With regard to uncertainties in climate projections, it is recommended that the number of GCM models and realizations and river based models with finer scale and temporal resolutions should be increased.

2. Improved Baseline Data Collection
   Baseline data are keys to an improved understanding of the water related impacts of a changing climate and of the rates of change at which those impacts appear. Slow rates of change, for example, provide time for preparation and response, while faster rates provide less time for such actions. Problems will always exist, however, with data, statistics, lack of carbon-adjusted statistics and difficulties in modeling countries' "mitigation potentials". Filling the gaps in baseline data, therefore, is an important aspect of adaptation (FAO Study). To achieve this, appropriate R&D capacity is required.

3. Set-up Early Warning Systems and Improved Monitoring Set-up
   While there are inherent uncertainties in climate change future projections, proper monitoring and the setting-up of early warning systems in areas identified as vulnerable can alert decision makers to climate changes that could result in potential adverse impacts.

5.2.2 *Research & Development (R&D)*

5.2.2.1 Current Status

Key areas of R&D relating to climate change and water are:

(a) Baselines
(b) Threshold change levels
(c) Monitoring thresholds
(d) Analysing past events
(e) Vulnerability mapping; and
(f) Resilience mapping.

Climate change projections as highlighted in the section above are one of the key R&D achievements for Malaysia. Apart from this, the following are studies/R&D that have been undertaken in Malaysia relating to climate change and water:

- A National Coastal Vulnerability Index (NCVI) study has been commenced with the pilot phase being completed.
- Forest CO_2 flux observations and the importance of rainfall patterns on gas exchanges in tropical rainforests.
- Technology development to harness renewable energy from biomass, micro/pico hydro and oceans amongst others
- Biofuels from palm oil
- Relationship between rainfall and dengue transmission
- Potential causes of coral bleaching; and
- Systematic observation through a network of climate and hydrological monitoring stations including 3 Global Atmospheric Watch stations.

Most of the research undertaken to date is on a sector basis apart from the NCVI which also includes socio-economic factors. This has enabled an enhanced understanding of the issues and impacts pertaining to the focus area of the study.

Malaysia has also recently commenced a domestic Economics of Climate Change study to better understand the cost implications of climate change. A Roadmap towards achieving the aspirational goal of reducing the emissions intensity by 40% is also underway. Both these studies should include water resources related costs be it for adaptation or mitigation. As noted in the NC2, some adaptation measures may result in a reduced need for future mitigation, and hence water impacts should also be considered in the roadmap study (Section 7.3, Chapter 7, NC2).

5.2.2.2 Gaps and Recommedations

Although systematic observation is conducted, a gap in the water sector as noted in the NC2 is that **there is limited long term historical data for hydrology and water resources and also that the number and frequency of hydrological and river flow data are still low**. Furthermore ongoing impact studies are specific for example for consumptive, irrigation, industrial, or non-consumptive use. However **without considering all these competitive water uses holistically, ineffective adaptation measures may be formulated**. Other gaps related to water identified in the NC2 include limited experimental data on the impact of climatic factors such as temperature and rainfall variability on agriculture, lack of long-term tidal records for good local models on sea level rise, climate impact research on coral bleaching and potential increase in brackish water ecosystems due to SLR and its impact on the spatial distribution of malaria. An important gap is the lack of a holistic approach to consider climate impacts. As noted above, while it is important to have sector specific information and data, analysis using an integrated approach such as on an ecosystem basis has not been conducted. (Section 7.2.3 (iv), Chapter 7, NC2)

The climate projections modeling exercises undertaken by Malaysia have advanced the country's abilities in understanding potential adaptation needs for the future. Nevertheless, as noted above, several inherent gaps exist that need to be overcome in ensuring that robust adaptation measures are undertaken.

In this regard, one of the things noted in the recommendation regarding improved baseline data collection above is that R&D is required to fill in gaps in existing baseline data. Research on natural sciences would generally provide the data and information required for baselines. However, generally, funding for such natural science research in the country is not as easily available as that for R&D with commercial prospects. The importance of such research not only in building an improved understanding of natural systems and the services they provide, but also as an indicator to avert future disasters and their consequent toll on socio-economic well being, cannot be underestimated. **The lack of funding for natural science research or other incentives to promote it is therefore a key gap**.

Research that is undertaken should also be targeted towards providing sound alternatives to simply relying fully on climate projections given their inherent uncertainties. Apart from baselines, a greater understanding is required with regard to threshold levels of ecosystems through research, observation and monitoring to detect ongoing variability and change such as the water cycle, extreme events and their impacts (Section 8.3, Chapter 8, NC2). **It can be seen that of the six key research areas identified in the section above, research in Malaysia so far only appears to touch on the first three**.

The recommendations identified in the NC2 are essentially to address the research gaps, advance capacity, update the national water resources study regarding annual rainfall and its distribution in terms of surface runoff, evapotranspiration and groundwater recharge, develop an integrated programme to research priority areas to address interdisciplinary concerns and inter-related sectors and adopt a holistic vulnerability and adaptation approach such as the ecosystem approach.

Apart from this, more funding should also be made available for natural science research. With regard to the Economics of Climate Change and Roadmap towards achieving Malaysia's voluntary emissions intensity reduction goal, water related impacts and costs should be included in the analysis if they already have not been. It is therefore recommended that water experts be involved in providing input for both these national studies.

In addition, to address the lack of certainty with climate projections and other inherent challenges that the issue of climate change poses, the following recommendations on the nature of research required is set out below:

1. Research on "Climate Change Warning Indicators"
   Given the slow rate of change generally associated with climate change, research on climate change warning indicators would enable the monitoring efforts to focus on the right criteria. This will enable responses to be taken to early warning signs of the subtle changes in the local characteristics of specific climates.

   In this regard, it is recommended that research on climate change baselines also define signs of progressive degradation as depicted in the FAO "hotspots" pyramid shown in *Figure 5.1* below. This will enable decision makers to take appropriate measures at reasonable costs before it is too late.

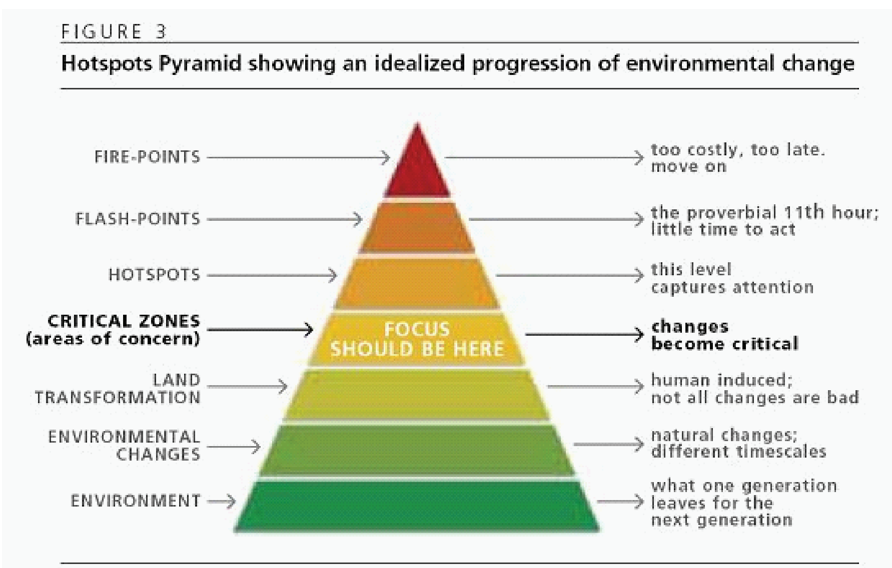


Figure 5.1. Climate Change Warning Indicators — The use of "Hotspots" Pyramid (FAO).

- *Hotspots* are locations of degradation of either the managed or the unmanaged environment. They indicate situations when mitigative action remains possible at relatively higher costs and appear before conditions deteriorate further to the flashpoint stage, the proverbial 11th hour when actions to restore environmental quality before long-term, irreversible destruction occurs.
- The *Flash-point* stage offers a brief, last window of opportunity for policy-makers to react before environmental collapse becomes inevitable; when (if) they do choose to react, however, the necessary measures for recovery will prove extremely costly in terms of time, money and political capital.
- *Fire-points* indicate that environmental conditions have collapsed – it's too late for policy making, as the degradation has overwhelmed all chances for recovery, and polluted rivers, for example, have to be abandoned for generations to come.

For example, when a water body like Lake Chini has been labeled a Hotspot, indicating that a crisis situation has emerged, it will begin to receive the serious attention of local officials and the national media. Such reactions are decidedly ill-timed, however, as more proactive attendance to foreseeable and developing crises would prove beneficial to all stakeholders, and especially to the environment itself.

The fact is that policy-makers should focus not on Hotspots but on the Critical Zones (Areas of Concern) in *Figure 5.1* because at this stage of the continuum not only does enough scientific evidence of degradation exist but so does enough lead time to proactively implement relatively low cost yet highly effective measures to arrest or reverse the devastation and avoid the negative consequences (again, both socially and environmentally) that accompany passage into the Hotspots stage. Indeed, Areas of Concern merit considerable attention as indicators of adverse change and as a focus for policy discussion and execution.

2. <u>Research on "Forecasting by Analogy"</u>

"Forecasting by Analogy" can also be used to compensate for the lack of certainty in climate modelling. Many of the adverse climate-change-related environmental scenarios being discussed, especially regarding the consequences of future human interactions with various types of ecosystems, from deserts (i.e. desertification) to mountain slopes (i.e. deforestation), have already been occurring for decades. Such scenarios should, therefore, no longer be viewed as speculation because the impacts of those changes have already been demonstrated, if not within one country, then within another.

Even where there is a paucity of data for one particular area, the results of similar modifications to the natural environment have already been tracked and tested in other areas, yielding results that have demonstrated these modifications as being either good or bad for the environment, for society, or for both. Such correlations are at the heart of "forecasting by analogy" (FAO Study). Collating knowledge of the sequence of events or characteristics resulting in changes that have already occurred can help identify potential similar changing patterns in the future.

Apart from the release of GHG emissions that can result in future changes in the climate, human activities can also result in creating or enhancing existing vulnerabilities to climate change. Hence forecasting by analogy can also help avoid mistakes of the past that can aggravate the impacts of inevitable climate change.

The information gathered from the research activities should be developed into:

1. Procedures and Risk Management practices for Climate Change
   Procedures and risk management practices to address climate change are needed to ensure proper planning and use of climate projections information. Such procedures and practices should incorporate the need for monitoring early warning signals and "forecasting by analogy". The outputs from climate change model projections coupled with the research outputs from both these research areas would enhance the understanding of the uncertainties and limitations of the projections.

   Furthermore, information prepared using these procedures and risk management practices would be more reliable and can be communicated with greater confidence to decision makers and end users.

2. Vulnerability and Resilience Mappings
   Vulnerability Mappings should be undertaken for all sectors based on the climate projections on water available for the country as well as forecasting by analogy. These sector mappings in turn should then be compiled together to get a more complete visual depiction of various vulnerabilities to water related climate stresses nationwide.

   To facilitate this undertaking, it is recommended that the government undertakes a comprehensive, two-pronged assessment of the country's (a) vulnerabilities and (b) resiliencies (defined in this instance as adaptive capacity). Vulnerabilities seem to be relatively easier to identify than are resiliencies.

   Information extracted from the NC2 provides the vulnerabilities identified in the water sector. Resiliencies can be either tangible (e.g. sea walls, effective state of the art early warning systems, available funds) or intangible (e.g. education, training, skills, awareness of risks, perceptive decision making). Assessments such as these can be extremely useful for identifying not-so-obvious vulnerabilities and resiliencies in a society's socioeconomic sectors (FAO Study).

> Mapping such a capacity to cope in a country is as important as mapping vulnerabilities to climate variability, extremes and change because such baseline data facilitates an understanding among planners and policy-makers of where risk is most critical.

Finally, though the scenarios for 2100 are interesting to planners at some level, it will be of much less concern to most decision makers than are the scenarios more proximate to our contemporary life time scale and governance. If science is going to be relevant to most policy-makers today, then its projections must also include time scales that are far closer to the present than those a century away. (FAO Study). In Malaysia, both PRECIS and the RegHCM-PM provide data for the short term before 2030, and mid term of 2050. In light of some extremities experienced in weather patterns in recent years and given Malaysia's as aspiration to attain developed status by 2020, it would be useful to also have climate projections focused on and around the years of 2020.

5.3 Information Management Capacity

5.3.1 *Current Status*

The NC2 notes that as with most countries, the collection of environmental, biodiversity and socioeconomic data in Malaysia is largely ad hoc and not well organized and needs to be better coordinated. There are a limited number of standards developed so far for observation and archiving of such data. It also notes that there is currently a lack of data sharing amongst agencies, sectors and stakeholders probably due to insufficient means to do so. Furthermore, there are limited activities for increasing awareness of communities to climate variability and climate change issues. (Sections 8.2 and 8.3, Chapter 8, NC2).

5.3.2 *Gaps and Recommendations*

In terms of the types of information, the NC2 has not reported on the efficacy of existing measures in preventing or reducing the impact of climate related disasters. For example, the reduction/alleviation of the numbers of flood or drought events by existing mitigatory measures such as the capacity enhancement of the Timah Tasoh dam or the construction of the SMART tunnel is not available in the report. Such information would be useful in working out the cost and benefit of undertaking adaptation measures to persuade policy and decision makers of the importance of undertaking appropriate adaptation measures. Standards for observing and archiving information should include recording potential disasters averted and such information should be easily available.

Also, as identified in the FAO Study, many people (researchers as well as policy-makers) tend to believe that historical information has become outdated because of scientific, engineering, or technological progress and because lessons about coping with disasters were learned. As a result, historical climate, water, and weather-related impact information, even information about recent impacts, is often neglected, even though such information could often provide context and guidance for present and future planning. While speculating about future impacts, therefore, these historical accounts must be exploited in developing adaptation strategies to cope with these issues at local to national levels. A poignant example is the Highland Tower disaster in Taman Hillview, Ampang Jaya and the immense impact of diverting natural water paths in the process of developing surrounding areas. This appeared to have been done without adequate access for the water flow. The collapse of Block 1, Highland Tower on that fateful day of 11 December 1993 was preceded by 10 days of continuous rain. Several other incidents of landslides, some resulting in fatalities, all resulting in property damage and loss have occurred in Hillview and surrounding areas of Bukit Antarabangsa since then.

The recommendations to address the gaps are as follows:

1. <u>Enhance our National Climate Service</u>
   It is recommended in the NC2 (Chap 8, para 8.2) that our national climate services needs to be enhanced to strengthen the production, availability, delivery and application of science-based climate predictions and services as well as coordinate climate information for the government and stakeholders. This enhancement should also include more coordinated climate research carried out among relevant agencies.

2. <u>Set-up Sector-specific Water and Climate Change Information Management Units (WCC-IMU)</u>
   In order to galvanise and focus each water-related sector agencies and departments effort to adapt to the impacts of climate change on water it is recommended that "Water and Climate Change Information Management Units (WCC-IMU)" be setup by each of the agencies and departments to systematically collect, compile and manage their relevant data related to climate change. The need for a dedicated WCC-IMU to facilitate systematic observation and monitoring systems need to encompass all relevant agencies, users, policy makers and stakeholders, as much as possible.

   The formation of the WCC-IMU will support the management and dissemination of information collected by the proposed enhanced observation and monitoring system to detect ongoing phenomena related to climate variability and change such as the water cycle, extreme events and their impacts. Also, the WCC-IMU should ensure that systematic environmental, biological, ecosystem and socio-economic data and information are compiled and organized to support assessment of human, biological, ecosystem and environmental vulnerabilities and to facilitate the planning of actions that must be taken to adapt to climate variability and change.

3. <u>Set-up a National Global Climate Observation System (GCOS) Committee</u>
   It is recommended that a national Global Climate Observation System (GCOS)

Committee be set-up to provide a means to enhance coordination between the different parties involved in observing and collecting information relating to climate change. (Chap 8, para 8.3, NC2)

4. Set-up a National Water and Climate Change Information Repository

It is recommended that a National Water and Climate Change Information Repository be set-up to store all studies and information relating to climate change and water for Malaysia. Such a central repository should also contain a complete archive of all water related incidents such as floods and droughts and record their socio-economic impact.

Monitoring the frequency of incidence (for example heavy rainfall that could have resulted in floods) and recording those that have been averted through existing mitigatory measures will enable better understanding of the benefits of early action from a cost perspective. Such records should also be deposited in this central repository.

As an example, information pertaining to the recent floods in the northern states (November 2010) should be collated and be made easily available in this repository. Sources of information too should be clearly noted for transparency and ease of verification. The item mentioned in Section 2.2.12.2 (a) on the need to upgrade the Timah Tasoh Dam, the cost involved and the allocation of the cost as reported in the NST should be included in such a repository. The news item reported the MB as identifying the 2 days of continuous rain (Oct 30 and Nov 1 average: 165.8 mm/day with a high of 205 mm in Padang Besar) as the cause of the floods in Perlis which is the worst in history. As mentioned in Chap 2, the Perlis Menteri Besar also noted that the state is requesting an allocation of RM576.9 million from the Federal Government to further upgrade the Timah Tasoh Dam and flood bypass system to overcome the flooding problem especially in Kangar. In noting that the flood loss was estimated to be more than RM200 million (with the actual amount expected to be higher once all the loss reports are compiled), the upgrade works for the Timah Tasoh Dam is to increase its present capacity by 2½ times to 87 million m^3. (NST, Wednesday, December 15, 2010, pg 26 Nation "MB: Good job in flood relief work"). Earlier reports also identified closure of parts of the North South Highway due to the flooding. The economic implications of this would be quite significant as the highway forms an important road transportation link along the west coast of the Peninsula.

The identity of the guardian of this repository as well as the form it is to assume (paperless, a library, etc.) requires further deliberation. A system to ensure delivery of all studies and information to this repository should also be formulated.

[Note: In this regard, it is worth noting here that DID Malaysia's Water Resources Management Division is currently in the process of commissioning the development of a central national water resources information repository that, includes the issue of climate change adaptation, as part of its information management focus. It may be able to address the need identified here].

5. Publicise and disseminate climate information
Apart from establishing a good and effective information management system, such information should also be regularly publicized and disseminated to relevant agencies, other stakeholders and the general public. In this regard, creative use of traditional and new media would enable the information to be easily and widely available. In addition, collaborating with the arts community would be an effective way of formulating information dissemination methods with the greatest impact using visual and performing arts, (Section 8.17, Chapter 8, NC2).

5.4 Stakeholder Awareness and Participation

5.4.1 *Current Status*

Generally, most adaptation is expected to occur autonomously at the individual, household or community levels. The NC2 notes that while anecdotal evidence shows an increase in general public awareness and understanding, nevertheless, affected populations are still not adequately informed and hence are not prepared to adapt to the anticipated changes in climate including to its impacts on water resources. Also, at the institutional level, gaps in technical understanding between the different agencies result in a time lag in decision making. (Section 7.2.3, Chapter 7 (iii), NC2)

5.4.2 *Gaps and Recommendations*

The gaps and recommendations to address them are as follows:

1. Climate Change Awareness and Participation of government agencies and departments
There is a need to increase the awareness of climate change and its impacts on water among the staffs of water-related government agencies and departments. Some ministries like NRE have already commenced learning platforms where knowledge is shared between staff through short seminars or other events. Such initiatives can be further expanded to an inter-ministry basis to generate wider awareness. There is a need also to ensure that departments responsible for water resources planning and management undertake multidisciplinary studies involving natural and social sciences so as to develop practical adaptation measures taking considerations of the needs of various stakeholders into account.

2. Climate Change Awareness and Participation of Disaster-relief Agencies
There is a need to identify partners who can assist in the adaptation process. Key

stakeholders who are involved in disaster-preparedness and risk reduction would be affected by climate change in their traditional role as emergency relief providers. They form natural partners for climate change adaptation implementation given their familiarity with issues on the ground and their inherent interest in reducing/averting disaster. They should be encouraged to participate in adaptation decision making. The National Security Council, National Red Crescent Society and Mercy Malaysia can provide effective communication channels to decision makers on the issues faced on the ground. It is useful to note that the International Federation of the Red Cross and Red Crescent (IFRC) has already identified climate change adaptation as a key strategy in its recently launched Strategy 2020 document.

3. Climate Change Awareness and Participation of the Community

Since adaptation measures may have implications on changing traditional practices or livelihoods, there will be behavioral resistance. Thus, it is important to have community-level engagement in developing and implementing adaptation measures best suited to issues on the ground. In many instances, the intimate knowledge of the land and its environment by those who occupy it would be indispensable in formulating adaptation strategies.

As noted in the Climate Change Adaptation Strategies to Cope with Water-related Disasters due to Global Warming (Draft Policy Report)[4] by Japan (pg 37, Disaster Risk Assessment)

"To discuss adaptation strategies, the impacts imposed on society and economy by water-related disasters due to climate change should be presented to the general public and related organizations as an easy-to-understand form of disaster risk. It is important to inform people of the vulnerabilities of land structure and social systems through such risk assessment. The selection of appropriate adaptation strategies will be possible only after people sufficiently understand those vulnerabilities.

Assessment results should be presented visually, for example, by plotting them on risk maps. Risk assessment is important not only to visually show current vulnerabilities but also to show differences to be made after the introduction of adaptation measures, which help people understand how effective they can be in terms of risk management."

To facilitate this, establishing climate change awareness forums starting at the community-level, and then replicating them all the way up to district, state and national levels should be considered. This could be similar in operations to that of Tun Razak's Operations Room in addressing rural development in the 1970s.

[4]Also known as the MLIT Climate Change Adaptation Draft Policy Report

5.5 Water Bodies Management Capacity

5.5.1 *Rivers*

5.5.1.1 Current Status

To facilitate the management of rivers and also to support the integrated management of river basins in Malaysia the DID has develop a register of all rivers and river basins in the country. It has also prepared maps delineating the river networks and river basin boundaries, and has also developed a number of river basin management plans based on the Integrated River Basin Management (IRBM) approach to facilitate river basin stakeholders' cooperation in achieving the IRBM vision for the basins. The IRBM approach for river basin management is also supported in RMK10 as part of the country's long-term strategy for water resource management to achieve water security.

The NC2 has highlighted that changing annual rainfall and seasonal rainfall patterns will affect river flow and river water quality. It noted the general characteristics of Malaysian rivers, as small and short, with flooding occurring frequently in low-lying and coastal areas during short intense rainfall or during long, low intensity rainfall. It also noted that during periods of low rainfall, the river water quality is prone to deteriorate and that small forest streams are breeding grounds for one of the malaria vectors.

5.5.1.2 Gaps and Recommendations

Due to the increased variability of river flow, where the range between the high and low flows are greater the stability of river banks will be affected, and the resulting river bank failures will result in increased erosion and sedimentation in the river. The variability of flow will also affect the physical and ecosystem functions of the floodplain and estuarine wetlands. Also, due to sea level rise there will be salinity intrusion at the river mouths which may cause problems related to sedimentation at the river mouth.

Also, the NC2 highlighted that the manner in which climate change impacts on rivers could affect their role as a breeding ground for malaria vectors should be studied in order to avoid future reintroduction/occurrence of malaria or at least be prepared for such an event.

The recommendations for this sector are as follows:

(a) To assess the impacts of increased variability of river flow on the stability of river banks and its resulting impacts on erosion and sedimentation in the river.
(b) To assess the impacts of the increased variability of river flow on the physical and ecosystem functions of the floodplains and estuarine wetlands.
(c) To assess the impacts of sea-level rise induced salinity intrusion at the river mouth on the sedimentation characteristics at the river mouth; and
(d) To study the how climate change may impact on rivers and their role as a breeding ground for the malaria vectors.

5.5.2 *Lakes*

5.5.2.1 <u>Current Status</u>

NAHRIM completed a study on the status of eutrophication of 90 lakes in Malaysia in 2005. The study found that 60 lakes were eutrophic. Following the study the Academy of Science Malaysia (ASM) and NAHRIM conducted a series of workshop to develop the strategies to manage the lakes in the country. NAHRIM has also developed a National Lake Inventory System to support the archiving and sharing of information on lakes in Malaysia.

The IPCC Technical Paper on Water and Climate Change has highlighted the following possible impacts on lakes due to climate change:

1. Intensified stratification and nutrient loss from surface waters, decreased hypolimnetic oxygen (below the thermocline) in deep, stratified lakes, and expansion in range for many invasive aquatic weeds.
2. Water levels in lakes at mid- and low latitudes are projected to decline.
3. Endorheic (terminal or closed) lakes are most vulnerable to a change in climate because of their sensitivity to changes in the balance of inflows and evaporation. Changes in inflows to such lakes can have very substantial effects and, under some climatic conditions, they may disappear entirely.
4. A unit increase in temperature in tropical lakes causes a proportionately higher density differential as compared with colder temperate lakes. Thus, projected tropical temperatures will lead to strong thermal stratification, causing anoxia in deep layers of lakes and nutrient depletion in shallow lake waters. Reduced oxygen concentrations will generally reduce aquatic species diversity, especially in cases where water quality is impaired by eutrophication; and
5. Effects of warming on riverine systems may be strongest in humid regions, where flows are less variable and biological interactions control the abundance of organisms. Drying of stream-beds and lakes for extended periods could reduce ecosystem productivity because of the restriction on aquatic habitat, combined with lowered water quality via increased oxygen deficits and pollutant concentrations.

5.5.2.2 <u>Gaps and Recommendations</u>

Apart from the extensive research on Putrajaya Lake and Tasik Chini there is not much information available on the major lakes in the country. Thus, there is a need for more monitoring and research on the major lakes in the country. The information is required as baseline data for any impact assessment arising from climate change on lakes.

The recommendations for this sector are as follows:

(a) To adopt and implement the lake management strategies developed by ASM and NAHRIM in 2008.
(b) To identify lakes that have important socio-economic objectives and carry out preliminary, indicative studies on the potential impacts of climate change on the lakes, taking note of the the potential climate change impact factors on lakes highlighted by the IPCC .

5.5.3 *Aquifers/Groundwater*

5.5.3.1 Current Status

The technical management of aquifers or groundwater resources in Malaysia is under the responsibility of the Department of Mineral and Geosciences (DMG). The DMG keeps records of groundwater wells and prepares the hydrogeological maps for the country. The licensing of groundwater development lies with the respective state government. Due to the abundance of surface water in the rivers the exploitation of groundwater as a source of water for both irrigation and potable use is not common, except in the state of Kelantan and some parts of Sabah where potable water supply are derived from groundwater sources.

In the RMK8 period (2000–2005), a study on groundwater resources in the states of Johor, Kedah, Negeri Sembilan, Sabah, Sarawak and Selangor was completed in 2002. Also, in the RMK9 period (2006–2010) the development of groundwater was promoted as an interim measures to address the anticipated shortage of water in Selangor, Kuala Lumpur and Putrajaya.

The NPP (2005) has identified groundwater resource and recharge areas that need to be protected from activities that cause pollution and reduce their yield. It highlighted that Structure Plans and Local Plans shall delineate ground water resource areas (wellheads) and recharge areas as part of the integrated land use management plans and that buffer requirement shall be imposed to protect the recharge areas and wellheads. Also, it highlighted the need for drainage controls to be imposed in the vicinity of important groundwater areas such as peat swamps and freshwater swamps to maintain the water table required to sustain the ecosystems within them. In order to avoid over-extraction of groundwater resources it also highlighted the need for monitoring the groundwater extraction of all public wells catering for commercial, industrial and agricultural activities.

The IPCC Technical Paper on Water and Climate Change (IPCC–WCC) has highlighted that sea-level rise is projected to extend areas of salinisation of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas.

The IPCC-WCC highlighted the following points related to the impacts of climate change on groundwater:

1. Climate change affects groundwater recharge rates (i.e. the renewable groundwater resources) and depths of groundwater tables. However, knowledge of current recharge and levels in both developed and developing countries is poor; and there has been very little research on the future impact of climate change on groundwater, or groundwater-surface water interactions.
2. As many groundwaters both change into and are recharged from surface water, the impacts of surface water flow regimes are expected to affect groundwater.
3. Increased precipitation variability may decrease groundwater recharge in humid areas because of more frequent heavy precipitation.
4. Where the depth of the water table increases and groundwater recharge declines, wetlands dependent on aquifers are jeopardised and the base flow runoff in rivers during dry seasons is reduced; and
5. In areas where water tables are already high, increased recharge might cause problems in towns and agricultural areas through soil salinisation and waterlogged soils.

5.5.3.2 Gaps and Recommendations

There is a need to monitor the recharge characteristics of important aquifers and also the depth of their water tables to identify the potential negative impacts of climate change on wetlands dependent on the aquifer. Also, there is a need to note the potential impacts of rising water tables on the salinity of soils in agricultural areas.

The recommendations for this sector are as follows:

(a) To increase monitoring of the groundwater tables levels of important aquifers and also the recharge characteristics to identify potential negative impacts of climate change on wetlands dependent on the aquifer and also on possible increased in soil salinity arising from rising water tables.

5.5.4 *Coastal Areas*

5.5.4.1 Current Status

DID completed a National Coastal Erosion Study (NCES) in 1985 in which a thorough assessment of the conditions of the Malaysian coastline in 1985 was carried out. The conditions of the coastlines were group into 3 categories — Cat-1: Critical erosion, Cat-2: Significant erosion and Cat-3: Mild or acceptable erosion. Since uncontrolled developments along a reach of a coastline can affect that in another reach there is a need for coastal development plans that take into account the dynamic, physical nature of the coastline. In order to address that need DID conducted a pilot study in 2002 to develop an Integrated Shoreline Management Plan (ISMP) for the Northern Pahang coastline. The ISMP can assist local planning authorities in approving development proposals along coastal areas and complements the statutory Local Plan. Since then a number of ISMPs have been completed by DID for the Southern Pahang, Negri Sembilan, Labuan and Penang coastlines.

The NPP (2005) and National Urbanisation Policy have also identified coastal areas where the sensitive coastal ecosystems within them need to be protected from coastal reclamation for urban expansion, except for the development of ports, marinas and jetties. It highlighted the need for the policy recommendations of the National Integrated Coastal Zone Management to be implemented.

The NC2 noted that a pilot study to establish the National Coastal Vulnerability Index (NCVI) has been conducted in two areas, Tanjung Piai in Johore and Pantai Chenang in Langkawi. The study found that a global-high worst-case SLR scenario (10mm/year increase) will result in a loss of about 1,820 hectares of coastal land in Tangjung Piai and 148 hectares in Pantai Cenang by the end of the 21st century.

The IPCC Technical Paper on Water and Climate Change highlighted the following impacts on coastal areas due to climate change:

1. Changes in the timing and volume of freshwater runoff will affect salinity, sediment and nutrient availability, and moisture regimes in coastal ecosystems. Climate change can affect each of these variables by altering precipitation and locally driven runoff or, more importantly, runoff from watersheds that drain into the coastal zone.
2. Hydrology has a strong influence on the distribution of coastal wetland plant communities, which typically grade inland from salt, to brackish, to freshwater species.
3. If river discharge decreases, the salinity of coastal estuaries and wetlands is expected to increase and the amount of sediments and nutrients delivered to the coast to decrease. In coastal areas where streamflow decreases, salinity will tend to advance upstream, thereby altering the zonation of plant and animal species as well as the availability of freshwater for human use.
4. Deltaic coasts are particularly vulnerable to changes in runoff and sediment transport, which affect the ability of a delta to cope with the physical impacts of climatic change. In Asia, where human activities have led to increased sediment loads of major rivers in the past, the construction of upstream dams is now depleting the supply of sediments to many deltas, with increased coastal erosion becoming a widespread consequence.
5. Some of the greatest potential impacts of climate change on estuaries may result from changes in physical mixing characteristics caused by changes in freshwater runoff. Freshwater inflows into estuaries influence water residence time, nutrient delivery, vertical stratification, salinity, and control of phytoplankton growth rates.
6. Changes in river discharges into shallow near-shore marine environments will lead to changes in turbidity, salinity, stratification and nutrient availability.

5.5.4.2 Gaps and Recommendations

The NC2 has highlighted that a lot of the climate change impacts in the coastal reaches will be the result of increased sea level rise (SLR) and increased wave action. This could result in erosion and eventually salt water intrusion. Ecosystems such as mangrove forests and mudflats and the biodiversity they support are susceptible to increases in brackish water areas. Another impact to water bodies in coastal areas is reduced river flow during dry periods making river mouths vulnerable to sedimentation risks.

The following are the gaps identified for this sector in the NC2 report:

(a) There is an absence of long term tidal records and also records of changes in physical oceanographic patterns.
(b) There is a lack of site-specific, quantitative data and assessment on the changes in coastal storm patterns and the frequency of coastal storm events. These data are necessary for a comprehensive nationwide analysis of the impacts of coastal storm surges on the coastlines.
(c) There is a lack of a common understanding among the various government agencies dealing with SLR, which results in those agencies with the enforcement powers on coastal development not adhering with the guidelines and recommendations of the technical agencies.
(d) No detail study on the impacts of the rise in sea temperature on coral bleaching has been carried out to date.

The recommendations for this sector are as follows:

(a) The NCVI studies should be carried out for coastal areas that are likely to suffer from serious socio-economic impacts from SLR. The outputs from the study will enable timely adaptation measures to be undertaken to reduce or eliminate the impact. Thus, the NC2 recommended that NCVI studies be carried out for the following coastal areas:
    - East Coast: Pantai Sabak, Kelantan, Kuantan, Pahang, K. Terengganu, Terengganu;
    - West Coast: Pelabuhan Klang, Selangor, P. Pinang, Batu Pahat, Johor;
    - Sarawak: Bintulu, Miri, Kuching
    - Sabah: Kota Kinabalu, Tawau, Sandakan
(b) A policy on coastal management should be implemented to ensure that all coastline developments are guided by an Integrated Shoreline Management Plans (ISMP). The "retreat, accommodate and protect" approach should be adopted as the step-by-step defensive options to address the threat of coastal SLR.
(c) Identify financial resources to accelerate the formulation of ISMP for the rest of the country's coastlines.

(d) Identify ways to ensure compliance with the ISMP recommendations, for example by adopting legal instruments, such as the Coastal Development Control Law, for consistency in the application of coastal development guidelines.
(e) Conduct long term wave measurement programmes for Malaysian coasts so as to support research on the impacts of storm surges and wave patterns on the coastlines.
(f) Conduct long term observation of the natural coastal evolution caused by storm surges and wave patterns since they have significant impacts on the coastlines.
(g) Conduct research to find the best methods to implement coastal reforestation, such as finding the most optimal planting methods to develop robust coastal forests, as well as soft engineering application of structural and biological concepts to solve coastal erosion problems and reduce its erosive forces.
(h) Develop a system to monitor, detect and predict SLR and their potential impacts.
(i) Conduct a study to assess the impact on sensitive, coastal ecosystem such as the Kuala Selangor firefly colonies arising from reduced river flow caused by prolonged dry periods. The reduced river flow would result in salt water intrusion which will have impacts on the sensitive Berembang trees upon which the fireflies rely on.
(j) Conduct detail studies on the effect of coral bleaching due to the increase of sea temperature.

5.6 Water Use Management Capacity

5.6.1 *Potable Water Supply*

5.6.1.1 Current Status

The following is a summary on the current status on potable water supply management covering the three aspects of water resources management, supply management and demand management.

(a) Water resources management
Most of the potable water supplies used in Malaysia for domestic and industrial consumption are derived from rivers. Thus, the government recognizes in RMK10 and also in the NPP (2005) the importance of managing and protecting the river catchment through the adoption of the IWRM and IRBM principles and approach in land use planning. RMK10 highlighted the need to develop a long-term strategy for water resources management to achieve water security. Also, the NPP (2005) highlighted the need for water-resources-rich states to protect their water catchments and develop them for export to water–stressed states.

(b) Water supply management
The NWRS (2000) for Peninsular Malaysia highlighted the need to develop major water supply capacities to meet projected future water supply deficits, including

the need for inter-basin water transfer from Pahang to Selangor across the Main Ranges of Peninsular Malaysia. A review of the NWRS (2000) study has highlighted a number of major deficiencies in the NWRS (2000) study. They are:

1. Grossly inflated per capita water demand figures based on a flawed method used to estimate industrial water demand.
2. Economic growth data used to make water demand projections has been over optimistic.
3. Population growth data used to make water demand projections has been over optimistic.
4. Major changes in the development plans for Peninsular Malaysia have taken place since completion of the NWRS (2000) Study and the development scenarios used to compute the projected water demand is now outdated; and
5. The NWRS (2000) Study overestimates water demand compared to the recent 2009 NAHRIM study on “Preliminary Climate Change Impact on Water Resources”.

The NC2 has also questioned the data used to estimate the projected water supply demand to justify the development of the major water supply infrastructures to provide the required water supply capacities. It noted that the current NWRS (2010) study to review and update the NWRS (2000) study may give a different picture of the “projected water supply constraints” if contemporary per capita water consumption figures achieved by other countries were used in the estimating the projected water demand, and water supply demand management measures such as reduction in water reticulation distribution losses and, water savings facilities and practices are widely adopted.

The results from the NAHRIM 2009 study indicated that based on the capacities of existing facilities (i.e. Klang Gates Dam, Batu Dam, Sg. Selangor Dam, Tinggi Dam and downstream catchment between Sg. Selangor Dam to Batang Berjuntai Intake Point, (excluding the Pahang-Selangor water transfer project), 28 (nearly 12%) out of a total 240 months are projected to face water supply deficit situations due to the increased variability of the river runoff arising from the projected climate change for Selangor. The projected monthly water deficits range from (+)3 MCM to 214 MCM. The highest surplus could be as high as 2,137 MCM.

NAHRIM’s estimates were based on demands from population that is increasing from nearly 5 million in 2010 to nearly 7 million in 2050. The estimates are also based on the assumption that per capita domestic consumption increases from 300 (2010) to 330 (2050) litres/capita/day and Non-Revenue Water (NRW) increases from 185 (2010) to 207 litres/capita/day (2050).

[Note: To ensure sustainability in the planning of future water supply capacities there is a need for the government to adopt a sustainable, target per capita water demand figure, and to implement measures to achieve the targeted figure. The current paradigm of our water supply planners of projecting an increasing per capita water demand figure for the future, and also increasing NRW losses, such as that adopted by the NWRS (2000) and NAHRIM (2009) study is not acceptable. Water resources and financial resources are limited and we cannot plan for a future with unlimited water demand!]

Also, RMK10 highlighted that the major institutional restructuring of the water utilities sector that took place on 1 January 2008, with the implementation of the Water Services Industry Services Act 2006 (Act 655) or WSIA, will continue. The WSIA was created to allow the Federal Government to provide and regulate the treated water supply services and sewerage services which was formerly under the responsibility of the state authorities. It is to ensure uniformity of the laws and policies for the proper control and regulation of water supply services and sewerage services throughout Peninsular Malaysia and the Federal Territories of Kuala Lumpur, Putrajaya and Labuan.

(c) <u>Water demand management</u>

Both RMK10 and the NPP (2005) highlighted the need to implement water demand management measures through the reduction of water reticulation losses, recycling of water use and the incorporation of green design elements like rain water harvesting facilities and water conservation features into housing.

With the restructuring of the water utilities sector in 2008 a major effort has been undertaken by the government to reduce the NRW losses through a series of measures. However, the planning paradigm and incentives given to the water supply providers have not changed since they are private sector entities and make profits from supplying water, not reducing the demand for it.

Currently, there is also a perceived loss in confidence of the consumers in the drinking quality of the potable water supply. This can be seen in the thriving bottled water industry and also increased sales of water filters. The reason for this is because of the increased incidences of murky water at the taps over the years due to the breakdown and poor maintenance of the water reticulation system over the years. Also, consumers are aware of the increased pollution of our rivers and with rising income is also increasingly health-consciousness.

The IPCC Technical Paper on Water and Climate Change highlighted that climate change-induced changes in both the seasonal runoff regime and inter-annual runoff variability can be as important for water availability as changes in the long-term average annual runoff.

5.6.1.2 Gaps and Recommendations

The major gaps in the potable water supply sector are as follows:

(a) Lack of an effective institutional framework to support the implementation of IWRM and IRBM principles and approach in land use planning, water resources planning, management and use.
(b) Planning and implementing future water supply infrastructures based on the recommendations from an outdated and flawed NWRS (2000) study.
(c) Flawed paradigm of our water supply planners and consultants in planning our future water supply capacity based on meeting unlimited water demand, rather than planning with a targeted, sustainable per capita water demand.
(d) Lack of confidence of the consumers in the drinking quality of the potable water supply.
(e) Lack of an effective institutional, legal and financial framework to support water supply demand management through widespread adoption of rainwater harvesting, water conservation and water recycling measures by the consumers.
(f) Lack of a financial incentive structure to change the primary objective of water supply providers from selling more water to helping the consumers to reduce their consumption of water.
(g) Lack of resiliency in our water supply system to cope with the projected increased in variability of our river runoff arising from climate change.

The following are recommendations to address the above identified gaps:

(a) **Set-up National and State-level IWRM Secretariats to develop strategies, implement, monitor and report regularly on the progress in the implementation of IWRM principles, including integrated thematic sector-based approaches based on IWRM principles such as IRBM, IFM, etc**.

To ensure that IWRM principles, including the thematic, sector-based approaches based on it, are adopted and implemented for the whole water cycle from the management of the water body sources and the sustainable development and use of the water resources there is a need to create an institutional body that is tasked with the responsibility to develop strategies, implement, monitor and report on the country's progress towards achieving the IWRM vision. Currently, there are high-level National and State-level Water Resources Councils chaired by the Deputy Prime Minister and State Chief Ministers, respectively. Also, since water and land are state matters the State Chief Ministers are members of the NWRC. What is missing from the current institutional framework is a national water policy and legal framework that is developed to facilitate the adoption and implementation of IWRM principles by all the states and water sectors.

To address the above identified needs the current, on-going NWRS (2010) Study has defined the following as part of the deliverables of the Study:

(i) A National Water Resources Policy
(ii) A National Water Resources Model Law; and
(iii) Proposed institutional framework to support the implementation of the water resources policy and the law.

In order to ensure successful implementation and monitoring of progress towards achieving the IWRM vision for the management and use of Malaysia's water resources it is recommended that National and State-level IWRM Secretariats that are responsible to both the NWRC and state level WRC, respectively, be setup and given the specific task of developing strategies, implementing, monitoring and reporting on the national and state-level progress towards achieving the IWRM vision. The institutional form and operational modes of the proposed IWRM Secretariats can vary to fit the specific institutional, legal and political constraints of each state. However, without a "taskforce, working-level type" IWRM secretariat entrusted with a specific task and with strong, institutional support provided by the NWRC and state-level WRC, the IWRM vision will not be achieved.

(b) **Review the existing and future water supply infrastructure development plans recommended in the NWRS (2000) study, to address the highlighted flaws in the Study, and to anchor the plans on a targeted, sustainable per capita water consumption figure that is benchmark with the contemporary figures achieved by other countries.**

Since the NWRS (2000) Study's assumptions are questionable and the methods used in the Study to estimate water demands are shown to be flawed there is a need to review and update all existing and planned water supply infrastructure development plans that are recommended in the NWRS (2000) study. One of the deliverables in the NWRS (2010) study is the review and updating of the proposed water supply infrastructure development plans in the NWRS (2000) study, including proposing new plans.

In view of the current, flawed paradigm adopted by our water supply planners and consultants in planning our future water supply capacity as highlighted in gap (c) above, there is a need to review the recommendations of the NWRS (2010) Study for the future water supply infrastructure development plans so that they are anchored on a targeted, sustainable per capita water consumption figure that is benchmark with the contemporary figures achieved by other countries.

(c) **Adopt a policy of water supply capacity planning based on a targeted, sustainable per capita water demand figure, and make water supply planners,**

operators and consultants aware of such a policy so that the planning and operations of water supply infrastructures will be based on a constrained demand.

Since water resources and financial resources are limited a planning paradigm based on meeting the unconstrained water demand of consumers is unsustainable in both physical and financial terms, is very wasteful, and a bad investment of the limited financial resources of a country. Thus, there is a need to establish an upper limit constraint on the per capita water consumption figure used for the planning of future water supply infrastructures.

Thus, it is recommended that SPAN defines a targeted, sustainable per capita water demand figure to be used by all water supply planners and consultants in the development of future water supply infrastructure plans. The targeted figure should be benchmark with the contemporary figures achieved by other countries, whose citizens are able to enjoy a developed country's lifestyle without suffering much discomfort, while living within the limits of their country's average per capita water demand consumption.

SPAN should make the targeted, sustainable per capita water demand figure a policy imperative and make water supply planners, operators and consultants aware of such a policy so that the planning and operations of water supply infrastructures will be based on a constrained demand.

(d) **SPAN to impose requirement on water supply providers to develop and implement Water Safety Plans (WSP) to address the loss in confidence of the consumers in the drinking quality of our potable water supply**.

The projected climate change for Malaysia indicated that there will be increased variability in river runoff. This will result in increased incidences of lower river water quality due to reduced dilution capacity of the river, with potential consequences on the capacity of water treatment plants to cope with the lower river water quality. To address the issue of the consumers' loss of confidence in the drinking quality of our potable water supply, which will become more serious with the impacts of climate change, it is recommended that SPAN (Suruhanjaya Perkhidmatan Air Negara) impose the requirement on water supply providers to develop and implement Water Safety Plans (WSP) (http://en.wikipedia.org/wiki/Water_safety_plan).

WSPs are considered by the WHO as the most effective means of maintaining a safe supply of drinking water to the public. Their use should ensure that water is safe for human consumption and that it meets regulatory water standards relating to human health. Comprehensive risk assessment and risk management form the backbone of these plans, which aim to steer management of drinking water-related health risks away from end-of-pipe monitoring and response. In order to produce a WSP, a thorough assessment of the water supply process from water source to the consumer's tap must be carried out by the water provider. Hazards and risks should be identified, and appropriate steps towards minimizing the risks are to be investigated.

(e) **SPAN to setup a Water Demand Management Taskforce (WDM-TF) to develop strategies, implement, monitor and report on the country's progress towards achieving the targeted, sustainable per capita water demand figure**.

To ensure that the targeted, sustainable per capita water demand figure that have been proposed to be adopted as a policy imperative for the estimate of all future water supply capacity there is a need to create an institutional body that is tasked with the responsibility to develop strategies, implement, monitor and report on the country's progress towards achieving the targeted, sustainable per capita water demand figure. Since SPAN is the National Water Management Services Commission it should be given this responsibility. Thus, it is recommended that SPAN setup a Water Demand Management Taskforce (WDM-TF) to fulfill this responsibility.

The strategies that the proposed WDM-TF should develop shall include strategies that will ensure widespread adoption of rainwater harvesting by the public both for new buildings, and also the retrofitting of existing buildings, adoption of water recycling and water conservation practices by the public. One of the strategies is a need to expand the use of economic incentives, including improved water metering and pricing structure, to encourage water conservation.

(f) **SPAN to develop financial incentive structures to make water supply providers earn their revenue from delivering water supply performance rather than selling more water to consumers to waste**.

The current business model for the water supply providers is to earn revenue by selling more water to the consumer. There is a need for the proposed SPAN's Water Demand Management Taskforce to develop strategies and create financial incentives to make the water supply providers SPAN's business partners in achieving the targeted, sustainable per capita water demand figure. A possible strategy for SPAN to do this is to award water supply concessions to water supply providers based on their business plan that should includes programs to work with the consumers to reduce their per capita water consumption. Their business plan should show clearly how they have a financial incentive to work with the consumer to reduce their per capita water consumption. A part of their revenue stream should come from helping the consumers reduce their water consumption.

(g) **Need to develop strategies to increase the resiliency of our water supply system to cope with the projected increased in variability of our river runoff arising from climate change**.

With the projected increased in variability of our river runoff arising from climate change there is a need to develop strategies to increase the resiliency of our water supply system to cope with potential drought-like situations. SPAN should require water operators to "stress-test" the water supply systems to potential drought-like situations and develop plans to increase the resiliency of the system to cope with the situation. The identification of "back-up" water sources in lakes and ponds and the building of contingency water infrastructures to tap into those sources would be part of the plan, in addition to increasing the capacity of water storage facilities within the systems. The introduction of rainwater harvesting systems in individual houses and buildings will also increase the resiliency of the water supply systems.

5.6.2 *Agriculture & Irrigation Water Supply*

5.6.2.1 Current Status

The NPP (2005) has identified eight strategic granary areas comprising the Muda (MADA), Kemubu (KADA), ADP Kerian-Sungai Manik, IADP Barat Laut Selangor, IADP Pulau Pinang, IADP Seberang Perak, IADP Terengganu Utara (KETARA) and IADP Kemasin-Semerak that are to be conserved. All of these granary areas are served by irrigation facilities.

The NC2 has highlighted that the irrigation facilities and their efficacy can be impacted by excessive rainfall, reduced rainfall and extreme weather patterns. With excessive rainfall, failure to contain excess water is anticipated which could result in flooding and crop damage/loss of yield.

Projections made by the RegHCM-PM model were used in the NAHRIM (2009) study to identify vulnerabilities in three granary areas – the Muda Agriculture Development Authority (MADA), Kemubu Agriculture Development Authority (KADA) and the Barat Laut Selangor granary areas.

The projections indicated that the MADA granary area could face excess water for 76% of the 240 months studied while there are indications of extreme surplus of up to (+) 5,438 MCM in the KADA granary area. Insufficient rainfall is anticipated for 10 out of the 40 planting seasons considered at the MADA scheme possibly warranting the cancellation of paddy planting in some, or in the worst case scenario, all of the MADA area. Likewise, for the Barat Laut Selangor irrigation scheme where one of the deficit events is projected to be severe enough to disrupt planting in some parts. KADA is not expected to face severe deficits.

The NC2 has also highlighted that rain-fed agriculture is also vulnerable to climate change impacts. In terms of rice for example, a 15% increase in rainfall in the early growth stages could result in an 80% decrease in yield. Apart from food security being vulnerable, economic security is also vulnerable as yields of important crops to the economy like oil palm, rubber and cocoa will also be affected. These impacts will reduce the number of rubber tapping days and increase fungal incidence in cocoa. Also, frequent and severe landslides are anticipated as is an increase in tree mortality.

The NC2 has also highlighted that coastal agricultural activities are also vulnerable to salt water intrusion arising from sea-level rise.

The IPCC Technical Paper on Water and Climate Change (IPCC-WCC) highlighted that agricultural practices which increase the productivity of irrigation water use – defined as crop output per unit water use — may provide significant adaptation potential for all land production systems under future climate change. At the same time, improvements in irrigation efficiency are critical to ensure the availability of water both for food production and for competing human and environmental needs.

The IPCC-WCC paper also highlighted a list of autonomous adaptation actions that can be implemented by individual farmers, rural communities and/or farmers' organisations, depending on perceived or real climate change in the coming decades, and without intervention and/or co-ordination by regional and national governments and international agreements. The options for autonomous adaptation are largely extensions or intensifications of existing risk management and production enhancement activities, and are therefore already available to the farmers and communities. They include, with respect to water the following:

- Heat shock and drought;
- Modification of irrigation techniques, including amount, timing or technology;
- Adoption of water-efficient technologies to 'harvest' water, conserve soil moisture (e.g. crop residue retention), and reduce siltation and saltwater intrusion;
- Improved water management to prevent waterlogging, erosion and leaching;
- Modification of crop calendars, i.e. timing or location of cropping activities; and
- Implementation of seasonal climate forecasting.

The IPCC-WCC paper also highlighted that higher temperatures and increased variability of precipitation would, in general, lead to increased irrigation water demand, even if the total precipitation during the growing season remains the same.

5.6.2.2 <u>Gaps and Recommendations</u>

The major gaps in this sector are as follows:

(a) No vulnerability assessment of the projected climate change impact on the national rice supply needs arising from the impacts on the operations and planting cycle in the eight granary areas. NAHRIM (2009) Study only assesses the climate change impacts on the supply of irrigation water to the three granary areas. There is a need to translate the impacts on the irrigation water supply on the production of the rice crops in the eight granary areas and how it affects the national rice supply.
(b) No vulnerability assessment has been carried out on the impacts on crop quality and on the yield reduction in cash crops such as oil palm (where a 10% decrease in mean annual rainfall results in 30% decrease in yield) and rubber (where the reduction below mean minimum and increase in temperature over 30 degrees centigrade will result in 10% yield decrease).
(c) No study has been carried out on the low-cost, farm-level adaptation actions, such as choice of crop variety, changes in the planting date, and changes in irrigation practices that can be made to adjust to the projected climate change impacts on agricultural cash crops and the irrigated rice crops in the granary areas.
(d) Irrigation consumes a major part of the water resources in a catchment. There is a need to improve irrigation efficiencies so that there will be more water resources to meet the needs of competing water users, and also to increase the resiliency of the irrigation system.
(e) There is a need to assess the impacts of salt water intrusion on coastal agricultural activities arising from sea-level rise.
(f) There is a need to assess the impacts of increased frequency of heavy rainfall and floods on agricultural crops; and
(g) There is a need to improve crop modeling projections, with better local data on the projected magnitude of climate change, together with crop parameters and soil properties.

The following are recommendations to address the above identified gaps:

(a) Conduct a vulnerability study to assess the projected climate change impacts on the irrigation water supply for the eight granary areas, and how it will impact on the national rice supply arising from increased frequency of floods destroying crops, or prolonged droughts destroying or reducing the yield of the rice crops.
(b) Conduct a vulnerability study to assess the projected climate change impacts on the quality and yield of our national cash crops like oil palm and rubber due to the potential change in rainfall and temperature regime.
(c) Conduct a study to identify the types of low-cost, farm-level adaptation actions that can be taken to address the potential changes in climate due to shifting rainfall patterns and characteristics on the major agricultural cash crops and the irrigated rice crops in the eight granary areas.
(d) Implement measures and strategies to improve irrigation efficiencies in the eight granary areas.

(e) Conduct a study to assess the impacts of salt water intrusion on coastal agricultural activities arising from sea-level rise.

(f) R&D should be enhanced to identify flood resistant crop varieties, while agricultural drainage system should be designed to efficiently regulate water tables and remove flood waters from agricultural land as quickly as possible.

(g) Also, specific measures like low intensity tapping system and rain gutters for the rubber industry should be used in a more widespread manner to address increased frequency of rainfall. Workers skills should also be enhanced to enable them to apply newer technologies such as low impact tapping.

(h) R&D should be carried out to improve crop modeling projections, with better local data on the projected magnitude of climate change, together with crop parameters and soil properties.

(f) As part of the adaptation measures for this sector there is a need to establish an early warning system to monitor changes in rice and cash crop yield, promote farm-level rain-water harvesting, soil water management and drainage improvement to increase the resiliency of our agricultural system to cope with climate change.

5.6.3 *Hydropower*

5.6.3.1 Current Status

The NPCC (2009) has two Key Actions (KA19 and KA23) where hydropower has been identified as one of the Renewal Energy (RE) solutions to be promoted among small and independent developers, including local communities, especially in rural electrification with mini and micro hydroelectric schemes.

RMK10 has identified the Central Region of Sarawak as the Sarawak Corridor Renewable Energy (SCORE) with its hydropower energy resources of 28,000 MW. It has also identified the development of hydropower as an alternative source of energy.

The NPP (2005) has highlighted the need to reduce the use of fossil fuels, and to utilise RE solution and Energy Efficiency (EE). Thus, the development of hydropower as a renewable energy resource is considered as part of the solution.

5.6.3.2 Gaps and Recommendations

There is a need to assess the projected impact of climate change on the runoff regime and how it affects the operations of existing hydropower schemes. A reduction in runoff will affect the hydropower generation capacity and will have an impact on the national energy supply grid.

The recommendations to address the above gap are as follows:

(a) To conduct vulnerability studies on the projected impacts of climate change on the existing hydropower schemes.
(b) To carry out medium and long term catchment management where the hydropower scheme is located to balance competing use of the limited runoff in times of reduced river runoff to ensure sufficient runoff for hydropower genera
(c) To promote the national implementation of grid connected rooftop solar panels to reduce disruption risks and ease the hydropower capacity requirements.

5.6.4 *River Navigation*

5.6.4.1 Current Status

River navigation is an important mode of human and cargo transport such as for timber in Sarawak. The NC2 recognises that changes in river flows due to more extreme rainfall patterns, as well as increased frequency of extreme weather such as storms, can reduced the navigability of water bodies such as rivers and lakes. It also recognizes that the increased sedimentation at river mouths will affect cargo transportation such as timber.

The IPCC Technical Paper on Water and Climate Change highlighted that increased flood periods in the future would disrupt navigation more often, and low flow conditions that restrict the loading of ships may increase.

5.6.4.2 Gaps and Recommendations

There is a need to assess the projected impact of climate change on river navigation and how it will affect the existing transport operations of human and timber cargo, especially in Sarawak. Thus, it is recommended that a study be carried out to highlight the potential impacts on river navigation, for various possible rainfall regime, and to define the possible adaptation options. The study can be carried out for navigation in Sabah and Sarawak rivers once the NAHRIM's RegHCM climate model projections study for Sabah and Sarawak is completed.

5.6.5 *Fisheries*

5.6.5.1 Current Status

The impacts of climate change on freshwater fisheries have not been considered in the NC2 report, apart from the potential impacts of climate change on coastal aquaculture activities. Coastal aquaculture activities are vulnerable to salt water intrusion, since coastal wetlands and mangrove areas are habitats for juveniles and changes in the water salinity may affect their population and sex ratio.

The IPCC Technical Paper on Water and Climate Change highlighted that the negative impacts of climate change on aquaculture and freshwater fisheries include: stress due to increased temperature and oxygen demand and decreased pH; uncertain future water quality and volume; extreme weather events; increased frequency of disease and toxic events; sea-level rise and conflicts of interest with coastal defence needs; and uncertain future supplies of fishmeal and oils from capture fisheries.

5.6.5.2 Gaps and Recommendations

There is a need for studies to be undertaken to better understand the impact on freshwater fisheries resulting from climate change impacts on rivers and lakes. At the same time, a holistic approach should be taken to ensure that climate change vulnerabilities are not further aggravated by other stressors such as over fishing and pollution.

Thus, it is recommended that a study be conducted to assess the projected impact of climate change on freshwater fisheries, including coastal aquaculture activities, for various possible rainfall regime, and to define the possible adaptation options.

5.6.6 *Water Ecosystems*

5.6.6.1 Current Status

The ecosystem is recognised as a national strategic resource in the NEM (2009) report. Its importance is also recognised in the NPCC (2009), RMK10, NPP (2005) and NBP (1998).

The NPCC (2009) has three Key Actions (KA15, KA16, KA17 and KA23) where the importance of the natural ecosystem has been identified. It recognizes that natural ecosystems are carbon pool sinks that needs to be conserve and that sensitive and degraded ecosystems are to be rehabilitated through sound management practices and land use planning. Also, it highlighted the need for the value of ecosystem services to be identified and integrated into the development planning process and that there is a need to carry out baseline studies on forest ecosystems as part of the development of a national carbon accounting system.

RMK10 recognises the need to value our nation's natural endowments and that healthy ecosystems are a key determinant of our physical and economic well-being. It highlighted the need to develop business models to compete sustainably in the global economy and that economic growth has to be decoupled from environmental degradation.

RMK10 also emphasized the importance to continue with programs to conserve our forests and that further initiatives will be undertaken to encourage States to gazette forests, especially water catchments, as protected areas. It also highlighted that the Government with the participation of the private sector, non-government organisations (NGOs) and the public at large will continue its efforts in planting more trees to green the country.

RMK10 also recognizes the need to enhance the conservation of our forest's biodiversity and to protect its biodiversity and habitats. Thus, the Central Forest Spine of 4.32 million hectares in Peninsular Malaysia and the Heart of Borneo of 6.0 million hectares in Sabah and Sarawak will be classified as Environmentally Sensitive Areas (ESA), where limited or no development will be permitted. They will also serve as biodiversity reservoirs and watershed areas, with the potential to be developed for eco-tourism.

The NPP (2005) has identified and categorised three types of ESA in Peninsular Malaysia. The ESA will be affected by climate change and thus there is a need to include them in any climate change adaptation plans.

The NBP (1998) highlighted the need to increase efforts to strengthen and integrate conservation programmes and that there is a need to ensure that all major sectoral planning and development activities incorporate considerations of biological diversity management.

The IPCC Technical Paper on Water and Climate Change (IPCC-WCC) has highlighted the following impacts of climate change on ecosystem:

1. Temperature and moisture regimes are among the key variables that determine the distribution, growth and productivity, and reproduction of plants and animals.
2. Changes in hydrology can influence species in a variety of ways, but the most completely understood processes are those that link moisture availability with intrinsic thresholds that govern metabolic and reproductive processes; and
3. The changes in climate that are anticipated in the coming decades will have diverse effects on moisture availability, ranging from alterations in the timing and volume of streamflow to the lowering of water levels in many wetlands, and a decline in mist water availability in tropical mountain forests.

The IPCC-WCC Paper has also highlighted the following impacts of climate change on wetlands:

1. Climate change will have its most pronounced effects on inland freshwater wetlands through altered precipitation and more frequent or intense disturbance events (droughts, storms, floods). Relatively small increases in precipitation variability can significantly affect wetland plants and animals at different stages of their life cycle.
2. Generally, climatic warming is expected to start a drying trend in wetland ecosystems. This largely indirect influence of climate change, will lead to alterations in the water level, and would be the main agent in wetland ecosystem change. Monsoonal areas are more likely to be affected by more intense rain events over shorter rainy seasons, exacerbating flooding and erosion in catchments and the wetlands themselves.
3. Most wetland processes are dependent on catchment-level hydrology, which can be altered by changes in land use as well as surface water resource management practices.

4. Recharge of local and regional groundwater systems, the position of the wetland relative to the local topography, and the gradient of larger regional groundwater systems are also critical factors in determining the variability and stability of moisture storage in wetlands in climatic zones where precipitation does not greatly exceed evaporation.
5. Changes in recharge external to the wetland may be as important to the fate of the wetland under changing climatic conditions, as are the changes in direct precipitation and evaporation on the wetland itself. Thus, it may be very difficult, if not impossible, to adapt to the consequences of projected changes in water availability.
6. Due, in part, to their limited capacity for adaptation, wetlands are considered to be among the ecosystems most vulnerable to climate change. Wetlands are often biodiversity hotspots. Many have world conservation status. Their loss could lead to significant extinctions, especially among amphibians and aquatic reptiles; and
7. The seasonal migration patterns and routes of many wetland species will have to change; otherwise some species will be threatened with extinction. For key habitats, small-scale restoration may be possible, if sufficient water is available.

5.6.6.2 <u>Gaps and Recommendations</u>

In view of the national strategic importance of wetlands as highlighted in all the policy statements and RMK10 there is a need to setup a national inventory system for wetlands where basic information on the wetlands, including regular monitoring information can be archived. There is also a need to conduct studies of important wetlands to identify the sensitive physical and biological parameters that will be affected by climate change, as highlighted by the IPCC Paper above. The studies will provide the necessary information for the setting-up of a monitoring program to detect the impacts of climate change on the wetlands.

The recommendations for this sector are as follows:

(a) To setup a national inventory system for wetlands where basic information on the wetlands, including regular monitoring information can be archived.
(b) To conduct studies of important wetlands to identify the sensitive physical and biological parameters that will be affected by climate change; and
(c) To setup monitoring program to detect the impacts of climate change on the wetlands.

5.6.7 *Competing Uses for Water*

The IPCC Technical Paper on Water and Climate Change noted that there are non-climatic factors that affect the use of freshwater, such as increased competition for the scarce water resources, which will be impacted by climate change. These non-climatic factors will increase the severity of the impacts of climate change and require adaptations measures that will need increased stakeholder awareness and participation to ensure acceptance of the measures.

The following are some of the non-climatic factors identified by IPCC:

1. Both the quantity and quality of water resources are influenced by land-use change, construction
2. Water use is driven by changes in population, food consumption, economy (including water pricing), technology, lifestyle and societal views regarding the value of freshwater ecosystems.
3. The vulnerability of freshwater systems to climate change also depends on national and international water management. It can be expected that Integrated Water Resources Management (IWRM) will be followed increasingly around the world and that such a movement has the potential to position water issues, both as a resource and an ecosystem, at the centre of the policy-making arena. This is likely to decrease the vulnerability of freshwater systems to climate change; and
4. Consideration of environmental flow requirements may lead to the modification of reservoir operations so that human use of these water resources might be restricted.

5.7 Water Management Capacity

5.7.1 *Floods*

5.7.1.1 Current Status

DID completed a study in 2003 to update the condition of flooding in Malaysia up to the year 2000. The study encompasses all reported flood-affected areas in the states of Peninsular Malaysia, Sabah and Sarawak. The reported flood-affected areas are grouped by states and also under their respective river basins. The study also produced updated flood maps up to the year 2000 for all river basins in the country.

Table 5.1 gives a summary of the flooding conditions in Malaysia up to the year 2000. It shows that the total flood affected area in Malaysia in 2000 is 29,799 sq.km, which is about 9% of the total 328,938 sq.km in the country compared to the 29,021 sq. km. of flood affected area reported in the JICA 1982 Study. The study highlighted that flood mitigation projects have reduced the flooded areas in the Perlis, Perak, Melaka, Kesang, Batu Pahat, South West Johor, Terengganu and Kemasin/Semerak river basins. However, the reduction was off-set by an increase of 2,683 sq. km of flooded areas due to the larger flood events reported after the JICA Study.

Table 5.1 also shows that the total number of people living in the flood affected areas is estimated to be 4.819 million, which is about 22 % of the total population of 22.2 million in Malaysia as at year 2000. This is an increase of 76% compared to the flood affected population reported in the JICA 1982 Study, which was 2.736 million, representing 20% of the population at that time. This increase is in tandem with the increase in the country's population since 1980. The table also shows that the estimated total Annual Average Flood Damage for Malaysia is RM 915 million (at 2000 prices), compared to the RM100 million (at 1980 prices) reported in the JICA 1982 Study.

In order to address the issue of increasing frequency and cost of flood damages in urban areas the government approved in 2001 the implementation of DID's Manual Saliran Mesra Alam (MSMA) urban stormwater drainage design guidelines. The focus of the MSMA is on managing the runoff at source and on ensuring that urban runoff quantity and quality regains as much as possible the quality of natural runoff. This will mitigate the unsustainable practice of overloading our urban rivers with both increased runoff and pollutants from urban development based on the pre-2001 drainage approach of rapid discharge of runoff and no control on the discharge of urban runoff pollutants.

The NPP (2005) has recommended that all flood prone areas adjacent to main drains, streams and rivers be designated as drainage or river reserves. It also recommended that Structure and Local Plans shall incorporate adequate reserves for all main drains and rivers and that the MSMA guidelines shall be applied in all urban areas. For rural areas that are subject to flooding it recommended that appropriate flood mitigation measures shall be adopted.

The NPP (2005) also recommended that flood mitigation based on the avoidance of flood prone areas for development shall apply, and thus recommended that flood-risk maps for Peninsular Malaysia shall be prepared so that adequate provision and consideration shall be given to this aspect in future physical and land use planning exercises. The principle is to curb intrusion of urban uses into wetlands and flood plain areas which serve as natural flood storage facilities. This environment friendly policy also promotes conservation of wetlands and their flora and fauna, as well as provides regional level recreation facilities for urban residents.

In support of the above flood mitigation principles RMK10 stated that Local Plans will incorporate open space strategies that move beyond the current practice of just allocating land for open space activities, to understanding how cities can enhance and attract people to these public spaces. Thus, RMK10 will provide support to local authorities to create a seamless network of interconnected green spaces within cities and recognises that these networks of interconnected green spaces can also be zoned as flood protection zones if they are located in low-lying areas.

TABLE 5.1 SUMMARY OF FLOOD CONDITIONS IN MALAYSIA (AS AT YEAR 2000)[a]

	Peninsular Malaysia	Sabah	Sarawak	Malaysia
Total Area (km^2)	131,574	73,712	124,449	329,735
Flood Affected Area (km^2)	15,620	3,285	10,895	29,800
% of Flood Affected Area	11.9%	4.5%	8.8%	9%
Total Population (nos.)	17,670,100	2,519,900	2,012,600	22,202,600
Population Living in Flood Affected Areas (nos.)	3,688,600	652,175	478,490	4,819,265
% of Population Living in Flood Affected Area	21%	26%	24%	22%
Annual Average Damage (RM million)	616.5	141.0	157.5	915
AAD per sq. km. of Flood Affected Area (RM)	39,470	42,920	14,460	30,700

Note: Figures for area and population are obtained from 'Population and Housing Census of Malaysia – Preliminary Count Report 2000' published by Department of Statistics Malaysia in October 2000.

[a](Source: DID 2003 report —"Updating of Condition of Flooding in Malaysia")

RMK10 also stated that the restoration of rivers and waterfronts in Malaysian cities will be a priority. It highlighted that RM5 billion will be allocated for flood mitigation programmes. This includes the application of the Integrated Flood Management (IFM) approach to manage the risks of flood damage through forecasting and warning facilities, as well as the development of disaster preparedness and community awareness programmes and flood hazard maps.

The IPCC Technical Paper on Water and Climate Change has highlighted the following points related to floods:

1. Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas. It highlighted that adaptation procedures and risk management practices that incorporate projected hydrological changes with related uncertainties are being developed in some countries and regions.
2. Future flood damages will depend greatly on settlement patterns, land-use decisions, the quality of flood forecasting, warning and response systems, and the value of structures and other property located in vulnerable areas, as well as on climatic changes per se, such as changes in the frequency of tropical cyclones.
3. The impact of climate change on flood damages can be projected, based on modelled changes in the recurrence interval of current 20- or 100-year floods, and

in conjunction with flood damages from current events as determined from stage-discharge relations and detailed property data.

5.7.1.2 <u>Gaps and Recommendations</u>

The NC2 recognises that increased rainfall and extreme weather events are expected to occur more frequently and with greater intensity and thus results in more frequent and serious flood events, and in areas that are historically flood free. Also, soil saturation and nutrient leaching can occur.

It also highlighted that water control structures like dams, barrages and bunds will be vulnerable, as they are likely to fail under the new rainfall characteristics, since their design specifications do not account for climate change impacts. For example, the NC2 reported that the Timah Tasoh dam had been upgraded recently. However the November 2010 floods resulted in breaching the dam alert levels requiring six sluice gates to be opened.

The NC2 also noted that if these anticipated impacts are not properly managed, soil erosion will be accelerated causing soil degradation and scouring of drainage structures. This will affect the effectiveness of flood mitigation schemes and cause problems of sedimentation in rivers and reservoirs.

The NC2 also noted that all the above impacts and vulnerabilities will have significant impacts on economic activities such as damage of power generation equipment, transmission pylons, roads, rail lines, bridges and fuel delivery systems. Also, public health will be vulnerable to the impacts with a possibility of increased breeding ground for malaria and dengue vectors and the spread of water borne diseases.

The NC2 also highlighted the need to present climate projections results in the form of time-series of maximum monthly rainfall, since they can reveal the potential severity of floods and influence policy decisions on the management of the quantity of water in a year.

The major gaps in this sector are as follows:

(a) Need to update DID's Hydrological Procedures (HP) related to design rainfalls and flood peaks, to include projected design rainfalls.
(b) Need to update design rainfalls in the MSMA manual, to include projected design rainfalls.
(c) Need to update DID 2003 Flood Study report, and derive the latest flood maps, including indicative flood maps for the projected design rainfalls.
(d) Need to review designs of all major drainage and flood mitigation projects with updated and projected design rainfalls and flood peaks.
(e) Need to review design of all dams with updated and projected design rainfalls; and

(f) Need to develop flood disaster and dam-break mitigation plans for updated and projected design rainfalls.

The following are recommendations to address the above identified gaps:

(a) **Update DID's Hydrological Procedures (HP) related to design rainfalls and flood peaks, to include projected design rainfalls**.

DID has developed the following HP for use by engineers in their hydrological design. The HPs were developed based on observed rainfall and stream flow data. There is a need to review and update HP1 and HP4 based on the new rainfall and stream flow data that have been collected since the development of the HPs, whereas the use of simplified methods like HP5 and HP11 to estimate flood peaks and flood hydrographs for rural catchments can be replaced by the use of computer simulation models using the updated design rainfalls:

(i) Hydrological Procedure No. 1 — Estimation of Design Rainstorms in Peninsular Malaysia
(ii) Hydrological Procedure No. 4 — Magnitude and Frequency of Floods in Peninsular Malaysia
(iii) Hydrological Procedure No. 5 — Rational Method of Flood Estimation for Rural Catchments in Peninsular Malaysia
(iv) Hydrological Procedure No. 11 — Design Flood Hydrograph Estimation for Rural Catchment in Peninsular Malaysia; and
(v) Hydrological Procedure No. 27 — Estimation of Design Flood Hydrograph using Clark Method for Rural Catchment in Peninsular Malaysia

In addition to the updated HP1 and HP4 based on the latest set of observed rainfall and stream flow data, the updated HP1 and HP4 should also contain the outputs of analysis of the simulation results from a number of projected rainfall characteristics for possible hydrological scenarios derived from the RegHCM model. For each of the hydrological scenarios the level of uncertainty stated in probabilistic terms shall be highlighted for each of the rainfall projections included in the updated HP1 and HP4. In this way, the updated HP1 and HP4 can still be a useful handbook for engineers to use in the design of new, and assessment of the vulnerabilities of existing, water infrastructures in a period of changing rainfall characteristics.

(b) **Update the design rainfalls in the MSMA manual, to include projected design rainfalls.**

The MSMA manual contains the coefficients of a fitted equation for rainfall IDF curves for 35 cities and towns in Malaysia, together with design rainfall temporal patterns for a number of standard chosen durations. The rainfall data used to derive the coefficients in the MSMA manual were based on 30 years records (1953 – 1983). There is a need to derive updated values of the IDF curves coefficients for the 35 cities in the MSMA manual based on the rainfall data that have been collected since 1983. There is also a need to derive a number of sets of IDF curves coefficients for a number of projected rainfall characteristics derived from the RegHCM model. For each of the projected rainfall IDF curves in the updated MSMA manual the uncertainty level stated in probabilistic terms shall be highlighted. In this way, the updated MSMA manual can be used by engineers to design new urban drainage systems, and also carry out assessment of the vulnerabilities of existing urban drainage system, for a changing climate.

(c) **Update DID 2003 Flood Study report, derive the latest flood maps, including indicative flood maps for the projected design rainfalls**.

In view of the series of major, unprecedented flood events that occurred over the past decade, especially the ones in Johore in 2006–2007 and the recent floods in November 2010 in Kedah and Perlis, there is a need to update the DID 2003 Flood Study report with the additional information on the flood events that have been recorded over the past decade from 2000. In addition to producing an updated set of flood maps for the country, this new study should also produce indicative flood maps for the projected design rainfalls, under the new climatic regime.

(d) **Review designs of all major drainage and flood mitigation projects with the updated design rainfalls and flood peaks given in the updated HP1, HP4 and MSMA manual**.

The historical design of all major drainage and flood mitigation projects should be reviewed using the updated design rainfalls, and also design rainfalls for the various possible hydrological scenarios, given in the HP1, HP4 and MSMA manual. In this way, the vulnerability and level of flood protection of the projects can be assessed and described in probabilistic terms, based on the uncertainty levels of the projected design rainfalls. Based on the assessment results the mitigation options for the projects can be developed for each of the projected climatic regime and their costs derived. One of the options will be the no-regret option of moving development away from low-lying areas and wetlands, and preserving them as the proposed green buffer and networks of interconnected urban green spaces as promoted in RMK10.

(e) **Review designs of all major dams with the updated and projected design rainfalls**

The historical design of all major dams should be reviewed using the updated design rainfalls, and also design rainfalls for the various possible hydrological scenarios, given in the HP1, HP4 and MSMA manual. In this way, the vulnerability of the dam to flood overtopping, and the change in the hydrological design protection level of the dam can be assessed for the projected rainfall design scenarios in the updated HP1, HP4 and MSMA manual. Based on the assessment results the mitigation options for the dams can be developed for each of the projected climatic regime and their costs derived. Existing dams and proposed new dams have to be checked against safe passage of Probable Maximum Floods for emergency spillways as a result of climate change impact. NAHRIM recently published Technical Research Publication No. 1 (TRP No. 1) " Derivation of Probable Maximum Precipitation (PMP) for Design Flood in Malaysia" which could be used as a guide to review the safety of dams in Malaysia.

(f) **Develop flood disaster and dam-break mitigation plans for updated and projected design rainfalls**

Based on the outputs from the review of the historical designs of major flood mitigation projects and dams in items (c) and (d) above, for the projected design rainfalls, the implications on existing flood disaster and dam-break mitigation plans can be assessed. Contingency flood disaster and dam-break mitigation plans can then be developed for the projected design rainfall scenarios, for use in the event such future rainfall scenarios do occur.

5.7.2 *Water Pollution*

5.7.2.1 Current Status

The DOE conducts regular monitoring of water quality in major rivers which provides raw water for water supply treatment. The results of the monitoring are reported annually in DOE's Annual Environmental Quality report.

RMK10 highlighted that the major sources of pollution in rivers include improper discharge from sewerage treatment plants, agro-based factories, livestock farming, land clearing activities and domestic sewage. It stated that during the RMK10 period measures will be taken to improve pollution control targeting the above identified sources through the following measures:

1. Strengthening the enforcement on industrial effluents and sewage discharge in line with the revisions to the regulations under the *Environmental Quality Act 1974*;
2. Assessing the Total Maximum Daily Load and carrying capacity of rivers to determine allowable discharge loads, for both point and non-point sources of pollution;
3. Revising the current Water Quality Index to incorporate additional parameters, such as biological parameters, for more accurate river water classification;

4. Developing the National Marine Water Quality Index to replace the current Marine Water Quality Criteria and Standard, which was developed in 2008; and
5. Expanding outreach and awareness programmes targeting various segments of society, such as the Langkawi Award, Rakan Alam Sekitar, Malaysia Environment Week, Promotion of Cleaner Production to Industries and Environmental Debate amongst higher institutions.

The NPP (2005) highlighted that there is a need for a major commitment to sewerage treatment to create world class cities.

The NC2 highlighted that water supply quality will deteriorate with climate change impacts such as floods, droughts and extreme weather patterns. This in turn will adversely affect public health and cause diseases like cholera to spread easily. It noted that improved sanitation coverage and safe water supply will reduce this impact.

The IPCC Technical Paper on Water and Climate Change highlighted the following impacts on water quality/pollution due to climate change:

1. Higher water temperatures, increased precipitation intensity, and longer periods of low flows are projected to exacerbate many forms of water pollution, including sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt and thermal pollution. This will promote algal blooms and increase the bacterial and fungal content. This will, in turn, impact ecosystems, human health, and the reliability and operating costs of water systems.
2. Rising temperatures are likely to lower water quality in lakes through increased thermal stability and altered mixing patterns, resulting in reduced oxygen concentrations and an increased release of phosphorus from the sediments.
3. More intense rainfall will lead to an increase in suspended solids (turbidity) in lakes and reservoirs due to soil fluvial erosion and pollutants will be introduced.
4. More frequent heavy rainfall events will overload the capacity of sewer systems and water and wastewater treatment plants more often; and
5. An increased occurrence of low flows will lead to decreased contaminant dilution capacity, and thus higher pollutant concentrations, including pathogens.

5.7.2.2 <u>Gaps and Recommendations</u>

There is a need to increase monitoring of the effects of temperature increase on lake and river water quality as they have significant effects on the pollution of lakes and rivers. The recommendation for this sector is to conduct monitoring studies on the effects of temperature increases on lake and river water quality.

5.7.3 *Water Scarcity/Drought*

5.7.3.1 Current Status

Currently some states suffer from water stress and are dependent on the water resources from adjacent states. Also, in times of a drought crisis situation, the current policy is always to sacrifice agriculture for water supply. However, this is only a short-duration strategy and is not a viable option for the long-term. For such regions with stiff competition for water, there are a number of adaptation options but each poses serious challenges for the existing policies.

One adaptation option would be to increase the water use efficiency and productivity of water in each sector, such as potable and irrigation water supply. Unfortunately achieving effectiveness (for example reducing per capita consumption from 250 litres/day to 150 litres/day or increasing irrigation efficiency to 90% and developing new less water consuming rice varieties) may not be achieved within the time frame of climate change. Another would be to ensure that policies such as the NPP and the National Urbanisation Policy and the measures that promote sustainable development are implemented nationwide.

5.7.3.2 Gaps and Recommendations

There is a need to develop and implement integrated drought management system, and to adopt policies to reduce the per capita demand of water and increase the crop irrigation efficiency.

5.7.4 *Human Health*

5.7.4.1 Current Status

The IPCC Technical Paper on Water and Climate Change has highlighted the following impacts on health due to climate change:

1. Human health, incorporating physical, social and psychological well-being, depends on an adequate supply of potable water and a safe environment. Human beings are exposed to climate change directly through weather patterns (more intense and frequent extreme events), and indirectly through changes in water, air, food quality and quantity, ecosystems, agriculture, livelihoods and infrastructure.
2. Floods have a considerable impact on health both in terms of number of deaths and disease burden, and also in terms of damage to the health infrastructure. While the risk of infectious disease following flooding is generally low in high-income countries, populations with poor infrastructure and high burdens of infectious disease often experience increased rates of diarrhoeal diseases after flood events.

3. There is increasing evidence of the impact that climate-related disasters have on mental health, with people who have suffered the effects of floods experiencing long-term anxiety and depression.
4. Flooding and heavy rainfall may lead to contamination of water with chemicals, heavy metals or other hazardous substances, either from storage or from chemicals already in the environment (e.g. pesticides). Increases in both population density and industrial development in areas subject to natural disasters increase both the probability of future disasters and the potential for mass human exposure to hazardous materials during these events.
5. Climate influences the spatial distribution, intensity of transmission, and seasonality of diseases transmitted by vectors (e.g. malaria).e.g..

   In the NC2, the climate sensitive health issues endemic in Malaysia that were identified are vector borne diseases (eg: dengue and malaria), water borne diseases (eg: cholera and typhoid), disaster related health problems and air pollution and temperature related mortality. Vectorial capacity modelling projected that the number of malaria cases may increase by about 15% to 20% with an increase of 1.5ºC to 2ºC in surface temperature in Peninsular Malaysia. Continuous effort is necessary towards achieving complete elimination of malaria.

5.7.4.2 Gaps and Recommendations

The NC2 highlighted that public health could be affected by the increased in areas of brackish water due to sea level rise in coastal areas, because of the increase in the coastal malaria vector population. The declining immunity as a result of effective control measures has rendered the rural population of all ages vulnerable to malaria. Lack of entomological data prevents an accurate assessment of the geographical extend of the vulnerability. A new practical approach to map the mosquito vector is required. The NC2 therefore recommends mapping of the malaria vector areas using remote sensing.

A better understanding of dengue transmission is necessary, which requires complex modelling. Capacity in this area is still very much lacking in the Ministry of Health which requires strengthening. More effective control tools are required to effectively adapt to the potential impact of climate change on dengue. One recommendation in the NC2 is to aedes-proof buildings through the review of building standards and guidelines and prevent/minimise rain water collection.

Little is known about air pollution and the impact of climatic factors on morbidity and mortality. Accurate assessment of the relationship is best addressed through a time series analysis. Availability of a reliable and complete database is critical.

No assessment has been made on the potential impact of extreme weather and disaster on health. Since the impact of such occurrence will be multi-sectoral, a multi-sectoral approach is suggested for such an assessment.

Capacity in carrying out appropriate quantitative and qualitative vulnerability assessment in all areas of health impact of climate change is limited and needs to be enhanced and strengthened.

The health impact of climate change is also influenced by other non-health factors. Future assessment should be carried out using an integrated ecosystem approach, rather than on a sectoral basis. In this approach, all sectors will work together within the same eco-system to assess the impact of climate change.

CHAPTER 6. THE WAY FORWARD

The information that have been compiled and summarised in this report will provide the basis for the ATF-CCW to organise follow-up stakeholder consultation workshops to create awareness on the impacts of climate change on water-related sectors and issues, develop consensus among the stakeholders on the adaptation measures that are required in each water sector and the strategies to achieve them. The stakeholder workshops will also provide opportunities for the ATF-CCW to gather additional information on what each of the stakeholders are doing in their respective sectors, and what they are planning to do to adapt to climate change.

Thus, the Consultants recommend that the following conference and workshops be carried out to achieve the desired output of a set of strategic action plans for adaptation to the impacts of climate change, for the various water sectors, that are agreed and endorsed by all stakeholders for submission to the Government for implementation.

(a) National Conference on Water and Climate Change Adaptations
(b) Seven Thematic Workshops on Water and Climate Change Adaptations, as listed below:

1) Governance and Institutional Capacity
2) Climate Projections and R&D Capacity
3) Information Management Capacity
4) Stakeholder Awareness and Participation
5) Water Bodies Management Capacity
6) Water Use Management Capacity; and
7) Water Management Capacity.

The objective of the National Conference is to create awareness among all the stakeholders on the key issues involved in water and climate change. In addition to the presentation of the key outputs from this study, paper presentations on key thematic topics from other stakeholders that have carried out work related to climate change and water shall also be included. The conference shall conclude with a panel discussions on the next steps forward – which is to conduct in-depth thematic, stakeholder workshops for the above seven themes.

The objectives of each of the seven thematic workshops are as follows:

i. To agree on the key issues to be addressed in each theme to adapt to the impacts of climate change on water,
ii. To clarify, prioritise and define the strategic action plans and develop their list of activities to address each of the agreed issues; and
iii. To estimate the indicative costs, where possible, of each of the strategic action plan based on their list of activities.

To facilitate the organising of the workshop the information compiled in this report and organised under the seven themes can be extracted and provided as background workshop materials, and as an initial framework and food-for-thoughts for the workshop participants' discussions.

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Appendix 1. NC2 Water related adaptation Issues, Gaps and Recommendations.

Water Bodies	Impact	Vulnerability	Adaptation	Gaps (Info management, knowledge, R&D, capacity building, funding	Recommendation (Socio econ – floods, health-pollution, agriculture, water supply)
Rivers	Rainfall pattern changes	River flow River water quality (low rainfalls). Floods in low lying and coastal areas during short intense rainfall or long low intensity rainfall as rivers generally small and short. This could result in infrastructure damage (coastal roads, bunds) and human habitat damage. Increase in malaria vector population which breeds in small forest streams.		Number and frequency of hydrological and river flow data stations low.	
Lakes	No information	N/A	N/A	N/A	N/A
Aquifers	No information	N/A	N/A	N/A	N/A

Wetlands	No information	N/A	N/A	N/A	N/A
Coastal Reaches	Intensity, duration and frequency of storms.	Erosion risk of coastal settlements and sedimentation risk of jetties and river mouths.	Coastal Management Policy drafted and under deliberation by EPU.	Absence of long term tidal records and changes in physical oceanographic patterns.	Device a system to monitor, detect and predict SLR and potential impacts.
	Wave action	Coastal ecosystems (mangrove forests, mudflats) functioning.	Conduct NCVI study.	Site-specific quantitative data and assessment are required for a more comprehensive nationwide analysis.	Resources to conduct NCVI required. Study on impact of SLR on coral bleaching.
	SLR	Increase in areas with brackish water could increase coastal malaria vector population.	Implement ISMP.	Information on changes in storm patterns and frequency of storm events.	All centres of excellence to produce one core subject on SLR. Create a centre of excellence for coastal issues.
	Saline intrusion	Coastal economic activities. eg: Coastal agriculture and aquaculture.	Adopt the retreat, accommodation, and protection approach as necessary.	Study sea surface temperature, increasing acidity and decreasing salinity impact on biodiversity and productivity.	Accelerate formulation of ISMP. Legal instrument (Coastal Development Control Law) for consistency in

	Changes in salinity of coastal waters Increase of sea water temperature	Global high worst case SLR scenario (10mm/ year increase) will result in loss of about 1,820 ha coastal land in T.Piai and 148 ha in Pantai Cenang.	R&D to better understand long term natural coastal evolution due to storm surges and wave patterns. Research on coastal reforestation to develop optimal planting methods and robust coastal forests. Soft engineering (application of structural and biological concepts to solve erosion and reduce erosive forces).	Lack of uniform understanding in various agencies dealing with SLR. Lack of enforcement powers for coastal development to adhere with guidelines.	the application of coastal development guidelines, application of ICZM and adherence to ISMP. Expand NCVI study to E. Coast: Pantai Sabak, Kelantan, Kuantan, Pahang, K. Terengganu, Terengganu; W Coast: Pel Klang, Selangor, P. Pinang, Batu Pahat, Johor; Sar: Bintulu, Miri, Kuching and Sabah: KK, Tawau, Sandakan) R&D on storm surges and wave patterns. Develop long term wave measurement programmes along Malaysian coasts. Soft engineering (application of structural and biological concepts to solve erosion and reduce erosive forces).

Water Use Sector					
Irrigation	Excessive rainfall Reduced rainfall Extreme weather	Failure to contain excess water resulting in flooding and loss of yield: MADA: 76% of 240 months studied KADA: indications of extreme surplus – flooding and crop damage. Insufficient water supply: MADA (10/40 planting seasons affected possibly resulting in cancellation of the planting season). BL Selangor – disruption of planting season	Early warning system. Rain water harvesting Soil water management and drainage improvement.	Impact considered in isolation of impacts on other consumptive uses (and non-consumptive uses) possibly leading to ineffective adaptation measures. Knowledge of on the ground adaptation experience. Information management: Coordination mechanism to transmit information top down and bottom up. Used data from the National Water Resources Study 2000 (NWRS 2000)	

	Excessive rainfall	Damage to irrigation infrastructure. Irrigation system performance designed to maximize use of rainfall and uncontrolled flows from rivers before resorting to dam releases hence susceptible to rainfall.			
Potable/ Water Sanitation	Reduced rainfall	Pollution of potable water supply due to overflows and damage to infrastructure. Insufficient supply at source. Increase in the incidence of typhoid, cholera and, diarrheal diseases.	Rainwater harvesting, reduce NRW, water demand management. Maintain water treatment plants and distribution pipes. Use economic incentives to encourage water conservation and reduce per capita water consumption.	Impact considered in isolation of impacts on other consumptive uses (and non-consumptive uses) possibly leading to ineffective adaptation measures. Used data and water demand methodology from the National Water Resources Study 2000 (NWRS 2000).	

Industrial	Extreme weather Reduced rainfall	Competition with other uses.	Rainwater harvesting, reduce NRW, water demand management.	Impact considered in isolation of impacts on other consumptive uses (and non-consumptive uses) possibly leading to ineffective adaptation measures.	
Hydropower		Infrastructure damage Insufficient supply for generation	Medium term and long term catchment management programmes for hydropower stations and national implementation of grid connected rooftop solar panels.		
Navigation	Changes in river flows due to more extreme rainfall patterns. Increased frequency of extreme weather such as storms	Reduced navigability of waters. Cargo transportation (timber) disruption.			

Fisheries	SLR Temperature	Encroachment into/ destruction of breeding grounds. Change in sex ratio.			
Ecosystem water needs	No information	N/A	N/A	N/A	N/A
Water Management Floods/ increased rainfall/ extreme storm weather	Increased frequency and intensity. Occurrence in historically flood free areas.	Failure of water control structures like dams, barrages and bunds. Rainfed Agriculture – rice (15% early in growing season could result in 80% decrease in yield), oil palm, rubber (effect tapping activity), cocoa (reduced yield due to increased fungal incidence).	Non-structural approaches such as improved rainfall and flood forecasting, effective disaster warning system, flood hazard mapping and review of flood management plans as part of coordinated disaster prevention and management plan. Review design standards for flood risk management in all new structures – water control, transportation, electrical, water and waste amenities.	Crop modeling projections need to be improved with better local data on estimated magnitude of CC, crop parameters and soil properties. R&D and funding to establish baseline data on effects of rainfall patterns on agricultural activities. Resources required to disperse LITs and rain gutters and to train workers.	Pay special attention to projections regarding maximum monthly rainfall as it can reveal potential severity of floods and influence policy decisions to enhance management of available water. Research into innovative rainwater management to reduce floods, drought and other climate risks. Change paradigm from draining rainwater to collecting rainwater with multiple benefits (source of water, prevention of urban flooding, control on non-point source

	Soil saturation Soil nutrient leaching	Accelerate soil erosion and cause soil degradation, scour drainage structures, sedimentation into rivers and reservoirs. Frequent and severe landslides. Tree mortality (forests) Disruption of economic activity Damage to general infrastructure (power generation equipment, transmission pylons, roads, rail lines, bridges). Health – possibly dengue, malaria spread with increased breeding ground Reduced water quality and quantity.	Retrofitting/ reinforcement of under designed structures. R&D for flood resistant varieties, efficient drainage to regulate water tables and prevent floods. Rubber: low intensity tapping system and rain gutters. Mapping of malaria vector areas using GIS, aedes proofing buildings through review of building standards and guidelines to prevent/ minimise rain water collection, wider access to malaria drugs		pollution, restoration of hydrological cycle, alleviation of urban heat islands, supplementing flows of urban streams, recreation/tourism.)

Scarcity/ droughts	Increased frequency and severity. Occurrence in historically drought free areas.	Rainfed Agriculture – rice (15% early in growing season could result in 80% decrease in yield), oil palm (10% decrease in mean annual rainfall results in 30% decrease in yield), rubber (reduction below mean minimum and increase in temperature over 30oC results in 10% yield decrease), cocoa (Reduced yield) Health – possibly dengue, malaria spread with increased breeding ground	Enhance water supply efficiency (improve storage efficiency by removing sediments and eliminate loses from leakage and theft). Enhanced capacity of dams to store water. Encourage rainwater harvesting for non potable uses. Encourage demand management in non potable water use. Incorporate weather forecasting data into a decision support system. R&D for drought resistant/high water use efficiency (WUE) varieties. Research on aerobic rice (consumes less water). Sufficient irrigation facilities.		Pay special attention to projections regarding minimum monthly rainfall as it can reveal potential severity of floods and influence policy decisions to enhance management of available water.

			Enhanced monitoring of likely vector breeding grounds using GPS, aedes proofing buildings, wider access to malaria drugs.		
Quality of water supply and water bodies	Floods, droughts and extreme weather patterns will reduce water quality.	Health -Increase of cholera incidence with pollution caused by floods/ droughts.	Improve sanitation and coverage of safe water supply.		
Physical changes to water bodies	No Information	N/A	N/A	N/A	N/A
Competing use of water resources	Drought	Insufficient water supply for irrigation, human consumption and industrial use in times of drought.	IWRM, Rainwater harvesting, reduce NRW, water demand management. National Water Services Commission Act 2006, Water Services Industry Act 2006 promoting sustainable water use and better water management.	Only consumptive use considered (irrigation, domestic and industrial). Non- consumptive uses not included in analyses (environmental services, power generation, recreation (tourism).	Adopt a more holistic approach towards formulating adaptation strategies by not only including non consumptive use but also looking at water needs from a spatial/regional or temporal perspective.

General				Analysis based on limited climate models. Gaps in technical understanding between different agencies results in a time lag in decision making. Affected population still generally unaware and not being prepared to adapt to anticipated changes. Last complete water resources study regarding annual rainfall and distribution conducted in 1982. Low understanding on uncertainties and limitations of CC projections and scenarios for effective communication to decision makers and end users.	Increase number of GCM models and realizations and river based models with finer scale and temporal resolutions. Identify and overcome various barriers that include economic, information and social ones. Undertake multidiscipline studies involving natural and social sciences to develop practical adaptation measures taking considerations of various stakeholders into account. Update water resources study information. Implement IWRM, IRBM

				Lack of data sharing amongst agencies, sectors, stakeholders. Lack of incorporation of hydrological and climate variability into flood, water supply and other water related management. Lack of procedures and risk management practices in incorporating projected hydrological changes with related uncertainties from fine grid regional HCMs. Lack of consideration of the reduction in the numbers of flood or drought events by existing mitigatory measures such as the capacity enhancement of the Timah Tasoh dam or the construction of the SMART tunnel.	Increase stakeholder and community involvement in water resources planning and management.

Appendix 2: Summary of Observations of Climate Change and Climate Change Projections

	Observed Change					Projected Change								
	Comparison timeframe	Model	PM	Sabah	Sarawak	Baseline	SRES	Model		2020-2029	2025-2034	2041-2050	2050-2059	2090-2099
Temperature						1990-1999	A1B	9 AOGCMs	PM	n/a			n/a	1.1-3.6°C
	Mean temperature from1998-2007 compared to1961-1990	MMD data	0.5-1.5°C	0.5-1.0°C					Sabah	n/a			n/a	1-3.5°C
									Sarawak	n/a			n/a	1-3.5oC
								Ensemble Mean Projected Temperature	PM		Increasing trend			2.8oC
									Sabah		Increasing trend			2.6oC
									Sarawak		Increasing trend			2.6oC
						1990-1999	A1B	PRECIS and HADCM3 (AOGCM)	PM					2.3-3.6
							A2	PRECIS and HADAM3P (AGCM)	Sabah					2.4-3.7
							B2	PRECIS and HADAM3P (AGCM)	Sarawak					2.4-3.7
						1990-1999	A1B	PRECIS and HADCM3 (AOGCM)	PM	1.1-1.5			1.7-2.0	2.9-3.2
									Sabah	1.0-1.2			1.7-1.9	2.8 - 3.0
									Sarawak	1.2-1.4			2	3.4-3.8
						1984-1993	IS92a							
Rainfall	Dry years in 1975-2005 compared to 1951-1975	MMD data	More frequent and intense	No increasing or decreasing trend in terms of rainfall		1990-1999	A1B	RegHCM-PM, CGCM1, MM5 and IRSHAM	PM		1-1.5			
								9 AOGCMs		No clear trend shown by the chosen models				
	2000-2007 compared to1990-1999	MMD Surface Observation Station data	6-10% increase (WC) 4-10% decrease (EC)	>10% increase	6-10% increase									
								Ensemble Mean Projected Temperature	PM		Incease in WC states Decrease in EC states			
									Sabah		N/A			
									Sarawak					Significant increase in W Sarawak.
						1990-1999	A1B							
							A2	PRECIS and HADCM3 (AOGCM) PRECIS and HADAM3P (AGCM) PRECIS and HADAM3P (AGCM)	PM		(-)19 to (+)19%			
							B2			2028 (Decrease El Nino) 2030-31 (Increase-La Nina)			2048 and 2061 (Decrease-El Nino) 2055-58 (Increase)	2079 (Decrease-El Nino) 2084-91 (Increase)
									Sabah		(-)30 to (+)15%			

Appendix 2 (cont.) : Summary of Observations of Climate Change and Climate Change Projections

					1990-1999	A1B		Sarawak	2028 (Decrease El Nino) 2030-31 (Increase-La Nina)	(-)27 to (+)15%	2048 and 2061 (Decrease-El Nino)	2079 (Decrease-El Nino) 2084-91 (Increase)
							PRECIS and HADCM3 (AOGCM)	PM	2028 (Decrease El Nino) 2030-31 (Increase-La Nina) (-)18.7 to (-)10.2 %		2048 and 2061 (Decrease-El Nino) (-) 6 to (+) 6.4 %	2079 (Decrease-El Nino) 2084-91 (Increase) 6/27/20116/27/2011
					1984-1993	IS92a		Sabah	(-)17.5 to (-) 8.9 %		(-) 1.2 to (-) 12.8 %	(-) 3.6 to (+) 0.3 %
								Sarawak	(-) 9.1 to (-) 8.8 %		(-) 1.3 to (+) 3.8 %	(+) 6.2 to (+) 14.6 %
							RegHCM-PM, CGCM1, MM5 and IRSHAM	PM		2028 and 2029 (dry) 2033 (wet); 2044 (dry) 2043 and 2049 (wet); (-)5 to (+)10 %		
Seasonal Precipitation Patterns	1998-2007 compared to 1961-1990		Decreasing	Increasing	1961-1990 (5 year runing mean)	A1B						
Winter Monsoon (DJF)	1961-1990	9AOGCMs (A1B) Ensemble (A1B)	850hPa 850hPa				PRECIS and HADCM3 (AOGCM)	PM Sabah Sarawak		DJF for 50 year span from 2035-2085 relaively dry MAM for last third of simulation from 2065-2099 shows upward trend. Overall weakening		

Appendix 3 — Selected Extracts on "Governance and Institutional Issue" from key National and International documents.

This appendix presents a compilation of the relevant national actions that have been identified by our national policy makers and technical managers on the issue of governance and institutional capacity to address the potential climate change impacts on water and the adaptation measures that need to be taken. It also presents the international scenarios on the issue, and in particular, highlights the key recommendations from the IPCC Technical Paper VI on Climate Change on Water (2008), the Stern Review on the Economics of Climate Change (2006) and the report on "The Economics of Climate Change in Southeast Asia: A Regional Review" (2009) by ADB. Some selected examples of international best practices that have been taken to address the issue are also given.

1. National Actions

The national actions that have been identified by our national policy makers and technical managers have been extracted from the following documents:

- National Policy on Climate Change (2009) – (NPCC)
- Tenth Malaysia Plan (2010-2014) – (RMK10)
- National Biodiversity Policy (1998) (NBP)

1.1 National Policy on Climate Change (2009) – (NPCC)

The NPCC has identified the following Key Actions (KA) that need to be taken to address the governance/institutional issue under the relevant Strategic Thrusts (ST).

KA1 - ST1: Conduct systematic reviews and harmonise existing legislation, policies and plans, taking into account and proposing relevant balanced adaptation and mitigation measures, to address the following:

- Agriculture and food security;
- Natural resources and environment (water, biodiversity, forestry, minerals, soil, coastal and marine and air);
- Energy security;
- Industries;
- Public health;
- Tourism;
- Transportation;
- Infrastructure;
- Land use and land use change (include land reclamation);
- Human settlements and livelihood;
- Waste management; and
- Disaster risk reduction.

KA2 - ST1: Incorporate climate change as a priority area in the National Development Planning Council.

KA3 - ST1: Establish an inter-ministerial and cross-sectoral committee to enable the implementation of climate change measures.

KA4 - ST2: Identify and recommend options towards low carbon economy for the following sectors:

- Energy security;
- Industries;
- Transportation;
- Public infrastructure;
- Waste management;
- Human settlements;
- Forestry; and
- Agriculture.

KA5 - ST2: Incorporate and facilitate implementation of climate-friendly measures and technologies by strengthening the following:

- Laws and regulations and Enforcement;
- Human resource development;
- Finance and incentives;
- Research and development;
- Transfer of technology; and
- Outreach to relevant stakeholders.

KA6 - ST2: Allocate adequate financing and appropriate technological measures for promoting low carbon economy through the following:

- Market mechanisms;
- Financial and fiscal incentives and disincentives;
- Mobilising public-private partnerships; and
- Involvement of financial and insurance sectors.

KA7 - ST2: Integrate balanced adaptation and mitigation measures into development plans.

KA8 - ST2: Establish criteria and indices for environmentally sustainable socio-economic growth.

KA9 - ST3: Strengthen investment evaluation mechanisms to capitalise and ensure a climate-resilient industry in achieving sustainable development.

KA10 - ST3: Establish a greenhouse gas (GHG) emissions reporting framework for industries with linkage to the Statistics Department to ensure a sustainable and quality assured reporting process.

KA11 - ST3: Institutionalise a mechanism, which includes the following means, to facilitate business and industrial responses:

- Financial incentives;
- Training of experts;
- Technology management;
- Outreach communication programmes; and
- Recognition awards.

KA12 - ST4: Integrate balanced adaptation and mitigation measures into policies and plans on environment and natural resources.

KA13 - ST4: Incorporate measures, including mobilising financing and technical assistance, into the following areas:

- Agriculture and food security;
- Natural resources and environment (water, biodiversity, forestry, minerals, soil, coastal and marine and air);
- Energy security;
- Industries;
- Public health;
- Tourism;
- Transportation;
- Infrastructure;
- Land use and land use change (include land reclamation);
- Human settlements and livelihood;
- Waste management; and
- Disaster risk reduction.

KA24 - ST6: Stocktaking of current measures, taking into account initiatives already implemented by stakeholders, and undertake economic evaluation for incorporation into future Malaysia Plans.

KA25 - ST6: Integrate measures into policies, plans, programmes and projects in the following areas:

- Agriculture and food security;
- Natural resources and environment (water, biodiversity, forestry, minerals, soil, coastal and marine and air);
- Energy security;
- Industries;
- Public health;
- Tourism;
- Transportation;
- Infrastructure;
- Land use and land use change (include land reclamation);
- Human settlements and livelihood;
- Waste management; and
- Disaster risk reduction.

KA26 - ST6: Integrate climate change considerations at the planning level by applying tools that includes the following:

- Integrated Environmentally Sensitive Areas;
- Strategic Environmental Assessment;
- Economic Evaluation of Ecological Services;
- Sustainable Development Indicators.

KA27 - ST6: Enhance the coordinating mechanism to oversee the planning, implementation and monitoring of climate change measures.

KA33 - ST7: Institutionalise measures to strengthen effective linking of climate science and policy.

KA37 - ST8: Strengthen collaborative networks and capacity of agencies at the federal, state and local government levels.

KA43 - ST10: Promote regional cooperation on climate change within existing inter-governmental and nongovernmental mechanisms.

1.2 Tenth Malaysia Plan (2010–2014) (RMK10)

The following is the relevant section from RMK10 that is pertinent to the governance and institutional issue on climate change.

(a) RMK10: Whole-of-Government Approach (page 314)
Increasingly, challenges and opportunities will transcend the traditional boundaries of public agencies in Malaysia, and therefore a higher level of inter-agency collaboration and cooperation is required. A whole-of-government approach will

be adopted to ensure cross-cutting issues are addressed with a focus on the people as customers.

This requires agencies to work across portfolio boundaries and across federal, state and local levels as an integrated government. This whole-of-government approach will be applied to policy formulation, programme development and delivery of outcomes.

1.3 National Biodiversity Policy (1998) (NBP)

The NBP has identified the following R&D related strategies (ST) for effective management of biodiversity. They are relevant within the context of adaptation to address the governance and institutional issue related to climate change adaptation.

ST4 - Strengthen the Institutional Framework for Biological Diversity Management
Establish and reinforce the mechanisms for planning, administration and management of biological diversity.

ST9 - Review Legislation to Reflect Biological Diversity Needs
Review and update existing legislation to reflect biological diversity needs and introduce new legislation where appropriate.

ST11 - Develop Policies, Regulations, Laws and Capacity Building on Biosafety
Introduce measures for the incorporation of biosafety principles and concerns, especially in relation to genetic engineering, and the importation, creation and release of genetically modified organisms.

ST15 - Establish Funding Mechanisms
Identify and establish appropriate funding mechanisms for biological diversity conservation and management.

2. International Scenarios

The following are the key recommendations extracted from the IPCC Technical Paper VI - Climate Change on Water, the Stern Review on the Economics of Climate Change and the ADB report on "The Economics of Climate Change in Southeast Asia: A Regional Review", together with selected examples of international best practices that have been taken to address this issue.

2.1 IPCC Technical Paper VI - Climate Change & Water (2008) (IPCC-CC & Water Report)

2.1.1 IPCC-CC & Water Report — Executive Summary

The following are the key recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that address the governance and institutional issue.

Point 13 – Mitigation measures can reduce the magnitude of impacts of global warming on water resources, in turn reducing adaptation needs.

1. Mitigation measures can reduce the magnitude of impacts of global warming on water resources, in turn reducing adaptation needs. However, they can have considerable negative side effects, such as increased water requirements for afforestation/reforestation activities or bio-energy crops, if projects are not sustainably located, designed and managed.
2. On the other hand, water management policy measures, e.g. hydrodams, can influence greenhouse gas emissions. Hydrodams are a source of renewable energy. Nevertheless, they produce greenhouse gas emissions themselves. The magnitude of these emissions depends on specific circumstance and mode of operation.

Point 14 – Water resources management clearly impacts on many other policy areas.

1. Water resources management clearly impacts on many other policy areas, e.g. energy, health, food security and nature conservation.
2. Thus, the appraisal of adaptation and mitigation options needs to be conducted across multiple water-dependent sectors.
3. Low-income countries and regions are likely to remain vulnerable over the medium term, with fewer options than high income countries for adapting to climate change.
4. Therefore, adaptation strategies should be designed in the context of development, environment and health policies.

2.1.2 IPCC-CC & Water Main Report

The following are the key recommendations extracted from the IPCC-CC & Water Main Report that address the governance and institutional issue for the following sectors:

- Agriculture and food security, land use and forestry
- Human Health
- Water Supply and Sanitation
- Settlement and Infrastructure
- Economy: Insurance, Tourism, Industry, Transportation

(a) **Agriculture and food security, land use and forestry sector [Sec 4.2, page 59]**

<u>Planned adaptation [Sec 4.2.4.2, page 65]</u>

1. Planned adaptation solutions should focus on developing new infrastructure, policies, and institutions that support, facilitate, co-ordinate and maximise the benefits of new management and land-use arrangements. This can be achieved in general through improved governance, including:

    - addressing climate change in development programmes;
    - increasing investment in irrigation infrastructure and efficient water-use technologies;
    - ensuring appropriate transport and storage infrastructure;
    - revising land tenure arrangements (including attention to well defined property rights);
    - and establishing accessible, efficiently functioning markets for products and inputs (including water pricing schemes) and for financial services (including insurance).

2. Planned adaptation and policy co-ordination across multiple institutions may be necessary to facilitate adaptation to climate change, in particular where falling yields create pressure to cultivate marginal land or adopt unsustainable cultivation practices, increasing both land degradation and the use of resources, including water.

3. Policies aimed at rewarding improvements in irrigation efficiency, either through market mechanisms or increased regulations and improved governance, are an important tool for enhancing adaptation capacity at a regional scale. Unintended consequences may be increased consumptive water use upstream, resulting in downstream users being deprived of water that would otherwise have re-entered the stream as return flow.

(b) **Human Health Sector [Sec 4.3, Page 67]**

<u>Adaptation, vulnerability and sustainable development [Sec 4.3.4, page 69]</u>

1. Weak public health systems and limited access to primary health care contribute both to high levels of vulnerability and to low adaptive capacity for hundreds of millions of people.

2. Poverty and weak governance are the most serious obstacles to effective adaptation.

3. Despite economic growth, low-income countries are likely to remain vulnerable over the medium term, with fewer options than high-income countries for adapting to climate change.

4. Therefore, if adaptation strategies are to be effective, they should be designed in the context of the development, environment and health policies in place in the target area.

(c) **Water Supply and Sanitation Sector [Sec 4.4, page 69]**
Adaptation, vulnerability and sustainable development [Sec 4.4.4, page 71]

1. Integrated water management, including climate change as an additional variable, should be considered as an efficient tool.

2. Reduced, increased or a greater variability in water availability will lead to conflicts between water users (agriculture, industries, ecosystems and settlements). The institutions governing water allocation will play a major role in determining the overall social impact of a change in water availability, as well as the distribution of gains and losses across different sectors of society.

3. Institutional settings need to find better ways to allocate water, using principles – such as equity and efficiency – that may be politically difficult to implement in practice. These settings also need to consider the management of international basins and surface and groundwater basins.

4. To confront the additional stress induced by climate change, public participation in water planning will be necessary, particularly in regard to changing views on the value of water, the importance and role that water reuse will play in the future, and the contribution that society is willing to make to the mitigation of water-related impacts.

5. To implement policy based on the principles of integrated water management, better co-ordination between different governmental entities should be sought, and institutional and legal frameworks should be reviewed to facilitate the implementation of adaptation measures.

6. Climate change will be felt by all stakeholders involved in the water management process, including users. Therefore, all should be aware of its possible impacts on the system in order to take appropriate decisions and be prepared to pay the costs involved.

7. In the case of wastewater disposal norms, for example, the overall strategy used will possibly need to be reviewed, as long as it is based on the self-purification capacity of surface water, which will be reduced by higher temperatures.

(d) **Settlement and Infrastructure [Sec 4.5, page 73]**
Adaptation [Sec 4.5.3, page 74]

1. The impacts of changes in the frequency of floods and droughts or in the quantity, quality or seasonal timing of water availability could be tempered by appropriate infrastructure investments, and by changes in water and land-use management.

2. Coordinated planning may be valuable because there are many points at which impacts on the different infrastructures interact. For instance, the failure of flood defences can interrupt power supplies, which in turn puts water and wastewater pumping stations out of action.

3. Improved incorporation of current climate variability into water related management would make adaptation to future climate change easier (very high confidence). For example, managing current flood risks by maintaining green areas and natural buffers around streams in urban settings would also help to reduce the adverse impacts of future heavier storm runoff.

4. However, any of these responses will entail costs, not only in monetary terms but also in terms of societal impacts, including the need to manage potential conflicts between different interest groups.

(e) **Economy: Insurance, Tourism, Industry, Transportation Sector [Sec 4.6, page 74]**

Socio-economic costs, mitigation, adaptation, vulnerability, sustainable development [Sec 4.6.2, page 75]

1. Of all the possible water-related impacts on transportation, the greatest cost is that of flooding. The cost of delays and lost trips is relatively small compared with damage to the infrastructure and to other property.

2. Industrial sectors are generally thought to be less vulnerable to the impacts of climate change than such sectors as agriculture. Among the major exceptions are industrial facilities located in climate-sensitive areas (such as floodplains) and those dependent on climate-sensitive commodities such as food-processing plants.

3. The specific insurance risk coverage currently available within a country will have been shaped by the impact of past catastrophes. Because of the high concentration of losses due to catastrophic floods, private-sector flood insurance is generally restricted (or even unavailable) so that, in several countries, governments have developed alternative state-backed flood insurance schemes.

4. For the finance sector, climate-change-related risks are increasingly considered for specific 'susceptible' sectors such as hydro-electric projects, irrigation and agriculture, and tourism.

5. Insurance spreads risk and assists with adaptation, while managing insurance funds has implications for mitigation.

The following are the key recommendations extracted from the IPCC-CC & Water Main Report that address the governance/institutional issue related to the implications on policy and sustainable development.

Implications for Policy and Sustainable Development [Sec 7, page 127]

1. Climate change poses a major conceptual challenge to water managers, water resource users (e.g. in agriculture) as well as to policymakers in general, as it is no longer appropriate to assume that past climatic and hydrological conditions will continue into the future.

2. Water resources management clearly impacts on many other policy areas (e.g. energy, health, food security, nature conservation). Thus, the appraisal of adaptation and mitigation options needs to be conducted across multiple water-dependent sectors.

Implications for policy by sector [Sec 7.1, page 127]

The implications for policy caused by climate change impacts on water for the following seven water-related sectors are described below:

- Water resource management
- Ecosystems
- Agriculture & forests
- Coastal systems and low-lying areas
- Industry, settlement and society
- Sanitation and human health
- Climate information needs

(a) Water resource management

1. Drought-affected areas are likely to increase; and extreme precipitation events, which are very likely to increase in frequency and intensity, will augment flood risk. Up to 20% of the world's population live in river basins that are likely to be affected by increased flood hazard by the 2080s in the course of climate change.

2. Efforts to offset declining surface water availability due to increasing precipitation variability will be hampered by the fact that groundwater recharge is projected to decrease considerably in some water-stressed regions, exacerbated by the increased water demand.

3. Higher water temperatures, increased precipitation intensity and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, and water system reliability and operating costs.

4. Areas in which runoff is projected to decline will face a reduction in the value of services provided by water resources. The beneficial impacts of increased annual runoff in some other areas will be tempered by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risks.

5. At the global level, the negative impacts of climate change on freshwater systems outweigh the benefits.

6. Adverse effects of climate on freshwater systems aggravate the impacts of other stresses, such as population growth, land-use change and urbanisation. Globally, water demand will grow in the coming decades, primarily due to population growth and increased affluence.

7. Climate change affects the function and operation of existing water infrastructure as well as water management practices. Current water management practices are very likely to be inadequate to reduce the negative impacts of climate change on water-supply reliability, flood risk, health, energy and aquatic ecosystems.

8. Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions (e.g. the Caribbean, Canada, Australia, the Netherlands, the UK, the USA and Germany) that recognize the uncertainty of projected hydrological changes, but evaluation criteria on effectiveness need to be developed.

(b) Ecosystems

1. The resilience of many ecosystems and their ability to adapt naturally is likely to be exceeded by 2100 by an unprecedented combination of change in climate, associated disturbances (e.g. flooding, drought, wildfire) and other global change drivers (e.g. land-use change, pollution, over-exploitation of resources).

2. Greater rainfall variability is likely to compromise wetlands through shifts in the timing, duration and depth of water levels.

3. Of all ecosystems, freshwater ecosystems will have the highest proportion of species threatened with extinction due to climate change.

4. Current conservation practices are generally poorly prepared to adapt to the projected changes in water resources during the coming decades.

5. Effective adaptation responses that will conserve biodiversity and other ecosystem services are likely to be costly to implement, but unless conservation water needs are factored into adaptation strategies, many natural ecosystems and the species they support will decline.

(c) <u>Agriculture & forests</u>

1. An increased frequency of droughts and floods negatively affects crop yields and livestock, with impacts that are both larger and earlier than predicted by using changes in mean variables alone. Increases in the frequency of droughts and floods will have a negative effect on local production, especially in subsistence sectors at low latitudes.

2. Impacts of climate change on irrigation water requirements may be large. New water storages, both surface and underground, can alleviate water shortages but are not always feasible.

3. Farmers may be able to partially adjust by changing cultivars and/or planting dates for annual crops and by adopting other strategies. The potential for higher water needs should be considered in the design of new irrigation supply systems and in the rehabilitation of old systems.

4. Measures to combat water scarcity, such as the reuse of wastewater for agriculture, need to be carefully managed to avoid negative impacts on occupational health and food safety.

5. Unilateral measures to address water shortages due to climate change can lead to competition for water resources.

6. International and regional approaches are required in order to develop joint solutions.

(d) <u>Coastal systems and low-lying areas</u>

1. Sea-level rise will extend areas of salinisation of groundwater and estuaries, resulting in a decrease in freshwater availability.

2. Settlements in low-lying coastal areas that have low adaptive capacity and/or high exposure are at increased risk from floods and sea-level rise. Such areas include river deltas, especially Asian megadeltas (e.g. the Ganges-Brahmaputra in Bangladesh and west Bengal), and low lying coastal urban areas, especially areas prone to natural or human-induced subsidence and tropical storm landfall (e.g. New Orleans, Shanghai).

(e) Industry, settlement and society

1. Infrastructures, such as urban water supply systems, are vulnerable, especially in coastal areas, to sea-level rise and reduced regional precipitation. Projected increases in extreme precipitation events have important implications for infrastructure: design of storm drainage, road culverts and bridges, levees and flood control works, including sizing of flood control detention reservoirs.

2. Planning regulations can be used to prevent development in high-flood-risk zones (e.g. on floodplains), including housing, industrial development and siting of landfill sites etc.

3. Infrastructure development, with its long lead times and large investments, would benefit from incorporating climate-change information.

(f) Sanitation and human health

1. Climate-change-induced effects on water pose a threat to human health through changes in water quality and availability. Although access to water supplies and sanitation is determined primarily by non-climate factors, in some populations climate change is expected to exacerbate problems of access at the household level.

2. Appropriate disaster planning and preparedness need to be developed in order to address the increased risk of flooding due to climate change and to reduce impacts on health and health systems.

(g) Climate information needs

1. Progress in understanding the climate impact on the water cycle depends on improved data availability. Relatively short hydrometric records can underestimate the full extent of natural variability.

2. Comprehensive monitoring of water-related variables, in terms of both quantity and quality, supports decision making and is a prerequisite for the adaptive management required under conditions of climate change.

Implications for policy by sector [Sec 7.1, page 127]

The implications for policy caused by climate change impacts on water for the following seven water-related sectors are described below:

Implications for climate mitigation policy [Sec 7.3, page 130]

1. Implementing important mitigation options such as afforestation, hydropower and bio-fuels may have positive and negative impacts on freshwater resources, depending on site specific situations.

2. Therefore, site-specific joint evaluation and optimisation of (the effectiveness of) mitigation measures and water-related impacts are needed.

3. Expansion of irrigated areas and dam-based hydro-electric power generation can lead to reduced effectiveness of associated mitigation potential. In the case of irrigation, CO_2 emissions due to energy consumption for pumping water and to methane emissions in rice fields may partly offset any mitigation effects.

4. Freshwater reservoirs for hydropower generation may produce some greenhouse gas emissions, so that an overall case-specific evaluation of the ultimate greenhouse gas budget is needed.

<u>Implications for sustainable development [Sec 7.4, page 130]</u>

1. Low-income countries and regions are expected to remain vulnerable over the medium term, with fewer options than high income countries for adapting to climate change.

2. Therefore, adaptation strategies should be designed in the context of development, environment and health policies. Many of the options that can be used to reduce future vulnerability are of value in adapting to current climate and can be used to achieve other environmental and social objectives.

3. In many regions of the globe, climate change impacts on freshwater resources may affect sustainable development and put at risk the reduction of poverty and child mortality.

4. It is very likely that negative impacts of increased frequency and severity of floods and droughts on sustainable development cannot be avoided.
5. However, aside from major extreme events, climate change is seldom the main factor exerting stress on sustainability.

6. The significance of climate change lies in its interactions with other sources of change and stress, and its impacts should be considered in such a multi-cause context.

2.2 Stern Review: The Economics of Climate Change (2006) (Stern Review)

2.2.1 *Stern Review - Executive Summary [Page 21]*

"Adaptation policy is crucial for dealing with the unavoidable impacts of climate change, but it has been under-emphasised in many countries"

1. Adaptation is the only response available for the impacts that will occur over the next several decades before mitigation measures can have an effect. Unlike mitigation, adaptation will in most cases provide local benefits, realized without long lead times. Therefore some adaptation will occur autonomously, as individuals respond to market or environmental changes. Some aspects of adaptation, such as major infrastructure decisions, will require greater foresight and planning. There are also some aspects of adaptation that require public goods delivering global and more climate-resilient crops and technologies.

2. Quantitative information on the costs and benefits of economy-wide adaptation is currently limited. Studies in climate-sensitive sectors point to many adaptation options that will provide benefits in excess of cost. But at higher temperatures, the costs of adaptation will rise sharply and the residual damages remain large. The additional costs of making new infrastructure and buildings resilient to climate change in OECD countries could be $15 – 150 billion each year (0.05 – 0.5% of GDP).

3. The challenge of adaptation will be particularly acute in developing countries, where greater vulnerability and poverty will limit the capacity to act. As in developed countries, the costs are hard to estimate, but are likely to run into tens of billions of dollars.

4. Markets that respond to climate information will stimulate adaptation among individuals and firms. Risk-based insurance schemes, for example, provide strong signals about the size of climate risks and therefore encourage good risk management.

5. Governments have a role in providing a policy framework to guide effective adaptation by individuals and firms in the medium and longer term. There are four key areas:

   - High-quality climate information and tools for risk management will help to drive efficient markets. Improved regional climate predictions will be critical, particularly for rainfall and storm patterns.
   - Land-use planning and performance standards should encourage both private and public investment in buildings and other long-lived infrastructure to take account of climate change.
   - Governments can contribute through long-term polices for climate-sensitive public goods, including natural resources protection, coastal protection, and mergency preparedness.
   - A financial safety net may be required for the poorest in society, who are likely to be the most vulnerable to the impacts and least able to afford protection (including insurance).

6. Sustainable development itself brings the diversification, flexibility and human capital which are crucial components of adaptation. Indeed, much adaptation will simply be an extension of good development practice – for example, promoting overall development, better disaster management and emergency response.

7. Adaptation action should be integrated into development policy and planning at every level.

2.2.2 *Stern Review – Main Report*

The following are the key recommendations extracted from the Stern Review Report that address the governance and institutional issue. Part V of the Report highlights the possible "Policy Responses for Adaptation".

(a) Understanding the Economics of Adaptation [Sec 18, page 404]
The key message from this section is summarized in Figure A3.1 below.

Key Messages

Adaptation is crucial to deal with the unavoidable impacts of climate change to which the world is already committed. It will be especially important in developing countries that will be hit hardest and soonest by climate change.

Adaptation can mute the impacts, but cannot by itself solve the problem of climate change. Adaptation will be important to limit the negative impacts of climate change. However, even with adaptation there will be residual costs. For example, if farmers switch to more climate resistant but lower yielding crops.

There are limits to what adaptation can achieve. As the magnitude and speed of unabated climate change increase, the relative effectiveness of adaptation will diminish. In natural systems, there are clear limits to the speed with which species and ecosystems can migrate or adjust. For human societies, there are also limits – for example, if sea level rise leaves some nation states uninhabitable.

Without strong and early mitigation, the physical limits to – and costs of – adaptation will grow rapidly. This will be especially so in developing countries, and underlines the need to press ahead with mitigation.

Adaptation will in most cases provide local benefits, realised without long lag times, in contrast to mitigation. Therefore some adaptation will occur autonomously, as individuals respond to market or environmental changes. Much will take place at the local level. Autonomous adaptation may also prove very costly for the poorest in society.

But adaptation is complex and many constraints have to be overcome. Governments have a role to play in making adaptation happen, starting now, providing both policy guidelines and economic and institutional support to the private sector and civil society. Other aspects of adaptation, such as major infrastructure decisions, will require greater foresight and planning, while some, such as knowledge and technology, will be of global benefit.

Studies in climate-sensitive sectors point to many adaptation options that will provide benefits in excess of cost. But quantitative information on the costs and benefits of economy-wide adaptation is currently limited.

Figure A3.1. Key Message on the Economics of Adaptation (Stern Review report).

(b) Adaptation in the Developed World [Sec 19, page 416]
The key message from this section is summarized in *Figure A3.2* below.

Key Messages

In developed countries, adaptation will be required to reduce the costs and disruption caused by climate change, particularly from extreme weather events like storms, floods and heatwaves. Adaptation will also help take advantage of any opportunities, such as development of new crops or increased tourism potential. But at higher temperatures, the costs of adaptation will rise sharply and the residual damages remain large. The additional costs of making new infrastructure and buildings more resilient to climate change in OECD countries could range from **$15 – 150 billion each year (0.05 – 0.5% of GDP)**, with higher costs possible with the prospect of higher temperatures in the future.

Markets that respond to climate information will stimulate adaptation amongst individuals and firms. Risk-based insurance schemes, for example, provide strong signals about the size of climate risks and encourage better risk management.

In developed countries, progress on adaptation is still at an early stage, even though market structures are well developed and the capacity to adapt is relatively high. Market forces alone are unlikely to deliver the full response necessary to deal with the serious risks from climate change.

Government has a role in providing a clear policy framework to guide effective adaptation by individuals and firms in the medium and longer term. There are four key areas:

- **High-quality climate information** will help drive efficient markets. Improved regional climate predictions will be critical, particularly for rainfall and storm patterns.
- **Land-use planning and performance standards** should encourage both private and public investment in buildings, long-lived capital and infrastructure to take account of climate change.
- **Government can contribute through long-term polices for climate-sensitive public goods**, such as natural resources protection, coastal protection, and emergency preparedness.
- **A financial safety net may be required to help the poorest in society** who are most vulnerable and least able to afford protection (including insurance).

Figure A3.2. Key Message on Adaptation in the Developed World (Stern Review report).

(c) Adaptation in the developing world [Sec 20, page 430]
The key message from this section is summarized in *Figure A3.3* below.

(d) Measures to strengthen adaptation [page 432]
Figure A3.4 below highlights measures to strengthen adaptation.

(e) Institutional constraints [page 439]

1. Governments face numerous constraints, including competing demands on scarce public resources. At present the adaptation process is generally channelled through the UNFCCC focal points, which are normally based in Ministries of the Environment.
2. Such ministries usually have limited influence with other line ministries and with the Ministry of Finance.

Key Messages

Adaptation to mute the impact of climate change will be essential in the poorer parts of the world. The poorest countries will be especially hard hit by climate change, with millions potentially pushed deeper into poverty.

Development itself is key to adaptation. Much adaptation should be an extension of good development practice and reduce vulnerability by:

- Promoting growth and diversification of economic activity;
- Investing in health and education;
- Enhancing resilience to disasters and improving disaster management;
- Promoting risk-pooling, including social safety nets for the poorest.

Putting the right policy frameworks in place will encourage and facilitate effective adaptation by households, communities and firms. Poverty and development constraints will present obstacles to adaptation but focused development policies can reduce these obstacles.

Adaptation actions should be integrated into development policy and planning at every level. This will incur incremental adaptation costs relative to plans that ignore climate change. But ignoring climate change is not a viable option – inaction will be far more costly than adaptation.

Adaptation costs are hard to estimate, because of uncertainty about the precise impacts of climate change and its multiple effects. But they are likely to run into tens of billions of dollars. This makes is still more important for developed countries to honour both their existing commitments to increase aid sharply and help the world's poorest countries adapt to climate change. More work is needed to determine the costs of adaptation.

Without global action to mitigate climate change, both the impacts and adaptation costs will be much larger, and so will be the need for richer countries to help the poorer and most exposed countries. The costs of climate change can be reduced through both adaptation and mitigation, but adaptation is the only way to cope with impacts of climate change over the next few decades.

Figure A3.3. Key Message on Adaptation in the Developing World (Stern Review report).

3. An integrated response requires activities led by a strong core ministry with overall responsibility such as Finance, Planning, Economic Affairs, and other line ministries.
4. Climate change faces the same challenges that other crosscutting issues, such as gender, HIV/AIDS, and rural livelihoods, have faced in the past. Given the importance of risk management in relation to climate change – and the potential impact on public sector investments — there are sound reasons for Finance and Economy Ministry engagement.

Box 20.1 Measures to strengthen adaptation

As discussed above, development itself is the most effective way to promote adaptation to climate change, because development increases resilience and reduces vulnerabilities. Beyond that broad development focus, fully integrating climate change will require ensuring that adaptation concerns are reflected across many aspects of government policy. Some of the required measures for strengthening adaptation include:

- **Ensuring access to high-quality information about the impacts of climate change and carrying out vulnerability assessment**. Early warning systems and information distribution systems help to anticipate and prevent disasters.
- **Increasing the resilience of livelihoods and infrastructure** using existing knowledge and coping strategies.
- **Improving governance**, including a transparent and accountable policy and decision-making process and an active civil society.
- **Empowering communities** so that they participate in assessments and feed their knowledge into the process at crucial points.
- **Integrating climate change impacts** in issues in all national, sub-national and sectoral planning processes and macro-economic projections. The national budget process is key here.
- **Encouraging a core ministry** with a broad mandate, such as finance, economics or planning, to be fully involved in mainstreaming adaptation.

Source: Adapted from Sperling (2003)

Figure A3.4. Measures to strengthen adaptation (Stern Review report).

2.3 The Economics of Climate Change in South East Asia: A Regional Review (2009) (ECC-SEA)

2.3.1 *EEC-SEA Report – Summary of Conclusions*

(a) **"Southeast Asia is among the regions with the greatest need for adaptation, which is critical to reducing the impact of changes already locked into the climate system" [page xxii].**

1. The review demonstrates that a wide range of adaptation measures are already being applied. But much more needs to be done. Adaptation requires building adaptive capacity and taking technical and non-technical measures in climate-sensitive sectors.

2. Further strengthening adaptive capacity in Southeast Asia requires mainstreaming climate change adaptation in development planning, that is, making it an integral part of sustainable development, poverty reduction and disaster risk management strategies. Some of the immediate priorities are:

- Stepping up efforts to raise public awareness of climate change and its impact;
- Undertaking more research to better understand climate change, its impact, and solutions, especially at local levels;
- Enhancing policy and planning coordination across ministries and different levels of government for climate change adaptation;
- Adopting a more holistic approach to building the adaptive capacity of vulnerable groups and localities and their resilience to shocks; and
- Developing and adopting more proactive, systematic, and integrated approaches to adaptation in key sectors that are cost-effective and that offer durable and long-term solutions.

3. The review notes that many sectors have adaptation needs, but water, agriculture, forestry, coastal and marine resources, and health require particular attention. While many countries have made significant efforts, the review identifies the following priorities for further action:

<u>Water resources</u> — Scale up water conservation and management; and widen use of integrated water management, including flood control and prevention schemes, flood early warning system, irrigation improvement, and demand-side management.

<u>Agriculture</u> — Strengthen local adaptive capacity through better climate information, research and development on heat-resistant crop varieties, early warning systems, and efficient irrigation systems; and explore innovative risk-sharing instruments such as index-based insurance schemes.

<u>Forestry</u> — Enhance early warning systems and awareness-raising programs to prepare for more frequent forest fires; and implement aggressive public-private partnerships for reforestation and afforestation.

<u>Coastal and marine resources</u> — Implement integrated coastal zone management plans, including mangrove conservation and planting.

<u>Health</u> — Expand or establish early warning systems for disease outbreaks, health surveillance, awareness-raising campaigns, and infectious disease control programs.

<u>Infrastructure</u> — Introduce “climate proofing” in transport-related investments and infrastructure, starting with public buildings.

(b) **“As a highly vulnerable region with considerable need for adaptation and great potential for mitigation, Southeast Asia should play an important part in a global solution [page xxiv].**

1. The region has in recent years taken encouraging actions to adapt to climate change impact and to mitigate GHG emissions. Each country in Southeast Asia has developed its own national plan or strategy, established a ministry or agency as the focal point, and implemented many programs supporting adaptation and mitigation. Going forward, the review identifies a number of policy priorities. [Note: The policy priorities pertinent to the governance and institutional issues are extracted and given below]

2. **Adaptation** — The priority is to enhance climate change resilience by building adaptive capacity and taking technical and non-technical adaptation measures in climate-sensitive sectors. While at a fundamental level, a country's adaptive capacity depends on its level of development, more effort in raising public awareness, more research to fill knowledge gaps, better coordination across sectors and levels of government, and more financial resources will go a long way toward enhanced adaptive capacity. In the key climate-sensitive sectors, including water resources, agriculture, coastal and marine resources, and forestry, the priority is to scale up action by adopting a more proactive approach and integrating adaptation.

3. **Policy coordination** — Given that climate change is an issue that cuts across all parts of government, there is a need for involving not only environment ministries and related offices, but also economic and finance ministries, and for strong inter-governmental agency policy coordination. There is also a need for putting in place or enhancing central government–local authority coordination mechanisms (such as planning and funding) to encourage local and autonomous adaptation actions, and to strengthen local capacity in planning and implementing initiatives addressing climate change. For effective coordination, there is a strong case for the government agency responsible for formulating and implementing the development plan and strategy to take the lead. Addressing climate change requires leadership at the highest level of government.

2.3.2 *EEC-SEA Main Report*

1. Put in place or enhance multi-ministerial coordination and planning mechanisms to promote multi-sector approaches to climate change adaptation, including linking climate change adaptation with disaster risk management. Given that climate change is an issue that cuts across all parts of government, it requires the attention of not just the ministries of the environment and the key agencies. Given that climate change is an issue that cuts across all parts of government, it requires the attention of not just the ministries of the environment and the key agencies. Climate policy should be led by heads of state and the economics and finance ministries. [page 94]

2. Put in place or enhance central government-local authority coordination, planning, and funding mechanisms to encourage local and autonomous adaptation actions, and to strengthen local capacity to plan and take adaptation initiatives. [page 94]

Appendix 4 — Selected Extracts on "Climate Change Projections and R&D Issue" from key National and International documents.

This appendix presents a compilation of the relevant national actions that have been identified by our national policy makers and technical managers on the issue of climate change projections and R&D capacity to address the potential climate change impacts on water and the adaptation measures that need to be taken. It also presents the international scenarios on the issue, and in particular, highlights the key recommendations from the IPCC Technical Paper VI on Climate Change on Water (2008), the Stern Review on the Economics of Climate Change (2006) and the report on "The Economics of Climate Change in Southeast Asia: A Regional Review" (2009) by ADB. Some selected examples of international best practices that have been taken to address the issue are also given.

1. National Actions

The national actions that have been identified by our national policy makers and technical managers have been extracted from the following documents:

- National Policy on Climate Change (2009) – (NPCC)
- Tenth Malaysia Plan (2010-2014) – (RMK10)
- National Biodiversity Policy (1998) – (NBP)

1.1 *National Policy on Climate Change (2009) – (NPCC)*

The NPCC has identified the following Key Actions (KA) that need to be taken to address the climate change projections and R&D issue under the relevant Strategic Thrusts (ST).

KA18 - ST4: Develop multiple national climate and hydroclimate projection models for identifying vulnerabilities and assessing potential impacts of climate change.

KA28 - ST7: Establish and implement a national R&D agenda on climate change taking into account the following areas:

- Agriculture and food security;
- Water security and services;
- Forestry and ecosystem services;
- Sustainable bio-energies;
- Public health services and delivery;
- Localised modelling for projection of future scenarios;
- Innovative socio-economic and financing mechanisms;
- Vulnerability due to extreme weather events and natural disasters; and
- Policy analysis harmonising national and international issues.

KA30 - ST7: Institutionalise the following stage-based climate-friendly technology transfer programme to nurture self-innovativeness and R&D sustainability in local firms and institutions:

- **Initiation Stage** – Assessment of technology needs, create enabling environment, importing of technologies;
- **Internalisation Stage** – Develop human and institutional capacities, enhance knowledge and awareness of emerging technologies, adopting and adapting technologies by local firms under flexible IPR regime; and
- **Generation Stage** – Source adequate capital to acquire better technologies, innovating and capacity building through R&D programme.

KA31 - ST7: Promote pragmatic cooperation programmes through:

- Effective mechanisms and tools for technology cooperation in specific sectors;
- Collaborative R&D to access knowledge and technologies;
- Support for endogenous development and diffusion of technology; and
- Regional cooperation on technology development.

KA32 - ST7: Identify a coordinating mechanism to oversee R&D activities, information dissemination, avoidance of duplication, and to support decision making.

1.2 *Tenth Malaysia Plan (2010-2014) (RMK10)*

The following is the relevant section from RMK10 that is pertinent to the climate change projections and R&D issue on climate change.

(a) **RMK10: Developing a Long-Term Strategy for Water Resource Management to Achieve Water Security (page 282)**

In addition, research and development efforts will be intensified in area of conservation of water resources to support efforts to develop a sustainable water sector for the national economy.

1.3 *National Biodiversity Policy (1998) (NBP)*

The NBP has identified the following R&D related strategies (ST) for effective management of biodiversity. They are relevant within the context of adaptation to address the climate change projections and R&D issue.

ST1 — Improve the Scientific Knowledge Base
Survey and document the biological diversity in Malaysia, and undertake studies to assess its direct and indirect values, and identify the potential threats to biological diversity loss, and how they may be countered.

ST2 — Enhance Sustainable Utilisation of the Components of Biological Diversity
Identify and encourage the optimum use of the components of biological diversity, ensuring fair distribution of benefits to the nation and to local communities.

ST3 — Develop a Centre of Excellence in Industrial Research in Tropical Biological Diversity
Establish Malaysia as a centre of excellence in industrial research in tropical biological diversity.

2. International Scenarios

The following are the key recommendations extracted from the IPCC Technical Paper VI - Climate Change on Water, the Stern Review on the Economics of Climate Change and the ADB report on "The Economics of Climate Change in Southeast Asia: A Regional Review", together with selected examples of international best practices that have been taken to address this issue.

2.1 *IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)*

2.1.1 <u>IPCC-CC & Water Report — Executive Summary</u>

The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses the climate change projections and R&D issue.

Point 1 – Observed warming over several decades has been linked to changes in the large-scale hydrological cycle

1. Observed warming over several decades has been linked to changes in the large-scale hydrological cycle such as: increasing atmospheric water vapour content; changing precipitation patterns, intensity and extremes; reduced snow cover and widespread melting of ice; and changes in soil moisture and runoff.
2. Precipitation changes show substantial spatial and inter-decadal variability. Over the 20th century, precipitation has mostly increased over land in high northern latitudes, while decreases have dominated from 10°S to 30°N since the 1970s.
3. The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) has increased over most areas (likely).
4. Globally, the area of land classified as very dry has more than doubled since the 1970s (likely). There have been significant decreases in water storage in mountain glaciers and Northern Hemisphere snow cover.
5. Shifts in the amplitude and timing of runoff in glacier and snowmelt-fed rivers, and in ice-related phenomena in rivers and lakes, have been observed (high confidence).

Point 2 – Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes (very likely)

1. Outside these areas, the sign and magnitude of projected changes varies between models, leading to substantial uncertainty in precipitation projections. [Projections considered are based on the range of non-mitigation scenarios developed by the IPCC Special Report on Emissions Scenarios (SRES)]
2. Thus projections of future precipitation changes are more robust for some regions than for others. Projections become less consistent between models as spatial scales decrease.

Point 3 – By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics.

1. These projections are based on an ensemble of climate models using the mid-range SRES A1B non-mitigation emissions scenario. Consideration of the range of climate responses across SRES scenarios in the mid-21st century suggests that this conclusion is applicable across a wider range of scenarios.
2. Many semi-arid and arid areas (e.g. the Mediterranean Basin, western USA, southern Africa and northeastern Brazil) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change (high confidence).

Point 15 – Several gaps in knowledge exist in terms of observations and research needs related to climate change and water

1. Observational data and data access are prerequisites for adaptive management, yet many observational networks are shrinking.
2. There is a need to improve understanding and modelling of climate changes related to the hydrological cycle at scales relevant to decision making.
3. Information about the water related impacts of climate change is inadequate – especially with respect to water quality, aquatic ecosystems and groundwater – including their socio-economic dimensions.
4. Finally, current tools to facilitate integrated appraisals of adaptation and mitigation options across multiple water-dependent sectors are inadequate.

2.1.2 <u>IPCC-CC & Water Main Report</u>

The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that address the climate change projections and R&D issue.

Observed changes as they relate to water [Sec 2.1, page 15]

Water is involved in all components of the climate system (atmosphere, hydrosphere, cryosphere, land surface and biosphere). Therefore, climate change affects water through a number of mechanisms. The following are the key conclusions from the report based on the current observation data.

1. Observed warming over several decades has been linked to changes in the large-scale hydrological cycle such as:
   - increasing atmospheric water vapour content;
   - changing precipitation patterns, intensity and extremes;
   - reduced snow cover and widespread melting of ice; and
   - changes in soil moisture and runoff.

2. Precipitation changes show substantial spatial and inter-decadal variability.

3. Over the 20th century, precipitation has mostly increased over land in high northern latitudes, while decreases have dominated from 10°S to 30°N since the 1970s.

4. The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) has increased over most areas (likely).

5. Globally, the area of land classified as very dry has more than doubled since the 1970s (likely).

6. There have been significant decreases in water storage in mountain glaciers and Northern Hemisphere snow cover. Shifts in the amplitude and timing of runoff in glacier- and snowmelt-fed rivers, and in ice-related phenomena in rivers and lakes, have been observed (high confidence).

<u>Projected changes in climate as they relate to water [Sec 3.2, page 24]</u>

The best-estimate projections from climate models indicate that decadal average warming over each inhabited continent by 2030 is insensitive to the choice of SRES scenario [see the four IPCC Special Report on Emissions Scenarios (SRES) "Storyline" below – Figure A4.1 below from the Report] and is very likely to be at least twice as large (around 0.2°C per decade) as the corresponding model-estimated natural variability during the 20th century.

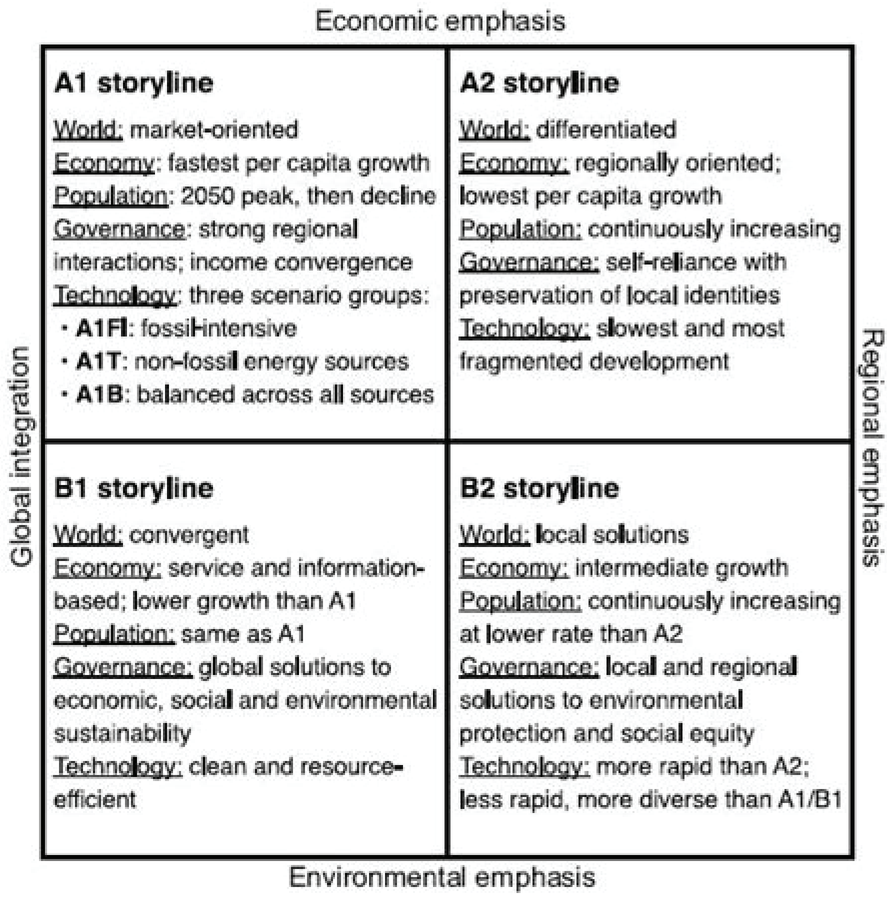

Figure A4.1. Summary Characteristics of the four SRES Storylines (IPCC –CC & Water Report).

The following are the key conclusions from the report based on the current climate model projections.

1. Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes (very likely) and parts of the tropics, and decreases in some subtropical and lower mid-latitude regions (likely).

2. Outside these areas, the sign and magnitude of projected changes varies between models, leading to substantial uncertainty in precipitation projections. [Projections considered are based on the range of non-mitigation scenarios developed by the IPCC Special Report on Emissions Scenarios (SRES).]

3. Thus projections of future precipitation changes are more robust for some regions than for others. Projections become less consistent between models as spatial scales decrease.

Uncertainties in the projected impacts of climate change on freshwater systems [Sec 3.2.8, Page 47]

1. Uncertainties in climate change impacts on water resources are mainly due to the uncertainty in precipitation inputs and less due to the uncertainties in greenhouse gas emissions, in climate sensitivities, or in hydrological models themselves.

2. A further source of uncertainty regarding the projected impacts of climate change on freshwater systems is the nature, extent, and relative success of those initiatives and measures already planned as interventions.

3. The feedbacks from adaptation measures to climate change are not fully considered in current future predictions, such as the longer growing season of crops and more regulations on river flow, with increased reservoir storage.

4. Multi-model probabilistic approaches are preferable to using the output of only one climate model, when assessing uncertainty in the impact of climate change on water resources. Since the TAR, several hydrological impact studies have used multi-model climate inputs at the global scale and at a river-basin scale), but studies incorporating probabilistic assessments are rare.

5. In many impacts studies, time-series of observed climate values are adjusted by using the computed change in climate variables to obtain scenarios that are consistent with present-day conditions. These adjustments aim to minimise the impacts of the error in climate modelling of the GCMs under the assumption that the biases in climate modelling are of similar magnitude for current and future time horizons. This is particularly important for precipitation projections, where differences between the observed values and those computed by climate models are substantial.

6. Changes in inter annual or daily variability of climate variables are often not taken into account in hydrological impact studies. This leads to an underestimation of future floods and droughts as well as water availability and irrigation water requirements.

7. Selections of indicators and threshold values to quantify the impact of climate change on freshwater resources are also sources of uncertainty.

8. So as to overcome the mismatch of spatial grid scales between GCM and hydrological processes, techniques have been developed that downscale GCM outputs to a finer spatial (and temporal) resolution. The main assumption of these techniques is that the statistical relationships identified for current climate will remain valid under changes in future conditions. Downscaling techniques may allow modelers to incorporate daily variability in future changes and to apply a probabilistic framework to produce information on future river flows for water resource planning. These approaches help to compare different sources of uncertainty affecting water resource projections.

9. Efforts to quantify the economic impacts of climate-related changes in water resources are hampered by a lack of data and by the fact that the estimates are highly sensitive to both the estimation methods and the different assumptions used regarding allocation of changes in water availability across various types of water uses, e.g. between agricultural, urban or in-stream uses.

The following are the key recommendations extracted from the IPCC-CC & Water Main Report that address the climate change projections and R&D issue for the following sectors:

- Ecosystem and biodiversity
- Agriculture and food security, land use and forestry
- Human Health; and
- Water Supply and Sanitation

(a) **Ecosystem and biodiversity [Sec 4.1, page 55]**
<u>Projected changes in hydrology and implications for global biodiversity [Sec 4.1.2, page 55]</u>

1. Impacts of warming and changes in precipitation patterns in tropical and sub-tropical regions have important implications for global biodiversity, because species diversity generally decreases with distance away from the Equator.

2. Ecosystem responses to changes in hydrology often involve complex interactions of biotic and abiotic processes. The assemblages of species in ecological communities reflect the fact that these interactions and responses are often non-linear, which increases the difficulty of projecting specific ecological outcomes.

3. Since the timing of responses is not always synchronous in species from different taxonomic groups, there may be a decoupling of species from their food sources, a disruption of symbiotic or facilitative relationships between species, and changes in competition between species.

4. Owing to a combination of differential responses between species and interactions that could theoretically occur at any point in a food web, some of the ecological communities existing today could easily be disaggregated in the future.

5. In montane forests, many species depend on mist as their source of water: global warming will raise the cloud base and affect those species dependent on this resource.

6. Of all ecosystems, however, freshwater aquatic ecosystems appear to have the highest proportion of species threatened with extinction by climate change

(b) **Agriculture and food security, land use and forestry [Sec 4.2, page 59]**
Projections [Sec 4.2.3, page 60]

1. Changes in water demand and availability under climate change will significantly affect agricultural activities and food security, forestry and fisheries in the 21st century. On the one hand, changes in evaporation:precipitation ratios will modify plant water demand with respect to a baseline with no climate change.

2. On the other hand, modified patterns of precipitation and storage cycles at the watershed scale will change the seasonal, annual and interannual availability of water for terrestrial and aquatic agro-ecosystems. Climate changes increase irrigation demand in the majority of world regions due to a combination of decreased rainfall and increased evaporation arising from increased temperatures.

3. It is expected that projected changes in the frequency and severity of extreme climate events, such as increased frequency of heat stress, droughts and flooding, will have significant consequences on food, forestry (and the risk of forest fires) and other agro-ecosystem production, over and above the impacts of changes in mean variables alone.

4. Finally, it may be important to recognise that production systems and water resources will be critically shaped in the coming decades by the concurrent interactions of socioeconomic and climate drivers. For instance, increased demand for irrigation water in agriculture will depend both on changed climatic conditions and on increased demand for food by a growing population; in addition, water availability for forest productivity will depend on both climatic drivers and critical anthropogenic impacts, particularly deforestation in tropical zones.

(c) **Human Health [Sec 4.3, page 67]**
Projections [Sec 4.3.3, page 69]

1. Climate change is expected to have a range of adverse effects on populations where the water and sanitation infrastructure is inadequate to meet local needs.
2. Access to safe water remains an extremely important global health issue. More than two billion people live in the dry regions of the world, and these people suffer more than others from malnutrition, infant mortality and diseases related to contaminated or insufficient water.
3. Water scarcity constitutes a serious constraint to sustainable development.

(d) **Water Supply and Sanitation [Sec 4.4, page 69]**
Observations [Sec 4.4.3, page 69]
Table A4.1 summarises possible linkages between climate change and water services.

TABLE A4.1. SUMMARY OF THE POSSIBLE LINKAGES BETWEEN CLIMATE CHANGE AND WATER SERVICES

Observed effect	Observed/possible impacts
Increase in atmospheric temperature	• Reduction in water availability in basins fed by glaciers that are shrinking, as observed in some cities along the Andes in South America (Ames, 1998; Kaser and Osmaston, 2002)
Increase in surface water temperature	• Reductions in dissolved oxygen content, mixing patterns, and self purification capacity • Increase in algal blooms
Sea-level rise	• Salinisation of coastal aquifers
Shifts in precipitation patterns	• Changes in water availability due to changes in precipitation and other related phenomena (e.g., groundwater recharge, evapotranspiration)
Increase in interannual precipitation variability	• Increases the difficulty of flood control and reservoir utilisation during the flooding season
Increased evapotranspiration	• Water availability reduction • Salinisation of water resources • Lower groundwater levels
More frequent and intense extreme events	• Floods affect water quality and water infrastructure integrity, and increase fluvial erosion, which introduces different kinds of pollutants to water resources • Droughts affect water availability and water quality

Projections [Sec 4.4.3, page 70]

1. Reduced water availability may result from decreased flows in basins fed by shrinking glaciers and longer and more frequent dry seasons, decreased summer precipitation leading to a reduction of stored water in reservoirs fed with seasonal rivers, interannual precipitation variability and seasonal shifts in streamflow,

reductions in inland groundwater levels, the increase in evapotranspiration as a result of higher air temperatures, lengthening of the growing season and increased irrigation water usage, salinisation.

2. In some areas, low water availability will lead to groundwater over-exploitation and, with it, increasing costs of supplying water for any use as a result of the need to pump water from deeper and further away. Additionally, groundwater over-exploitation may lead in some cases to water quality deterioration.
3. Increasing water scarcity combined with increased food demand and/or water use for irrigation as a result of higher temperatures are likely to lead to enhanced water reuse. Areas with low sanitation coverage might be found to be practising (as a new activity or to a greater degree) uncontrolled water reuse (reuse that is performed using polluted water or even wastewater).
4. Water quality deterioration as result of flow variation. Where a reduction in water resources is expected, a higher water pollutant concentration will result from a lower dilution capacity. At the same time, increased water flows will displace and transport diverse compounds from the soil to water resources through fluvial erosion.
5. Similarly, an increase in morbidity and mortality rates from water-borne diseases for both more humid and drier scenarios is expected, owing to an insufficient supply of potable water, and the greater presence of pathogens conveyed by high water flows during extreme precipitation.
6. Increased precipitation may also result in higher turbidity and nutrient loadings in water.
7. Increased runoff. In some regions, more water will be available which, considering the present global water situation, will be generally beneficial. Nevertheless, provisions need to be made to use this to the world's advantage. For example, while increased runoff in eastern and southern Asia is expected as a result of climate change, water shortages in these areas may not be addressed, given a lack of resources for investing in the new storage capacity required to capture the additional water and to enable its use during the dry season.
8. Higher precipitation in cities may affect the performance of sewer systems; uncontrolled surcharges may introduce microbial and chemical pollutants to water resources that are difficult to handle through the use of conventional drinking water treatment processes.
9. In addition, extreme precipitation leading to floods puts water infrastructure at risk. During floods, water and wastewater treatment facilities are often out of service, leaving the population with no sanitary protection.
10. Water quality impairment as result of higher temperatures. Warmer temperatures, combined with higher phosphorus concentrations in lakes and reservoirs, promote algal blooms that impair water quality through undesirable colour, odour and taste, and possible toxicity to humans, livestock and wildlife. Dealing with such polluted water has a high cost with the available technology, even for water utilities from developed countries.

11. Higher water temperatures will also enhance the transfer of volatile and semi volatile pollutants (ammonia, mercury, PCBs (polychlorinated biphenyls), dioxins, pesticides) from water and wastewater to the atmosphere.
12. Increased salinisation. The salinisation of water supplies from coastal aquifers due to sea-level rise is an important issue, as around one-quarter of the world's population live in coastal regions that are generally water-scarce and undergoing rapid population growth. Salinisation can also affect inland aquifers due to a reduction in groundwater recharge

The following are the gaps in knowledge and suggestions for further work extracted from the IPCC-CC & Water Main Report that address the climate change projections and R&D issue.

<u>Gaps in knowledge and suggestions for further work [Sec 8, page 135]</u>

1. There is abundant evidence from observational records and climate projections that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change. However, the ability to quantify future changes in hydrological variables, and their impacts on systems and sectors, is limited by uncertainty at all stages of the assessment process.
2. Uncertainty comes from the range of socio-economic development scenarios, the range of climate model projections for a given scenario, the downscaling of climate effects to local/regional scales, impacts assessments, and feedbacks from adaptation and mitigation activities.
3. Limitations in observations and understanding restrict our current ability to reduce these uncertainties. Decision making needs to operate in the context of this uncertainty.
4. Robust methods to assess risks based on these uncertainties are at an early stage of development.
5. Capacity for mitigation of climate change and adaptation to its impacts is limited by the availability and economic viability of appropriate technologies and robust collaborative processes for decision making among multiple stakeholders and management criteria.
6. Knowledge of the costs and benefits (including avoided damages) of specific options is scarce.
7. Management strategies that adapt as the climate changes require an adequate observational network to inform them.
8. There is limited understanding of the legal and institutional frameworks and demand-side statistics necessary for mainstreaming adaptation into development plans to reduce water-related vulnerabilities, and of appropriate channels for financial flows into the water sector for adaptation investment.

Observational Needs [Sec 8.1, page 135]

1. Better observational data and data access are necessary to improve understanding of ongoing changes, to better constrain model projections, and are a prerequisite for adaptive management required under conditions of climate change.
2. Progress in knowledge depends on improved data availability. Shrinkage of some observational networks is occurring. Relatively short records may not reveal the full extent of natural variability and confound detection studies, while long term reconstruction can place recent trends and extremes in a broader context.
3. Major gaps in observations of climate change related to freshwater and hydrological cycles were identified as follows:
   - Difficulties in the measurement of precipitation remain an area of concern in quantifying global and regional trends. Precipitation measurements over oceans (from satellites) are still in the development phase. There is a need to ensure ongoing satellite monitoring, and the development of reliable statistics for inferred precipitation.
   - Many hydrometeorological variables e.g. streamflow, soil moisture and actual evapotranspiration, are inadequately measured. Potential evapotranspiration is generally calculated from parameters such as solar radiation, relative humidity and wind speed. Records are often very short, and available for only a few regions, which impedes complete analysis of changes in droughts.
   - There may be opportunities for river flow data rescue in some regions. Where no observations are available, the construction of new observing networks should be considered.
   - Groundwater is not well monitored, and the processes of groundwater depletion and recharge are not well modeled in many regions.
   - Monitoring data are needed on water quality, water use and sediment transport.
   - More information is needed on plant evapotranspiration responses to the combined effects of rising atmospheric CO2, rising temperature and rising atmospheric water vapour concentration, in order to better understand the relationship between the direct effects of atmospheric CO2 enrichment and changes in the hydrological cycle.
   - Quality assurance, homogenisation of data sets, and inter calibration of methods and procedures could be important whenever different agencies, countries etc., maintain monitoring within one region or catchment.

Understanding and projecting climate change [Sec 8.2.1, page 135]

Major uncertainties in understanding and modelling changes in climate relating to the hydrological cycle include the following:

- Changes in a number of radiative drivers of climate are not fully quantified and understood (e.g. aerosols and their effects on cloud properties, methane, ozone, stratospheric water vapour, land-use change, past solar variations).

- Confidence in attributing some observed climate change phenomena to anthropogenic or natural processes is limited by uncertainties in radiative forcing, as well as by uncertainty in processes and observations. Attribution becomes more difficult at smaller spatial and temporal scales, and there is less confidence in understanding precipitation changes than there is for temperature. There are very few attribution studies for changes in extreme events.

- Uncertainty in modelling some modes of climate variability, and of the distribution of precipitation between heavy and light events, remains large. In many regions, projections of changes in mean precipitation also vary widely between models, even in the sign of the change. It is necessary to improve understanding of the sources of uncertainty.

- In many regions where fine spatial scales in climate are generated by topography, there is insufficient information on how climate change will be expressed at these scales.

- Climate models remain limited by the spatial resolution and ensemble size that can be achieved with present computer resources, by the need to include some additional processes, and by large uncertainties in the modelling of certain feedbacks (e.g. from clouds and the carbon cycle).

- Limited knowledge of ice sheet and ice shelf processes leads to unquantified uncertainties in projections of future ice sheet mass balance, leading in turn to uncertainty in sea level rise projections.

<u>Water-related impacts [Sec 8.2.2, page 136]</u>

1. Because of the uncertainties involved, probabilistic approaches are required to enable water managers to undertake analyses of risk under climate change. Techniques are being developed to construct probability distributions of specified outcomes. Further development of this research, and of techniques to communicate the results, as well as their application to the user community, are required.
2. Further work on detection and attribution of present-day hydrological changes is required; in particular, changes in water resources and in the occurrence of extreme events. As part of this effort, the development of indicators of climate change impacts on freshwater, and operational systems to monitor them, are required.
3. There remains a scale mismatch between the large-scale climatic models and the catchment scale – the most important scale for water management. Higher-

resolution climate models, with better land-surface properties and interactions, are therefore required to obtain information of more relevance to water management. Statistical and physical downscaling can contribute.

4. Most of the impact studies of climate change on water stress in countries assess demand and supply on an annual basis. Analysis at the monthly or higher temporal resolution scale is desirable, since changes in seasonal patterns and the probability of extreme events may offset the positive effect of increased availability of water resources.
5. The impact of climate change on snow, ice and frozen ground as sensitive storage variables in the water cycle is highly non-linear and more physically- and process-oriented modelling, as well as specific atmospheric downscaling, is required. There is a lack of detailed knowledge of runoff changes as caused by changing glaciers, snow cover, rain– snow transition, and frozen ground in different climate regions.
6. Methods need to be improved that allow the assessment of the impacts of changing climate variability on freshwater resources. In particular, there is a need to develop localscale data sets and simple climate-linked computerized watershed models that would allow water managers to assess impacts and to evaluate the functioning and resilience of their systems, given the range of uncertainty surrounding future climate projections.
7. Feedbacks between land use and climate change (including vegetation change and anthropogenic activity such as irrigation and reservoir construction) should be analysed more extensively; e.g. by coupled climate and land-use modelling.
8. Improved assessment of the water-related consequences of different climate policies and development pathways is needed.
9. Climate change impacts on water quality are poorly understood for both developing and developed countries, particularly with respect to the impact of extreme events.
10. Relatively few results are available on the socio-economic aspects of climate change impacts related to water resources, including climate change impacts on water demand.
11. Impacts of climate change on aquatic ecosystems (not only temperatures, but also altered flow regimes, water levels and ice cover) are not understood adequately.
12. Despite its significance, groundwater has received little attention in climate change impact assessment compared to surface water resources.

2.2 *Stern Review: The Economics of Climate Change (2006) (Stern Review)*

2.2.1 Stern Review - Executive Summary

(a) **"The scientific evidence points to increasing risks of serious, irreversible impacts from climate change associated with business-as-usual (BAU) paths for emissions" [page 3]**

1. The scientific evidence on the causes and future paths of climate change is strengthening all the time. In particular, scientists are now able to attach probabilities to the temperature outcomes and impacts on the natural environment associated with different levels of stabilisation of greenhouse gases in the atmosphere. Scientists also now understand much more about the potential for dynamic feedbacks that have, in previous times of climate change, strongly amplified the underlying physical processes.
2. The stocks of greenhouse gases in the atmosphere (including carbon dioxide, methane, nitrous oxides and a number of gases that arise from industrial processes) are rising, as a result of human activity.
3. The current level or stock of greenhouse gases in the atmosphere is equivalent to around 430 parts per million (ppm) CO2, compared with only 280ppm before the Industrial Revolution. These concentrations have already caused the world to warm by more than half a degree Celsius and will lead to at least a further half degree warming over the next few decades, because of the inertia in the climate system.
4. Even if the annual flow of emissions did not increase beyond today's rate, the stock of greenhouse gases in the atmosphere would reach double pre-industrial levels by 2050 - that is 550ppm CO2e - and would continue growing thereafter. But the annual flow of emissions is accelerating, as fast-growing economies invest in high carbon infrastructure and as demand for energy and transport increases around the world. The level of 550ppm CO2e could be reached as early as 2035. At this level there is at least a 77% chance - and perhaps up to a 99% chance, depending on the climate model used - of a global average temperature rise exceeding 2°C.
5. Under a BAU scenario, the stock of greenhouse gases could more than treble by the end of the century, giving at least a 50% risk of exceeding 5°C global average temperature change during the following decades. This would take humans into unknown territory. An illustration of the scale of such an increase is that we are now only around 5°C warmer than in the last ice age.
6. Such changes would transform the physical geography of the world. A radical change in the physical geography of the world must have powerful implications for the human geography - where people live, and how they live their lives. Figure 2 summarises the scientific evidence of the links between concentrations of greenhouse gases in the atmosphere, the probability of different levels of global average temperature change, and the physical impacts expected for each level. The risks of serious, irreversible impacts of climate change increase strongly as concentrations of greenhouse gases in the atmosphere rise.

(b) **"Climate change may initially have small positive effects for a few developed countries, but is likely to be very damaging for the much higher temperature increases expected by mid- to late-century under BAU scenarios" [page 8]**

1. In higher latitude regions, such as Canada, Russia and Scandinavia, climate change may lead to net benefits for temperature increases of 2 or 3°C, through higher agricultural yields, lower winter mortality, lower heating requirements, and a possible boost to tourism. But these regions will also experience the most rapid rates of warming, damaging infrastructure, human health, local livelihoods and biodiversity.
2. Developed countries in lower latitudes will be more vulnerable — for example, water availability and crop yields in southern Europe are expected to decline by 20% with a 2°C increase in global temperatures. Regions where water is already scarce will face serious difficulties and growing costs.
3. The increased costs of damage from extreme weather (storms, hurricanes, typhoons, floods, droughts, and heat waves) counteract some early benefits of climate change and will increase rapidly at higher temperatures. Based on simple extrapolations, costs of extreme weather alone could reach 0.5 – 1% of world GDP per annum by the middle of the century, and will keep rising if the world continues to warm.
   - A 5 or 10% increase in hurricane wind speed, linked to rising sea temperatures, is predicted approximately to double annual damage costs, in the USA.
   - In the UK, annual flood losses alone could increase from 0.1% of GDP today to 0.2 – 0.4% of GDP once the increase in global average temperatures reaches 3 or 4°C.
   - Heat waves like that experienced in 2003 in Europe, when 35,000 people died and agricultural losses reached $15 billion, will be commonplace by the middle of the century.
4. At higher temperatures, developed economies face a growing risk of large-scale shocks - for example, the rising costs of extreme weather events could affect global financial markets through higher and more volatile costs of insurance.

(c) **"Greater international co-operation to accelerate technological innovation and diffusion will reduce the costs of mitigation"**

1. The private sector is the major driver of innovation and the diffusion of technologies around the world. But governments can help to promote international collaboration to overcome barriers in this area, including through formal arrangements and through arrangements that promote public-private co-operation such as the Asia Pacific Partnership. Technology co-operation enables the sharing of risks, rewards and progress of technology development and enables co-ordination of priorities.
2. A global portfolio that emerges from individual national R&D priorities and deployment support may not be sufficiently diverse, and is likely to place too little weight on some technologies that are particularly important for developing countries, such as biomass.

3. International R&D co-operation can take many forms. Coherent, urgent and broadly based action requires international understanding and co-operation. These may be embodied in formal multilateral agreements that allow countries to pool the risks and rewards for major investments in R&D, including demonstration projects and dedicated international programmes to accelerate key technologies. But formal agreements are only one part of the story - informal arrangements for greater coordination and enhanced linkages between national programmes can also play a very prominent role.
4. Both informal and formal co-ordination of national policies for deployment support can accelerate cost reductions by increasing the scale of new markets across borders. Many countries and US states now have specific national objectives and policy frameworks to support the deployment of renewable energy technologies.
5. Transparency and information-sharing have already helped to boost interest in these markets. Exploring the scope for making deployment instruments tradable across borders could increase the effectiveness of support, including mobilising the resources that will be required to accelerate the widespread deployment of carbon capture and storage and the use of technologies that are particularly appropriate for developing countries.
6. International co-ordination of regulations and product standards can be a powerful way to encourage greater energy efficiency. It can raise their cost effectiveness, strengthen the incentives to innovate, improve transparency, and promote international trade.
7. The reduction of tariff and non-tariff barriers for low-carbon goods and services, including within the Doha Development Round of international trade negotiations, could provide further opportunities to accelerate the diffusion of key technologies.

2.3 *The Economics of Climate Change in South East Asia: A Regional Review (2009) (ECC-SEA)*

2.3.1 <u>EEC-SEA Report – Summary of Conclusions</u>

“As a highly vulnerable region with considerable need for adaptation and great potential for mitigation, Southeast Asia should play an important part in a global solution [page xxiv].

1. The region has in recent years taken encouraging actions to adapt to climate change impact and to mitigate GHG emissions. Each country in Southeast Asia has developed its own national plan or strategy, established a ministry or agency as the focal point, and implemented many programs supporting

adaptation and mitigation. Going forward, the review identifies a number of policy priorities. [Note: The policy priorities pertinent to the climate change projection and R&D issues are extracted and given below]

2. Research — More research is required to better understand climate change challenges and cost effective solutions at the local level and to fill knowledge gaps. Despite the emergence of more and more regional and country-specific studies on climate change in Southeast Asia in recent years, knowledge gaps remain huge.

2.3.2 EEC-SEA Main Report

(a) Climate Change and Its Impact: A Review of Existing Studies [Chapter 3, page 21]
The key message from this Chapter is summarized in Figure A4.2 below.

(b) Modelling Climate Change and Its Impact [Chapter 4, page 62]
The key message from this Chapter is summarized in Figure A4.3 below.

Key Messages

Southeast Asia's average temperature has increased at a rate of 0.1–0.3°C per decade and sea level has risen at 1–3 millimeter (mm) each year over the last 50 years or so. The region also experienced a downward trend in precipitation during 1960–2000.

The increasing frequency and intensity of extreme weather events such as heat waves, droughts, floods, and tropical cyclones in recent decades are also evidence that climate change is already affecting the region. Climate change is worsening water shortages; constraining agricultural production and threatening food security; and causing forest fires, coastal degradation, and greater health risks.

Without global action, climate change is likely to intensify in the decades to come. The region is projected to warm further, following the global trend; become drier still in the coming decades in many parts, particularly in Indonesia, Thailand, and Viet Nam; and experience further rises in sea level.

Southeast Asia is likely to suffer more from climate change than the global average, in terms of increased frequency and intensity of extreme weather events; declining crop yields; loss of rich forests; damage to coastal resources; increased outbreaks of diseases; and associated economic losses and human suffering. The region therefore has a high stake in taking action against climate change.

Figure A4.2. Key Message on Current Status of Climate Change in Southeast Asia (ADB Review Report).

(c) The Uncertainties of Modelling Climate Change and Its Impact [page 64]

The uncertainties in modeling climate change are summarized in *Figure A4.4* below.

Key Messages

Climate change modeling carried out under this study using an integrated assessment model confirms many of the findings documented in existing studies and provides new estimates of climate change and its likely impact in coming decades, with a particular focus on Indonesia, Philippines, Thailand, and Viet Nam.

Climate patterns in Southeast Asia are likely to change significantly, with impact on the environment and economies expected to be more severe than the world average. The actual extent of climate change and impact depends on the assumed future emission scenarios, and on the level of global mitigation action.

The region's mean temperature by 2100 is projected to increase 2.5°C under B2—a medium emissions scenario—and 4.8°C under A1FI—a high emissions scenario—from 1990, without global mitigation. With stabilization under A1FI, from 1990, temperature will only increase 2.3°C at 550 parts per million (ppm) and 1.8°C at 450 ppm.

Increasingly drier weather conditions are projected to afflict Indonesia, Thailand, and Viet Nam over the next 2–3 decades although this trend is projected to reverse by mid-century.

Global mean sea level is projected to rise 70 cm by the end of this century relative to the 1990 level under A1FI, and Southeast Asia is to follow this global trend, threatening economic activity and population in coastal areas and islands.

Climate change is likely to worsen water stress in parts of the region, particularly Thailand and Viet Nam, in coming decades; water resources in Indonesia, Thailand and Viet Nam are projected to be most vulnerable.

Under A1FI, rice yield potential in the four countries is projected to decline about 50% by 2100 on average, relative to 1990, without adaptation or technical improvements. Part of the decline could be offset by productivity improvements and adaptation.

Figure A4.3. Key Message on Modelling Climate Change and its impacts in Southeast Asia (ADB Review Report).

Box 4.1. The Uncertainties of Modeling Climate Change

Estimating precisely how climate change would evolve is subject to considerable uncertainty. Some of the well recognized uncertainties are:

Emissions uncertainty
Emissions are a function of projected population growth, technological innovation, and patterns of production and consumption. These determine the level of production and its degree of carbon intensity. Emissions are difficult to accurately project over a period of five years, let alone a century.

Uncertainty over atmospheric concentrations and sinks
The ultimate mapping from emissions to concentrations is subject to great uncertainty. This is because the duration of greenhouse gases in the atmosphere itself depends on the rate at which so-called carbon sinks such as oceans and vegetation extract carbon from the atmosphere, and these sink processes are subject to a number of complex feedback mechanisms.

Uncertainty over solar radiation and the effect of other gases
Other gases such as anthropogenic and natural aerosols (for example, volcanic), or changing intensity of solar radiation also affect the climate. Uncertainty about their effect on temperature contributes further to uncertainty about future warming.

Model uncertainty
There are a number of uncertainties in climate model specification. These include the functional form of key equations, the specification of key parameters, data inputs, the scale and resolution, and the nature and interpretation of the empirical estimation properties. Differences in models inevitably yield differences in results but models are constrained by underlying theoretical physical properties and observed data.

Parameter and functional form uncertainty
Parameter estimation is determined by theoretical science and observed data, but is inevitably estimated with error. The overarching parameter driving all climate models is so-called "climate sensitivity" which relates the physical 'climate forcing' (or greenhouse gas effect) from increased concentrations of greenhouse gases to the temperature change. Estimation of this parameter from observed data needs to account for concentrations of other industrial aerosols, a key driver of parameter uncertainty.

Damage uncertainty
At the global level, total climate change damage is often simplified as a direct function of temperature change, and the parameter behind this is subject to uncertainty. This modeling simplification is intended to capture a vast array of impacts and cannot adequately reflect the detailed nature of the climate problem.

Uncertainty about climate change should not be seen as a reason for inaction, or for failing to model likely risks. In fact, policy options that provide protection against low-probability, highly damaging events can yield substantial expected benefits; it is important that modeling exercises appropriately quantify and warn of such risks. To fully appreciate the dangers ahead, economic analysis therefore must look beyond the average expectation and consider the entire probability distribution rather than just the mean. Models and projections that do not take full account of uncertainties and the possibility of extreme events tell only part of the story and mark a subset of the total expected damages. Chapter 5 of this study explicitly models uncertainty and catastrophic risks.

Source: Zenghelis (2009).

Figure A4.4. The Uncertainties of Modelling Climate Change (ADB Review Report).

Appendix 5 — Selected Extracts on "Information Management Issue" from key National and International documents.

This appendix presents a compilation of the relevant national actions that have been identified by our national policy makers and technical managers on the issue of information management capacity to address the potential climate change impacts on water and the adaptation measures that need to be taken. It also presents the international scenarios on the issue, and in particular, highlights the key recommendations from the IPCC Technical Paper VI on Climate Change on Water (2008), the Stern Review on the Economics of Climate Change (2006) and the report on "The Economics of Climate Change in Southeast Asia: A Regional Review" (2009) by ADB. Some selected examples of international best practices that have been taken to address the issue are also given.

1. National Actions

The national actions that have been identified by our national policy makers and technical managers have been extracted from the following documents:

- National Policy on Climate Change (2009) – (NPCC)
- National Biodiversity Policy (1998) (NBP)

1.1 *National Policy on Climate Change (2009) – (NPCC)*

The NPCC has identified the following Key Actions (KA) that need to be taken to address the information management issue under the relevant Strategic Thrusts (ST).

KA1 - ST1: Conduct systematic reviews and harmonise existing legislation, policies and plans, taking into account and proposing relevant balanced adaptation and mitigation measures, to address the following:

- Agriculture and food security;
- Natural resources and environment (water, biodiversity, forestry, minerals, soil, coastal and marine and air);
- Energy security;
- Industries;
- Public health;
- Tourism;
- Transportation;
- Infrastructure;
- Land use and land use change (include land reclamation);
- Human settlements and livelihood;
- Waste management; and
- Disaster risk reduction.

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KA29 - ST7: Strengthen national data repository through periodic national inventory by:

- Reviewing and expanding the role of the Department of Statistics as the central depository for environmental information, including GHG;
- Formulating measures for responsible reporting and collation of data by the Department of Statistic, key agencies and other stakeholders; and
- Establishing database inventory on natural disasters and extreme weather events.

KA32 - ST7: Identify a coordinating mechanism to oversee R&D activities, information dissemination, avoidance of duplication, and to support decision making.

1.2 *National Biodiversity Policy (1998) (NBP)*

The NBP has identified the following R&D related strategies (ST) for effective management of biodiversity. They are relevant within the context of adaptation to address the information management issue related to climate change adaptation.

ST2 - Enhance Sustainable Utilisation of the Components of Biological Diversity
Identify and encourage the optimum use of the components of biological diversity, ensuring fair distribution of benefits to the nation and to local communities.

2. International Scenarios

The following are the key recommendations extracted from the IPCC Technical Paper VI — Climate Change on Water, the Stern Review on the Economics of Climate Change and the ADB report on "The Economics of Climate Change in Southeast Asia: A Regional Review", together with selected examples of international best practices that have been taken to address this issue.

2.1 *IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)*

2.1.1 <u>IPCC-CC & Water Report — Executive Summary</u>

The following are the key recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that address the governance and institutional issue.

Point 10 — Current water management practices may not be robust enough to cope with the impacts of climate change.

1. Current water management practices may not be robust enough to cope with the impacts of climate change on water on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems.

2. In many locations, water management cannot satisfactorily cope even with current climate variability, so that large flood and drought damages occur.
3. As a first step, improved incorporation of information about current climate variability into water-related management would assist adaptation to longer-term climate change impacts. Climatic and non-climatic factors, such as growth of population and damage potential, would exacerbate problems in the future (very high confidence).

Point 15 — Several gaps in knowledge exist in terms of observations and research needs related to climate change and water.

1. Observational data and data access are prerequisites for adaptive management, yet many observational networks are shrinking. There is a need to improve understanding and modelling of climate changes related to the hydrological cycle at scales relevant to decision making.
2. Information about the water related impacts of climate change is inadequate – especially with respect to water quality, aquatic ecosystems and groundwater – including their socio-economic dimensions.
3. Finally, current tools to facilitate integrated appraisals of adaptation and mitigation options across multiple water-dependent sectors are inadequate.

2.1.2 <u>IPCC-CC & Water Main Report</u>

The following are the key recommendations extracted from the IPCC-CC & Water Main Report that address the information management capacity issue:

<u>Observational Needs [Section 8.1, page 135]</u>

1. Better observational data and data access are necessary to improve understanding of ongoing changes, to better constrain model projections, and are a prerequisite for adaptive management required under conditions of climate change.
2. Progress in knowledge depends on improved data availability. Shrinkage of some observational networks is occurring. Relatively short records may not reveal the full extent of natural variability and confound detection studies, while long term reconstruction can place recent trends and extremes in a broader context.
3. Major gaps in observations of climate change related to freshwater and hydrological cycles were identified as follows:
    - Difficulties in the measurement of precipitation remain an area of concern in quantifying global and regional trends. Precipitation measurements over oceans (from satellites) are still in the development phase. There is a need to ensure ongoing satellite monitoring, and the development of reliable statistics for inferred precipitation.

- Many hydrometeorological variables e.g. streamflow, soil moisture and actual evapotranspiration, are inadequately measured. Potential evapotranspiration is generally calculated from parameters such as solar radiation, relative humidity and wind speed. Records are often very short, and available for only a few regions, which impedes complete analysis of changes in droughts.
- There may be opportunities for river flow data rescue in some regions. Where no observations are available, the construction of new observing networks should be considered.
- Groundwater is not well monitored, and the processes of groundwater depletion and recharge are not well modeled in many regions.
- Monitoring data are needed on water quality, water use and sediment transport.
- Snow, ice and frozen ground inventories are incomplete. Monitoring of changes is unevenly distributed in both space and time. There is a general lack of data from the Southern Hemisphere.
- More information is needed on plant evapotranspiration responses to the combined effects of rising atmospheric CO2, rising temperature and rising atmospheric water vapour concentration, in order to better understand the relationship between the direct effects of atmospheric CO2 enrichment and changes in the hydrological cycle.
- Quality assurance, homogenisation of data sets, and inter calibration of methods and procedures could be important whenever different agencies, countries etc., maintain monitoring within one region or catchment.

2.2 *Stern Review: The Economics of Climate Change (2006) (Stern Review)*

2.2.1 Stern Review – Main Report

The following are the key recommendations extracted from the Stern Review Report that address the information management capacity issue.

(a) Providing information and tools [Sec 19.3, page 418]

High quality information on climate change will drive efficient markets for adaptation. Improved regional climate predictions will be critical, particularly for rainfall and storm patterns.

1. To make rational and effective adaptation decisions, organisations require detailed information about the full economic impacts of climate change in space and time.
2. Clear information will help ensure that climate risks are properly priced in the market. For example, production of flood hazard maps will increase house-buyers' awareness of flood risk and what individuals can do. They will also potentially influence land and house prices.

3. The scale and complexity of climate information make it unlikely that individual organisations will undertake basic research into future changes. Generic but high-quality information on climate change could be considered a public good.
4. Government-funded research programmes have advanced our understanding of climate change substantially. A central challenge for adaptation remains the uncertainty in climate predictions, particularly changing regional rainfall patterns, which are a key determinant of many likely adaptation requirements, for example the size and location of new sewers to cope with heavier downpours.
5. Improved regional climate predictions will help to integrate climate risk into long-term planning and provide a rationale for adaptation action. High-quality climate information is an important starting point for adaptation, but effective communication to stakeholders will also be required.
6. Information should not be too complex and should provide practical pointers without being excessively prescriptive, because local choice and flexibility are important.
7. The UK Climate Impacts Programme(UKCIP) has developed an important tool for helping stakeholders deal with risk and uncertainty and incorporate climate change into project appraisal (See *Figure A5.1*). The programme overall has been instrumental in raising awareness of adaptation issues among a broad range of stakeholders in the UK and driving forward the first steps towards adaptation actions.

Box 19.1 UKCIP Adaptation Wizard

The Government has established the UK Climate Impacts Programme (UKCIP) to provide individuals and organisations with the necessary tools and information on climate impacts to allow them to adapt successfully to the changing climate. The UKCIP (2005) Adaptation Wizard has been set up to help organisations move from a simple understanding of climate change to integration of climate change into decision-making. The Wizard draws heavily on Willows and Connell (2003) and provides web-based tools for four stages of adaptation:

- Scoping the impacts
- Quantifying risks
- Decision-making and action planning
- Adaptation strategy review.

One of the most valuable UKCIP tools is an up-to-date set of climate change scenarios that are available free of charge and used by a wide range of stakeholders, including local authorities, public agencies, and businesses. New scenarios will be published in 2008 that quantify risks and uncertainties in a more robust and quantitative manner to help stakeholders plan adaptation strategies. UKCIP has further tools on handling uncertainty and costing the impacts.

Source: UKCIP (2005)

Figure A5.1 An example of Climate Change Impact Adaptation Information Diseemination — The UK Climate Impacts Programme(UKCIP) Adaptation Wizard.

2.3 *The Economics of Climate Change in South East Asia: A Regional Review (2009) (ECC-SEA)*

2.3.1 <u>EEC-SEA Main Report</u>

1. Step up efforts in information and knowledge dissemination. [page 94]

Appendix 6 — Selected Extracts on "Stakeholder Participation and Awareness Issue" from key National and International documents.

This appendix presents a compilation of the relevant national actions that have been identified by our national policy makers and technical managers on the issue of stakeholders' awareness and participation to address the potential climate change impacts on water and the adaptation measures that need to be taken. It also presents the international scenarios on the issue, and in particular, highlights the key recommendations from the IPCC Technical Paper VI on Climate Change on Water (2008), the Stern Review on the Economics of Climate Change (2006) and the report on "The Economics of Climate Change in Southeast Asia: A Regional Review" (2009) by ADB. Some selected examples of international best practices that have been taken to address the issue are also given.

1. National Actions

The national actions that have been identified by our national policy makers and technical managers have been extracted from the following documents:

- National Policy on Climate Change (2009) – (NPCC)
- Tenth Malaysia Plan (2010-2014) – (RMK10)

1.1 National Policy on Climate Change (2009) – (NPCC)

The NPCC has identified the following Key Actions (KA) that need to be taken to address the governance/institutional issue under the relevant Strategic Thrusts (ST).

KA14 - ST4: Develop and implement plans for public-private, NGOs and communities collaboration on climate change.

KA23 - ST5: Empower local communities in basic Renewal Energy maintenance, especially in rural electrification including mini and micro hydroelectric schemes.

KA30 - ST7: Institutionalise the following stage-based climate-friendly technology transfer programme to nurture self-innovativeness and R&D sustainability in local firms and institutions:

- **Initiation Stage** — Assessment of technology needs, create enabling environment, importing of technologies;
- **Internalisation Stage** — Develop human and institutional capacities, enhance knowledge and awareness of emerging technologies, adopting and adapting technologies by local firms under flexible IPR regime; and
- **Generation Stage** — Source adequate capital to acquire better technologies, innovating and capacity building through R&D programme.

KA31 - ST7: Promote pragmatic cooperation programmes through:

- Effective mechanisms and tools for technology cooperation in specific sectors;
- Collaborative R&D to access knowledge and technologies;
- Support for endogenous development and diffusion of technology; and
- Regional cooperation on technology development.

KA34 - ST8: Establish and institutionalise effective and efficient communication and consultation mechanisms among all stakeholders.

KA35 - ST8: Strengthen legislative provisions for participatory planning and decision making.

KA36 - ST8: Promote community-based climate change responses and programmes.

KA37 - ST8: Strengthen collaborative networks and capacity of agencies at the federal, state and local government levels.

KA38 - ST9: Adopt systematic and targeted formal and informal education and awareness raising on climate change through the following approaches:

- Involvement of various stakeholders including non-government organisations (NGOs), community based organisations (CBOs) and the media;
- Enhance cooperation between government and private sectors including corporate responsibility; and
- Targeting special groups.

KA39 - ST9: Promote sustainable lifestyles and explore incentives that encourage them.

KA40 - ST10: Establish a register and expand the pool of climate change experts.

KA41 - ST10: Institutionalise a mechanism for coordinating consultation among stakeholders on national positions and responses to address current and emerging issues for international negotiations.

KA42 - ST10: Institute continuous capacity building programmes to support negotiation and implementation of international obligations.

1.2 *Tenth Malaysia Plan (2010–2014) (RMK10)*

The following is the relevant section from RMK10 that is pertinent to the governance and institutional issue on climate change.

(a) RMK10: Ensuring Equitable and Sustainable Utilisation of Resources (page 307)
Local communities play an important role in conservation and utilisation of environmental resources as they possess a depth and breadth of knowledge and capabilities in matters relating to nature handed down over many generations. Initiatives involving local communities include:

- Co-opting local communities in conservation efforts. Local communities will play a big role in sustainable use in resources. As an additional source of income, communities can also play a big role in conservation activities such as acting as tour guides and forest guides. A successful example of how local communities have played a role in eco-tourism activities is the Tagal system for conserving fish stock in rivers, which has been practiced for many generations amongst the Dusun community in Sabah; and

- Introducing the Access and Benefit Sharing framework. Indigenous people and local communities in Malaysia possess traditional knowledge with potential value for development into medicinal, pharmaceutical, nutraceutical and bio-technological products. The Government will establish a legal framework on access and benefit sharing to ensure that the resources are shared equitably. This framework will be supported by an institutional arrangement to enhance awareness and disseminate information.

2. International Scenarios

The following are the key recommendations extracted from the ADB report on "The Economics of Climate Change in Southeast Asia: A Regional Review", together with selected examples of international best practices that have been taken to address this issue.

2.1 *The Economics of Climate Change in South East Asia: A Regional Review (2009) (ECC-SEA)*

2.1.1 <u>EEC-SEA Report — Main Report</u>

1. Step up efforts to raise public awareness of climate change and its impact, with a view to building consensus for public action and engaging all stakeholders including households, businesses, government agencies, nongovernment organizations, civil society, and development partners in combating climate change. [page 94]
2. Adopt a more holistic approach to building vulnerable groups' and localities' adaptive capacity and resilience to shocks beyond technical solutions, including developing their capacity to diversify local economies, livelihoods, and coping strategies. [page 94]

Appendix 7 — Selected Extracts on "Water Bodies Management Issue" from key National and International documents.

This appendix presents a compilation of the relevant national actions that have been identified by our national policy makers and technical managers on the water bodies management issue to address the potential climate change impacts on water and the adaptation measures that need to be taken. It also presents the international scenarios on the issue, and in particular, highlights the key recommendations from the IPCC Technical Paper VI on Climate Change on Water (2008), the Stern Review on the Economics of Climate Change (2006) and the report on "The Economics of Climate Change in Southeast Asia: A Regional Review" (2009) by ADB. Some selected examples of international best practices that have been taken to address the issue are also given.

The national actions that have been identified by our national policy makers and technical managers have been extracted from the following documents.

- National Policy on Climate Change (2009) – (NPCC)
- Tenth Malaysia Plan (2010-2014) – (RMK10)
- National Biodiversity Policy (1998) – (NBP)
- National Physical Plan (2005) – (NPP)
- New Economic Model for Malaysia (2009) – (NEM)
- Second National Communication Report to the UNFCCC project (2010) (NC2)

The extracts have been organized under the following water bodies:

- Rivers
- Lakes
- Aquifers/Groundwater
- Coastal Areas

1. Rivers

1.1 *National Documents*

1.1.1 <u>Second National Communications to UNFCCC (2010) (NC2) Extracts</u>

The components of water bodies are rivers, lakes, aquifers, wetlands and coastal reaches. Of these, the NC2 analysis only considers impacts related to rivers and coastal reaches. One key gap is the lack of information on the impacts of climate change on other water bodies such as lakes, aquifer and wetlands. These should be studied and measures to adapt should be identified for these water bodies.

The changing annual rainfall and seasonal rainfall patterns will affect river flow and river water quality. Given the characteristics of Malaysian rivers which are generally small and short, flooding especially in low lying and coastal areas is likely during short intense rainfall or long, low intensity rainfall. During periods of low rainfall, river water quality is prone to deteriorate. Small forest streams are also breeding grounds for one of the malaria vectors. The manner in which climate change impacts on rivers could affect their role as a breeding ground for malaria vectors should be studied in order to avoid future reintroduction/occurrence of malaria or at least be prepared for such an event.

One major gap is the low number and frequency of hydrological and river flow data stations.

1.2 *International Documents*

1.2.1 <u>IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)</u>

(a) <u>IPCC-CC & Water Report — Executive Summary</u>
The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

(b) <u>IPCC-CC & Water — Main Report</u>
The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

<u>Non-climatic drivers of freshwater systems in the future [Sec 3.2.2, Page 43]</u>

1. Many non-climatic drivers affect freshwater resources at the global scale. Both the quantity and quality of water resources are influenced by land-use change, construction and management of reservoirs, pollutant emissions and water and wastewater treatment.

2. Water use is driven by changes in population, food consumption, economy (including water pricing), technology, lifestyle and societal views regarding the value of freshwater ecosystems.

3. The vulnerability of freshwater systems to climate change also depends on national and international water management. It can be expected that Integrated Water Resources Management (IWRM) will be followed increasingly around the world and that such a movement has the potential to position water issues, both as a resource and an ecosystem, at the centre of the policy-making arena. This is likely to decrease the vulnerability of freshwater systems to climate change.

4. Consideration of environmental flow requirements may lead to the modification of reservoir operations so that human use of these water resources might be restricted.

2. Lakes

2.1 IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)

(a) IPCC-CC & Water Report — Executive Summary
The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

(b) IPCC-CC & Water — Main Report
The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

3. Aquifers/Groundwater

3.1 *National Documents*

3.1.1 National Physical Plan (2005) (NPP) Extracts

The following are the relevant extracts from the NPP related to the technical management of aquifers/groundwater.

The NPP2005 has identified the ground water resource and recharge areas that need to be protected from activities that cause pollution and reduce their yield. The recommended measures are as follows:

1. Structure Plans and Local Plans shall delineate ground water resource areas (wellheads) and recharge areas as part of the integrated land use management plans.
2. Land use controls and buffer requirement shall be imposed to protect ground water resources including recharge areas and wellheads.
3. The use of public wells and important ground water resources catering for commercial, industrial and agricultural activities shall be monitored, particularly to avoid over-extraction.
4. Drainage controls shall be imposed in the vicinity of important ground water areas such as peat swamps and freshwater swamps to maintain the water table required to sustain these ecosystems.

3.2 *International Documents*

3.2.1 IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)

(a) IPCC-CC & Water Report — Executive Summary

The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

Point 6 - Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution

1. In addition, sea-level rise is projected to extend areas of salinisation of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas.

(b) IPCC-CC & Water – Main Report

The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

Groundwater [Sec 3.2.1.1, Page 38]

1. Climate change affects groundwater recharge rates (i.e. the renewable groundwater resources) and depths of groundwater tables. However, knowledge of current recharge and levels in both developed and developing countries is poor; and there has been very little research on the future impact of climate change on groundwater, or groundwater-surface water interactions.

2. As many groundwaters both change into and are recharged from surface water, impacts of surface water flow regimes are expected to affect groundwater.

3. Increased precipitation variability may decrease groundwater recharge in humid areas because more frequent heavy precipitation

4. Where the depth of the water table increases and groundwater recharge declines, wetlands dependent on aquifers are jeopardised and the base flow runoff in rivers during dry seasons is reduced.

5. In areas where water tables are already high, increased recharge might cause problems in towns and agricultural areas through soil salinisation and waterlogged soils. [WGII 3.4.2]

4. Coastal Areas

4.1 *National Documents*

4.1.1 National Physical Plan (2005) (NPP) Extracts

The following are the relevant extracts from the NPP related to the technical management of coastal areas.

(a) Sensitive Coastal Ecosystems
The NPP has identified the sensitive coastal ecosystems that need to be protected. The sensitive coastal ecosystems areas are shown in the map below. The recommended measures are as follows:

1. Coastal reclamation for future urban expansion shall not be carried out except the development of ports, marinas and jetties.
2. Sensitive coastal ecosystems of national importance shall be gazetted as Protected Areas and could be utilised for low-impact nature tourism.
3. All islands within marine parks should be designated as ESA Rank 3 as minimum requirement, and development should be controlled accordingiy to help safeguard the marine parks. Subject to further studies, some marine park islands will be designated ESA Rank 1 or 2.
4. Other sensitive coastal ecosystems shall continue to be identified in the Structure Plans.
5. Adopt policy recommended by National Integrated Coastal Zone Management for coastal areas.
6. Coastal area land use plan shall be prepared.

In addition to this, the National Urbanisation Policy along with planning guidelines and circulars are also relevant. In the National Urbanisation Policy, the following are some of the measures which would enhance/improve the measures mentioned above in the technical management of coastal areas:

1. optimal and balanced landuse planning emphasis in urban development, hence all development shall be compatible with the surrounding landuses and concentrated within the urban growth limit so as to create a compact city.
2. environmental conservation and improving the urban quality of life.
3. encourage development that reduces the impact of urban heat islands and to ensure that urban development will take into account reduction of air, noise and water pollution.
   In terms of planning guidelines and circulars, the Planning Guidelines for Roof Top Garden, 1997 by the Federal Department of Town and Country Planning which is presently being reviewed and updated and the circular from the Secretary-

General, Ministry of Housing and Local Government on Rain Water Harvesting System, 1999 (SPAH) are relevant not only for coastal management, but generally for urban management.

4.1.2 Second National Communications to UNFCCC (2010) (NC2) Extracts

The following are the relevant synthesized points extracted from the NC2 report related to the technical management of coastal areas.

(a) Coastal Reaches

A lot of the climate change impacts in water bodies in coastal reaches will be the result of increased sea level rise (SLR) and increased wave action. This could result in erosion and eventually salt water intrusion. Ecosystems such as mangrove forests and mudflats and the biodiversity they support are susceptible to increases in brackish water areas. Coastal agricultural and aquaculture activities are also vulnerable to salt water intrusion. Public health could also be jeopardised as increased areas of brackish water could increase the coastal malaria vector population.

Another impact to water bodies in coastal areas is reduced river flow during dry periods making river mouths vulnerable to sedimentation risks.

A pilot of the National Coastal Vulnerability Index (NCVI) study has been conducted in two areas, Tanjung Piai in Johore and Pantai Chenang in Langkawi. The study finds amongst other things that the global high worst case SLR scenario (10mm/year increase) will result in a loss of about 1,820 hectares of coastal land in Tangjung Piai and 148 hectares in Pantai Cenang by the end of the 21st century.

As one of the measures towards adaptation, not only for climate change impacts on coastal water bodies, but for impacts generally in coastal areas, the NCVI should be conducted throughout the country.

Another adaptation measure is to pass a Coastal Management Policy and ensure all coastline developments have Integrated Shoreline Management Plans (ISMP). The retreat, accommodate and protect approach should be adopted as necessary in an integrated manner.

R&D is also necessary to better understand long term natural coastal evolution due to storm surges and wave patterns as these will also have an impact on water bodies in coastal reaches. Research on coastal reforestation has also been proposed to develop optimal planting methods and robust coastal forests as well as soft engineering (application of structural and biological concepts) to solve erosion and reduce erosive forces.

Gaps identified include the absence of long term tidal records and changes in physical oceanographic patterns. Site-specific quantitative data and assessment is also lacking as is information on changes in storm patterns and frequency of storm events. These would be required for a more comprehensive nationwide analysis. Furthermore, the lack of a uniform understanding in various agencies dealing with SLR as well as the lack of enforcement powers for coastal development to adhere with guidelines are gaps that need to be addressed.

Some of the recommendations made to overcome these gaps include devising a system to monitor, detect and predict SLR and potential impacts as well as creating a centre of excellence for coastal issues.

Means to accelerate the formulation of ISMP and adherence to it should also be implemented including using legal instruments such as the Coastal Development Control Law for consistency in the application of coastal development guidelines.

The NCVI study should be expanded to the East Coast: Pantai Sabak, Kelantan, Kuantan, Pahang, K. Terengganu, Terengganu; West Coast: Pelabuhan Klang, Selangor, P. Pinang, Batu Pahat, Johor; Sarawak: Bintulu, Miri, Kuching and Sabah: KK, Tawau, Sandakan. R&D on storm surges and wave patterns should be conducted along with developing long term wave measurement programmes along Malaysian coasts.

In terms of the NCVI it can be noted that some of the areas identified as being vulnerable to impacts like SLR would be coastal water bodies and the socio economic activities they help support. Focusing on such areas would help channel limited resources to the most critical areas and enable timely adaptation measures to be undertaken to reduce or eliminate the impact. This of course should be done in a holistic integrated manner. However in order to do so, a strong understanding of the impact on the specific water body would be necessary.

Following on from the NC2 findings, specific studies could be done in some particularly sensitive areas such as the coastal areas in Kuala Selangor supporting firefly colonies. Such an area would be especially vulnerable to dry periods which would affect river flow which in turn could result in salt water intrusion affecting the sensitive berembang trees which the fireflies rely on. The earlier measure to overcome water scarcity during future drought periods by constructing a dam upstream has already made the downstream coastal areas vulnerable. Climate change impacts resulting in extended dry periods could render the existing measures to overcome the reduction in river flow due to the dam construction useless.

Additionally the NC2 has not specifically looked at the impacts of climate change on fisheries. Coastal reaches such as wetlands and mangrove areas are habitats for juveniles and changes in water salinity may affect population and the sex ratio.

4.2 *International Documents*

4.2.1 IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)

(a) IPCC-CC & Water Report — Executive Summary

The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

Point 9 — Climate change affects the function and operation of existing water infrastructure — including hydropower, structural flood defences, drainage and irrigation systems — as well as water management practices.

1. Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation (very high confidence).
2. Globally, water demand will grow in the coming decades, primarily due to population growth and increasing affluence; regionally, large changes in irrigation water demand as a result of climate change are expected (high confidence).

(b) IPCC-CC & Water — Main Report

The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

4.2.2 Stern Review: The Economics of Climate Change (2006) (Stern Review)

The following are the key observations and recommendations extracted from the Stern Review report that address this issue.

Coastal Areas [page 410]

1. For coastal protection, the avoided damages of climate change can be calculated from the value of land, infrastructure, activities and so on protected by sea walls, while the cost of sea walls can be calculated by scaling up from engineering estimates of construction costs.
2. Coastal protection should – in theory – occur up to the point where the cost of the next unit of protection is just equal to the benefit. In general, these studies suggest

that high levels of protection may be economically efficient and reduce the costs of land loss substantially.

3. According to one recently analysis, the effectiveness of adaptation declines with higher amounts of sea level rise. This analysis found that for 0.5-m of sea level rise damage costs were reduced by 80 – 90% with enhanced coastal protection than without, while the costs were only reduced by 10 – 70% for 1-m of sea level rise.
4. For most countries, protection costs based on these calculations are likely to be below 0.1% of GDP, at least for rises up to 0.5-m. But for low-lying countries or regions, costs could reach almost 1% of GDP.10 For 1-m of sea level rise, the costs could exceed several percent of GDP for the most vulnerable nations.

4.2.3 The Economics of Climate Change in South East Asia: A Regional Review (2009) (ECC-SEA)

The following are the key observations and recommendations extracted from the ADB Review report that address this issue.

Coastal and Marine Resources Sector

Figure A7.1 shows a table summarizing the key adaptations in the coastal and marine resources sector. [page 116]

Table 6.9. Summary of Key Adaptation Options in Coastal and Marine Resources Sector

Practice	Reduced Impact	Scale	Reactive/ Proactive	Planned/ Autonomous	Beneficiary Sector	Example
Mangrove conservation and plantation	Storms, cyclones, coastal erosion	Local	Reactive	Planned/ Autonomous	Agriculture, Forestry Household	Widely used
Strengthening and reinforcing existing revetments, dikes, sea walls, etc.	Sea level rise, coastal erosion	Regional	Reactive	Planned	Agriculture, Household, Industry	Widely used
Relocation of aquaculture farms, coastal infrastructure	Sea level rise	Local	Reactive	Autonomous	Agriculture	Thailand, Viet Nam
Better design and standard for construction of houses, industrial areas, and infrastructure	Storms, cyclones, coastal erosion	Local/ Sub-regional	Proactive	Planned/ Autonomous	Household, Industry	Indonesia, Viet Nam
Provision of information and awareness, raising program	Storms, cyclones, coastal erosion, sea-level rise	Regional/ National	Proactive	Planned	Agriculture, Household, Industry	Philippines
Monitoring sea level rise	Sea level rise	Regional/ National	Proactive	Planned	Agriculture, Household, Industry	Thailand
Pumping to relieve flooding	Storms, cyclones	Local	Reactive	Autonomous	Agriculture, Household	Viet Nam
Preparation of hazard and vulnerability maps	Storms, cyclones,	Local/ Sub-regional	Proactive	Planned	Agriculture, Household	Philippines

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

Figure A7.1 Summary of key adaptations in the coastal and marine resources sector (ADB Review report).

Appendix 8 — Selected Extracts on "Water Use Management Issue" from key National and International documents.

This appendix presents a compilation of the relevant national actions that have been identified by our national policy makers and technical managers on the water use management issue to address the potential climate change impacts on water and the adaptation measures that need to be taken. It also presents the international scenarios on the issue, and in particular, highlights the key recommendations from the IPCC Technical Paper VI on Climate Change on Water (2008), the Stern Review on the Economics of Climate Change (2006) and the report on "The Economics of Climate Change in Southeast Asia: A Regional Review" (2009) by ADB. Some selected examples of international best practices that have been taken to address the issue are also given.

The national actions that have been identified by our national policy makers and technical managers have been extracted from the following documents.

- National Policy on Climate Change (2009) – (NPCC)
- Tenth Malaysia Plan (2010-2014) – (RMK10)
- National Biodiversity Policy (1998) – (NBP)
- National Physical Plan (2005) – (NPP)
- New Economic Model for Malaysia (2009) – (NEM)
- Second National Communication Report to the UNFCCC project (2010) (NC2)

The extracts have been organized under the following water use management issues:

- Potable Water Supply
- Agriculture & Irrigation Water Supply
- Hydropower
- River Navigation
- Fisheries
- Water Ecosystems
- Competing Uses for Water

1. Potable Water Supply

1.1 *National Documents*

1.1.1 <u>Tenth Malaysia Plan (2010-2014) (RMK10) Extracts</u>

The following are the relevant extracts from RMK10 related to the technical management of potable water supply.

(a) <u>RMK10: Strengthening Efforts to Deliver High Quality and Environmentally Sustainable Housing [page 279]</u>

The Government will review tax incentives, such as tax breaks for buildings and designs that are environmentally friendly, incorporating green design elements like solar panels for heating, rain water harvesting facilities and water conservation features".

(b) RMK10: Managing Water Endowment and Supply [page 281]
Malaysia is blessed with an abundance of water, with water resources of 21,500 cubic meters per capita per year. However, with a growing economy, Malaysia will need to become more prudent and efficient in its management of water resources and supply. The highest demand for water comes from the agricultural sector. In Peninsular Malaysia, projected demand for irrigation water in 2010 comprises 54% of total demand for water or 33,100 million cubic metres. Demand for water, excluding the agriculture sector, is expected to grow from 8,550 million litres per day in 2009 to 10,520 million litres per day by 2015.

Malaysia will reassess the management of its resources across the entire water cycle – from where water is drawn, to how water is treated and supplied to citizens and how wastewater is returned to the environment. During the Plan period, Malaysia's strategy for ensuring sustainable water supply will have three areas of focus:

- Developing a long-term strategy for water resource management to achieve water security;
- Continuing efforts to restructure the water services industry; and
- Protecting rivers from pollution.

(c) RMK10: Developing a Long-Term Strategy for Water Resource Management to Achieve Water Security [page 282]
Other measures to be implemented during the Plan period include expanding the implementation of the Integrated Water Resources Management and Integrated River Basin Management approaches in planning, managing, protecting and rehabilitating water resources. The Government will provide RM5 billion for flood mitigation programmes. This includes the application of the Integrated Flood Management approach to manage the risks of flood damage through forecasting and warning facilities as well as the development of disaster preparedness and community awareness programmes and flood hazard maps. In addition, research and development efforts will be intensified in area of conservation of water resources to support efforts to develop a sustainable water sector for the national economy.

(d) RMK10: Continuing Efforts to Restructure the Water Services Industry [page 283]
Restructuring of the water service industry, covering water supply and sewerage services began during the Eighth Plan period with the objective of creating

an efficient and sustainable water services industry. During the Plan period, restructuring efforts will enter into its final phase, as shown in Chart 6–14, with a focus on the following areas:

- *Completing the migration of state water operators.*
- *Moving towards full cost recovery.*
- *Driving efficiency in operations and capital expansion.*
- *Improving water services infrastructure.*
- *Integrating water and sewerage services.*

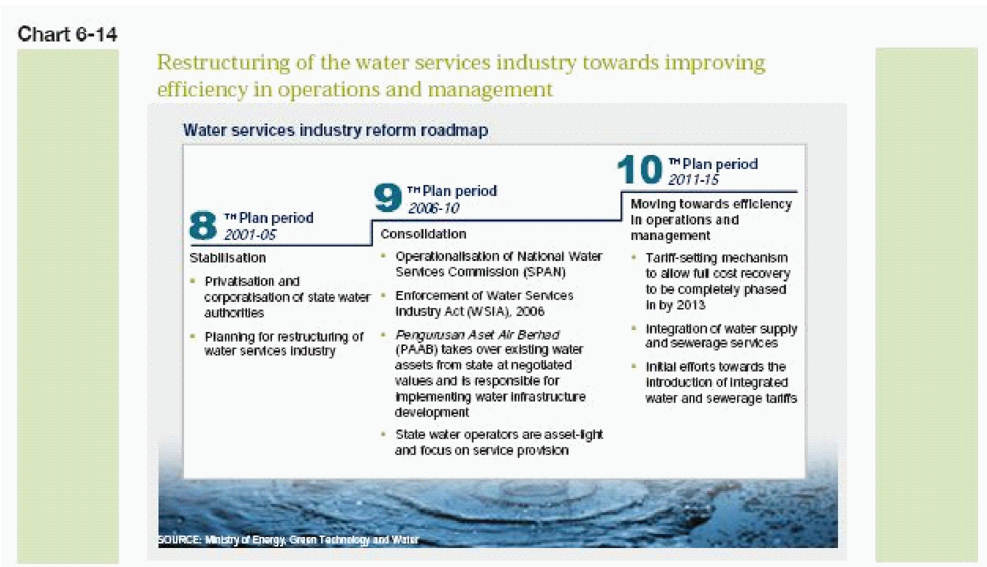

Figure A8.1. Chart 6-14: Restructuring of the water services industry in Malaysia (RMK10).

1.1.2 National Physical Plan (2005) (NPP) Extracts

The following are the relevant extracts from the NPP related to the technical management of potable water supply.

(a) Water Supply

The NPP recommended measures to address the water resources issues are as follows:

1. National policies on water shall be formulated to encompass issues such as water resources conservation, alternative sources for water-stressed areas.

opportunity costs for conservation of water catchments, reduction of water loss. reuse and recycling of water and water demand management.

2. States with the ability to supply water to water-stressed areas shall be encouraged to protect water catchments and to develop their export potential of this resource.
3. Integrated Water Resource Management (IWRM) and Integrated River Basir Management (IRBM) are to be adopted as input of land use planning.

(b) Protection of Water Catchments

The NPP has identified the water catchment areas in Peninsular Malaysia that are subjected to threats from pollution from industrial activities within them. The map below shows the water catchments and the industrial sites located within them. The recommended protection measures are as follows:

1. Surface and ground water resource and recharge areas shall be identified and delineated as areas requiring special land use management and subject to specific land use control.
2. All existing and future land use activities within surface and ground water resource and recharge areas should not jeopardise nor add to the cost of water treatment for human consumption.
3. New industrial development and other activities that could be a source of water borne pollution shall not be permitted in water catchments.
4. Existing industries within water catchments shall be required to adopt appropriate environmental management measures to protect public health and the water quality.
5. Water catchments upstream of dams shall be gazetted as protection forests to ensure that there will be no further encroachment of incompatible land uses into such areas.
6. Water bodies shall be managed to protect the aquatic flora and fauna, with the objective to sustain living rivers.

1.1.3 Second National Communications to UNFCCC (2010) (NC2) Extracts

The following are the relevant synthesized points extracted from the NC2 report related to the technical management of potable water supply.

(a) Water Use

The components of water use are irrigation, potable/water sanitation, industrial, hydropower, navigation, fisheries, ecosystem water needs. Of these, the NC2 analysis only considers consumptive water uses.

A key gap in the NC2 analysis is lack of consideration pertaining to non-consumptive water use such as for ecosystem water needs and recreational/tourism needs.

(b) Potable/Water Sanitation

Excessive rainfall leading to floods, reduced rainfall leading to droughts and extreme weather events can all affect the quality and quantity of water. Water pollution can result from overflows and damage to water supply infrastructure. Water supply can also be disrupted by droughts as was experienced in Selangor in the late part of the last decade.

The NAHRIM 2009 study indicates that based on the capacities of existing facilities (i.e. Klang Gates Dam, Batu Dam, Sg. Selangor Dam, Tinggi Dam and downstream catchment between Sg. Selangor Dam to Batang Berjuntai Intake Point, (excluding the Pahang-Selangor water transfer project), 28 (nearly 12%) out of the total 240 months are projected to face water supply deficit situations. These monthly water deficits range from (+)3 MCM to 214 MCM. The highest surplus could be as high as 2,137 MCM.

These estimates were based on demands from population that is increasing from nearly 5 million in 2010 to nearly 7 million in 2050. The estimates are also based on the assumption that per capita domestic consumption increases from 300 (2010) to 330 (2050) litres/capita/day and Non-Revenue Water (NRW) increases from 185 (2010) to 207 litres/capita/day (2050). Floods aspects are not considered and these may affect some of the facilities.

Health concerns can also arise such as an increase in the incidence of typhoid, cholera and diarrheal diseases.

The adaptation measures proposed include both demand and supply management. Demand management measures include encouraging water conservation and reduction of per capita water consumption through economic incentives and promoting rainwater harvesting. Supply management includes reducing the non revenue water (NRW) and regular maintenance of water treatment plans and distribution pipes.

Gaps are similar to those identified for the irrigation component.

(c) Industrial

Impacts on industrial water use are similar to those identified for irrigation and potable use. The vulnerabilities, proposed adaptation measures and gaps in the analysis are likewise similar.

Essentially for all these three water use areas, competition for limited water resources during droughts will be a concern. Hence an integrated water use management is required. This can be somewhat addressed through the implementation of IWRM with the proviso that climate change related stressors should be accounted for in its implementation.

During times of excess rain water or extreme weather, the integrity and efficacy of water supply infrastructure are at risk.

(d) Competing use of water resources

As noted earlier in the water use section, the analysis in the NC2 was done on an isolated basis. The projected increase in frequency and severity of droughts however will result in enhanced competition for water resources with reduced availability and supplies not being able to meet the consumptive water use demands.

Adaptation measures proposed include implementing IWRM, rainwater harvesting, reducing NRW and better water demand management. The National Water Services Commission Act 2006 and Water Services Industry Act 2006 have been identified as promoting sustainable water use and better water management.

A major gap in this analysis is that non-consumptive water use such as for ecosystem services, power generation, recreation and tourism has not been included in considering competition for water resources.

A more holistic approach in formulating adaptation measures is recommended to avoid maladaptation. Such an approach will not only incorporate water resources needs for non-consumptive purposes, but would change the perspective by analysing the needs based on a spatial/regional or temporal dimension rather than a narrow sector based approach.

1.2 *International Documents*

1.2.1 IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)

(a) PCC-CC & Water Report — Executive Summary

The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

Point 3 — By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics.

1. These projections are based on an ensemble of climate models using the mid-range SRES A1B non-mitigation emissions scenario. Consideration of the

range of climate responses across SRES scenarios in the mid-21st century suggests that this conclusion is applicable across a wider range of scenarios.

2. Many semi-arid and arid areas (e.g. the Mediterranean Basin, western USA, southern Africa and northeastern Brazil) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change (high confidence).

Point 7 — Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits (high confidence).

1. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress.
2. Areas in which runoff is projected to decline face a clear reduction in the value of the services provided by water resources. Increased annual runoff in some areas is projected to lead to increased total water supply.
3. However, in many regions, this benefit is likely to be counterbalanced by the negative effects of increased precipitation variability and seasonal runoff shifts in water supply, water quality and flood risks (high confidence).

Point 12 — Adaptation options designed to ensure water supply during average and drought conditions require integrated demand-side as well as supply-side strategies.

1. The former improve water-use efficiency, e.g. by recycling water. An expanded use of economic incentives, including metering and pricing, to encourage water conservation and development of water markets and implementation of virtual water trade, holds considerable promise for water savings and the reallocation of water to highly valued uses.
2. Supply-side strategies generally involve increases in storage capacity, abstraction from water courses, and water transfers. Integrated water resources management provides an important framework to achieve adaptation measures across socio-economic, environmental and administrative systems. To be effective, integrated approaches must occur at the appropriate scales.

(b) <u>IPCC-CC & Water — Main Report</u>

The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

Impacts of climate change on freshwater availability in the future [Sec 3.2.3, Page 44]

1. With respect to water supply, it is very likely that the costs of climate change will outweigh the benefits globally. One reason is that precipitation

variability is very likely to increase, and more frequent floods and droughts are anticipated. The impacts of floods and droughts could be tempered by appropriate infrastructure investments and by changes in water and land-use management, but the implementation of such measures will entail costs.

2. Water infrastructure, usage patterns and institutions have developed in the context of current conditions. Any substantial change in the frequency of floods and droughts, or in the quantity and quality or seasonal timing of water availability, will require adjustments that may be costly, not only in monetary terms but also in terms of societal and ecological impacts, including the need to manage potential conflicts between different interest groups.
3. Hydrological changes may have impacts that are positive in some aspects and negative in others. For example, increased annual runoff may produce benefits for a variety of both in-stream and out-of-stream water users by increasing renewable water resources, but may simultaneously generate harm by increasing flood risk.
4. Increased runoff could also damage areas with a shallow water table. In such areas, a water-table rise disturbs agricultural use and damages buildings in urban areas. In addition, an increase in annual runoff may not lead to a beneficial increase in readily available water resources, if that additional runoff is concentrated during the high-flow season.

<u>Impacts of climate change on freshwater demand in the future [Sec 3.2.4, Page 44]</u>

1. Higher temperatures and increased variability of precipitation would, in general, lead to increased irrigation water demand, even if the total precipitation during the growing season remains the same.
2. The increase in household water demand (for example through an increase in garden watering) and industrial water demand, due to climate change, is likely to be rather small, e.g. less than 5% by the 2050s at selected locations. An indirect, but small, secondary effect would be increased electricity demand for the cooling of buildings, which would tend to increase water withdrawals for the cooling of thermal power plants.

<u>Impacts of climate change on water stress in the future [Sec 3.2.5, Page 45]</u>

1. Climate change is only one of many factors that influence future water stress; demographic, socio-economic and technological changes possibly play more important roles at most time horizons and in most regions.
2. In the 2050s, differences in the population projections of the four IPCC SRES scenarios would have a greater impact on the number of people living in water-stressed river basins than the differences in the climate scenarios. The number of people living in water-stressed river basins would increase significantly.

3. It should be noted that, using the per capita water availability indicator, climate change would appear to reduce overall water stress at the global level. This is because increases in runoff are concentrated heavily in the most populous parts of the world, mainly in eastern and south-eastern Asia. However, given that this increased runoff occurs mainly during high-flow seasons, it may not alleviate dry-season problems if the extra water is not stored; and would not ease water stress in other regions of the world.
4. Changes in seasonal patterns and an increasing probability of extreme events may offset the effects of increased annual available freshwater resources and demographic changes.
5. If water stress is assessed not only as a function of population and climate change but also of changing water use, the importance of non-climatic drivers (income, water-use efficiency, water productivity, and industrial production) increases.
6. Income growth sometimes has a larger impact than population growth on increasing water use and water stress (when expressed as the water withdrawal: water resources ratio).

<u>Impacts of climate change on costs and other socio-economic aspects of freshwater [Sec 3.2.6, Page 46]</u>

1. The amount of water available for withdrawal is a function of runoff, groundwater recharge, aquifer conditions (e.g. degree of confinement, depth, thickness and boundaries), water quality and water supply infrastructure (e.g. reservoirs, pumping wells and distribution networks).
2. Safe access to drinking water depends more on the level of water supply infrastructure than on the quantity of runoff. However, the goal of improved safe access to drinking water will be harder to achieve in regions where runoff and/or groundwater recharge decreases as a result of climate change.
3. Climate change leads to additional costs for the water supply sector, e.g. due to changing water levels affecting water supply infrastructure, which might hamper the extension of water supply services to more people. This leads, in turn, to higher socio-economic impacts and follow-up costs, especially in areas where the prevalence of water stress has also increased as a result of climate change.
4. Climate change-induced changes in both the seasonal runoff regime and inter-annual runoff variability can be as important for water availability as changes in the long-term average annual runoff.

<u>Water Supply and Sanitation (Sec 4.4, page 69)</u>

1. Access to safe water is now regarded as a universal human right. However, the world is facing increasing problems in providing water services, particularly

in developing countries. There are several reasons for this, which are not necessarily linked to climate change. A lack of available water, a higher and more uneven water demand resulting from population growth in concentrated areas, an increase in urbanisation, more intense use of water to improve general well-being, and the challenge to improve water governance, are variables that already pose a tremendous challenge to providing satisfactory water services.

2. In this context, climate change simply represents an additional burden for water utilities, or any other organisation providing water services, in meeting customers' needs. It is difficult to identify climate change effects at a local level, but the observed effects combined with projections provide a useful basis to prepare for the future.

<u>Adaptation, vulnerability and sustainable development [Sec 4.4.4, page 71]</u>

1. Given the problems envisaged above, it is important for water utilities located in regions at risk to plan accordingly. Most water supply systems are well able to cope with the relatively small changes in mean temperature and precipitation that are projected to occur in the decades ahead, except at the margin where a change in the mean requires a change in the system design or the technology used; e.g. where reduced precipitation makes additional reservoirs necessary, or leads to saline intrusion into the lower reaches of a river, or requires new water treatment systems to remove salts.
2. Water services are usually provided using engineered systems. These systems are designed using safety factors and have a life expectancy of 20–50 years (for storage reservoirs it can be even longer). Reviews of the resilience of water supplies and the performance of water infrastructure have typically been done by using observed conditions alone. The use of climate projections should also be considered, especially in cases involving systems that deal with floods and droughts.
3. Decrease in water availability. Except for a few industrialized countries, water use is increasing around the world due to population and economic growth, lifestyle changes and expanded water supply systems. It is important to implement efficient water-use programmes in regions where water availability is likely to decrease, as large investments might be required to ensure adequate supplies, either by building new storage reservoirs or by using alternative water sources.
4. Reductions in water use can delay, or even eliminate, the need for additional infrastructure. One of the quickest ways to increase water availability is through minimising water losses in urban networks and in irrigation systems. Other alternatives for reducing the need for new water supplies include rainwater harvesting as well as controlled reuse.

5. Lower water quality caused by flow variations. The protection of water resources is an important, cost-effective strategy for facing future problems concerning water quality. While this is a common practice for some countries, new and innovative approaches to water quality management are required around the world. One such approach is the implementation of water safety plans (WSP) to perform a comprehensive assessment proposed by the WHO.
6. Also, the design and operation of water and wastewater treatment plants should be reviewed periodically, particularly in vulnerable areas, to ensure or increase their reliability and their ability to cope with uncertain flow variations.
7. Desalinisation. Water treatment methods are an option for dealing with increasing salt content in places at risk, such as highly urbanised coastal areas relying on aquifers sensitive to saline intrusion. At present, available technologies are based mostly on membranes and are more costly than conventional methods for the treatment of freshwater supplies. Fortunately the cost of desalinisation has been falling, although it still has a high energy demand. Desalinisation costs need to be compared with the costs of extending pipelines and eventually relocating water treatment works in order to have access to freshwater. As a rough working rule, the cost of construction of the abstraction and treatment works and the pumping main for an urban settlement's water supply is about half the cost of the entire system.
8. More and different approaches for coping with wastewater. For sewers and wastewater treatment plants, strategies for coping with higher and more variable flows will be needed. These should include new approaches such as the use of decentralized systems, the construction of separate sewers, the treatment of combined sewer overflows (i.e. the mixture of wastewater and runoff in cities), and injecting rainwater into the subsoil.
9. Given the high cost involved in increasing the capacity of urban wastewater treatment plants, appropriately financed schemes should be put in place to consider local conditions. For rural areas, sanitation coverage is generally too low, and local action plans need to be formulated using low-cost technologies, depending on the locality and involving the community.
10. <u>Developed countries</u>. In developed countries, drinking-water receives extensive treatment before it is supplied to the consumer and the wastewater treatment level is high. Such benefits, as well as proper water source protection, need to be maintained under future climatic change, even if additional cost is to be incurred, for instance by including additional water treatment requirements. For small communities or rural areas, measures to be considered may include water source protection as a better cost–benefit option.

Implications for drinking-water quality [Sec 4.3.1.1, page 67]

1. The relationship between rainfall, river flow and contamination of the water supply is highly complex, as discussed below both for piped water supplies and for direct contact with surface waters. If river flows are reduced as a consequence of less rainfall, then their ability to dilute effluent is also reduced – leading to increased pathogen or chemical loading. This could represent an increase in human exposures or, in places with piped water supplies, an increased challenge to water treatment plants.
2. Drainage and storm water management is important in low income urban communities, as blocked drains can cause flooding and increased transmission of vector-borne diseases. Cities with combined sewer overflows can experience increased sewage contamination during flood events.
   In high-income countries, rainfall and runoff events may increase the total microbial load in watercourses and drinking water reservoirs, although the linkage to cases of human disease is less certain because the concentration of contaminants is diluted.
3. A significant proportion of notified water-borne disease outbreaks are related to heavy precipitation events, often in conjunction with treatment failures.
4. Freshwater harmful algal blooms (HABs) produce toxins that can cause human diseases. The occurrence of such blooms in surface waters (rives and lakes) may increase due to higher temperatures. However, the threat to human health is very low, as direct contact with blooms is generally restricted. There is a low risk of contamination of water supplies with algal toxins but the implications for human health are uncertain.
5. In areas with poor water supply infrastructure, the transmission of enteric pathogens peaks during the rainy season. In addition, higher temperatures were found to be associated with increased episodes of diarrhoeal disease. The underlying incidence of these diseases is associated with poor hygiene and lack of access to safe water.

1.2.2 The Economics of Climate Change in South East Asia: A Regional Review (2009) (ECC-SEA)

The following are the key observations and recommendations extracted from the ADB Review report that address this issue.

Water resources sector

Figure A8.2 shows a table summarizing the key adaptations in the water resources sector. [page 100]

Table 6.3. Summary of Key Adaptation Options in Water Resources Sector

Practice	Reduced Impact	Scale	Reactive/ Proactive	Planned/ Autonomous	Beneficiary Sector	Example
Rehabilitation of damaged irrigation and drainage facilities	Water shortage, drought, erratic rainfall	Local/ Sub-regional	Reactive	Planned	Agriculture	Indonesia, Singapore, Thailand, Viet Nam
Extension of small-scale irrigation schemes						Viet Nam
Flood warning system	Extreme events, e.g. floods, storm surges	Local/ Sub-regional	Proactive	Planned	Agriculture, Coastal, Household, Industry	Viet Nam
Improved flood control facilities, such as pumping stations, water gate		Regional			Agriculture, Household, Industry	Thailand
Multi-purpose reservoirs, dams, water-impounding system	Drought, flood, erratic rainfall pattern, water shortage	Regional	Proactive	Planned	Agriculture, Household, Industry, Power generation	Philippines, Viet Nam
Integrated river basin development, water catchment areas					Agriculture, Household, Industry	Singapore, Thailand
Rain harvesting technologies	Water shortage, drought, erratic rainfall pattern	Local	Reactive	Autonomous	Household	Indonesia
Conjunctive use of water, training for efficient use of water from irrigation					Household, Agriculture	Indonesia, Thailand, Viet Nam
Metering and pricing to encourage water conservation	Water shortage	Local	Reactive	Autonomous	Household	Philippines, Singapore
Reclamation of used water	Water shortage	Regional/ National	Proactive	Planned	Household, Industry	Singapore
Sea water osmosis plant						

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

Figure A8.2 Summary of key adaptations in the water resources sector (ADB Review report).

2. Agriculture and Irrigation Water Supply

2.1 *National Documents*

2.1.1 National Physical Plan (2005) (NPP) Extracts

The following are the relevant extracts from the NPP related to the technical management of agriculture and irrigation water supply.

(a) Major Granary Areas

The NPP identified eight strategic granary areas comprising the Muda (MADA), Kemubu (KADA), ADP Kerian-Sungai Manik, IADP Barat Laut Selangor, IADP Pulau Pinang, IADP Seberang Perak, IADP Terengganu Utara (KETARA) and IADP Kemasin-Semerak that are to be conserved. The recommended conservation measures are:

1. Permanent development limits for all urban centres within these areas shall be established.

2. There shall be no conversion of paddy land in these areas to urban or any other uses beyond the established urban limits except for paddy related activities.
3. In the Structure Plans for states with granary areas, urban development shall be diverted from these areas and alternative locations for urban development shall be identified.
4. Water catchments for the granary areas shall be identified and conserved to ensure adequate and quality water supply for paddy cultivation.

. Fiscal measures shall be introduced to assist states that are required to conserve granary areas.

2.1.2 Second National Communications to UNFCCC (2010) (NC2) Extracts

The following are the relevant synthesized points extracted from the NC2 report related to the technical management of agriculture and irrigation water supply.

(a) Irrigation (Chap 4, Section 4.7(a)(i) Draft NC2)

Irrigation facilities and their efficacy can be impacted by excessive rainfall, reduced rainfall and extreme weather patterns. With excessive rainfall, failure to contain excess water is anticipated which could result in flooding and crop damage/loss of yield. Projections made by the RegHCM-PM model were used to identify vulnerabilities in three important granary areas, Muda Agriculture Development Authority (MADA), Kemubu Agriculture Development Authority (KADA) and the Barat Laut Selangor granary areas.

The projections indicate that the MADA granary area could face excess water for 76% of the 240 months studied while there are indications of extreme surplus of up to (+) 5,438 MCM in the KADA granary area. Insufficient rainfall is anticipated for 10 out of the 40 planting seasons considered at the MADA scheme possibly warranting the cancellation of paddy planting in some, or in the worst case scenario, all of the MADA area. Likewise, for the Barat Laut Selangor irrigation scheme where one of the deficit events is projected to be severe enough to disrupt planting in some parts. KADA is not expected to face severe deficits.

Some of the adaptation measures proposed are as follows: establishing an early warning system, rain water harvesting, soil water management and drainage improvement.

The gaps identified in the NC2 are twofold, first that the impacts have been considered in isolation and not in conjunction with impacts to other consumption and non-consumption uses of water. Second, the data used in the analysis has been taken from the National Water Resources Study (2000). The assumptions and information contained in this study is currently being revisited. A more updated analysis may provide a different picture of the constraints on water use.

The NC2 has not provided information on how much of the nation's rice needs are met by each of these granary areas as well as how much they are anticipated to provide in the future. Rice is a staple crop. It would be important to identify this in future analysis to understand the vulnerability of the nation's food security to projected climate change impacts in these and other rice production areas.

2 Scarcity

Similar to the impacts of water excesses, water scarcity is also expected to be more frequent and severe and to occur in areas which were historically drought free. Agriculture and public health are vulnerable to these impacts.

Rainfed rice agriculture is equally vulnerable to a decrease in seasonal rainfall during the early growth stage with a 15% decrease likely resulting in a 80% reduction in yield. Crop quality will also be adversely affected. Yield reduction in cash crops such as oil palm (10% decrease in mean annual rainfall results in 30% decrease in yield), rubber (reduction below mean minimum and increase in temperature over 30oC results in 10% yield decrease) and cocoa is anticipated.

Public health risks include an increase in vector borne diseases as mosquito breeding grounds may increase with more pronounced wet and dry spells. Furthermore availability of water supply will also be reduced resulting in impacts already discussed under the water use section.

Adaptation measures that have been identified include enhancing water supply efficiency such as improving storage capacity and efficacy by removing sediments and eliminating losses from leakage and theft, enhancing existing dam capacity to store more water, encouraging rainwater harvesting for non potable uses, encouraging demand management in non potable water use and creating a decision support system that incorporates weather forecasting.

R&D should be enhanced to discover drought resistant/high water use efficiency (WUE) varieties. In particular, for rice, research on aerobic rice which consumes less water should be enhanced. Irrigation facilities may also need to be introduced in areas that were previously entirely rainfed. Public health measures are similar to those proposed for excess water management.

Here again special attention should be paid to monthly rainfall minimums to make appropriate policy decisions on managing available water.

2.2 *International Documents*

2.2.1 IPCC Technical Paper VI - Climate Change & Water (2008) (IPCC-CC & Water Report)

(a) IPCC-CC & Water Report — Executive Summary

The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

Point 8 — Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilisation.

This is expected to lead to decreased food security and increased vulnerability of poor rural farmers, especially in the arid and semi-arid tropics and Asian and African mega deltas.

Point 9 — Climate change affects the function and operation of existing water infrastructure — including hydropower, structural flood defences, drainage and irrigation systems — as well as water management practices.

1. Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation (very high confidence).
2. Globally, water demand will grow in the coming decades, primarily due to population growth and increasing affluence; regionally, large changes in irrigation water demand as a result of climate change are expected (high confidence).

(b) IPCC-CC & Water — Main Report

The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

Agriculture and Food Security, Land use and forestry [Sec 4.2, Page 59]

1. The productivity of agricultural, forestry and fisheries systems depends critically on the temporal and spatial distribution of precipitation and evaporation, as well as, especially for crops, on the availability of freshwater resources for irrigation.
2. Production systems in marginal areas with respect to water face increased climatic vulnerability and risk under climate change, due to factors that include, for instance, degradation of land resources through soil erosion, over-extraction of groundwater and associated salinisation, and over-grazing of dryland.

Agriculture and food security [Sec 4.2.1.1, page 59]

1. Global food production depends on water not only in the form of precipitation but also, and critically so, in the form of available water resources for irrigation.

Indeed, irrigated land, representing a mere 18% of global agricultural land, produces 1 billion tonnes of grain annually, or about half the world's total supply; this is because irrigated crops yield on average 2–3 times more than their rain-fed counterparts.

2. While too little water leads to vulnerability of production, too much water can also have deleterious effects on crop productivity, either directly, e.g. by affecting soil properties and by damaging plant growth, or indirectly, e.g. by harming or delaying necessary farm operations.
3. Socio-economic pressures over the next several decades will lead to increased competition between irrigation needs and demand from non-agricultural sectors, potentially reducing the availability and quality of water resources for food.

<u>Land use and forest ecosystems [Sec 4.2.1.2, page 59]</u>

1. Forests are key determinants of water supply, quality and quantity, in both developing and developed countries. The importance of forests as watersheds may increase substantially in the next few decades, as freshwater resources become increasingly scarce, particularly in developing countries.
2. Forests contribute to the regional water cycle, with large potential effects of land-use changes on local and regional climates. On the other hand, forest protection can have drought and flood mitigation benefits, especially in the tropics.
3. Afforestation and reforestation may increase humidity, lower temperature and increase rainfall in the regions affected; deforestation can instead lead to decreased local rainfall and increased temperature. In Amazonia and Asia, deforestation may lead to new climate conditions unsuitable for successful regeneration of rainforest species.

<u>Crops [Sec 4.2.3.1, page 61]</u>

1. In general, while moderate warming in high-latitude regions would benefit crop and pasture yields, even slight warming in low-latitude areas, or areas that are seasonally dry, would have a detrimental effect on yields.
2. Increases in the frequency of climate extremes may lower crop yields beyond the impacts of mean climate change.
3. Impacts of climate change on irrigation water requirements may be large.

<u>Pastures and livestock [Sec 4.2.3.2, page 62]</u>

1. The impact on animal productivity due to increased variability in weather patterns is likely to be far greater than effects associated with changes in average climatic conditions.

2. The most frequent catastrophic losses arising from a lack of prior conditioning to weather events occur in confined cattle feedlots, with economic losses from reduced cattle performance exceeding those associated with cattle death losses by several-fold.
3. Other impacts on livestock occur directly through the increase in thermal heat load.

<u>Fisheries [Sec 4.2.3.3, page 62]</u>

1. Negative impacts of climate change on aquaculture and freshwater fisheries include: stress due to increased temperature and oxygen demand and decreased pH; uncertain future water quality and volume; extreme weather events; increased frequency of disease and toxic events; sea-level rise and conflicts of interest with coastal defence needs; and uncertain future supplies of fishmeal and oils from capture fisheries.

<u>Adaptation, vulnerability and sustainable development [Sec 4.2.4, page 63]</u>

1. Water management is a critical component that needs to adapt in the face of both climate and socio-economic pressures in the coming decades. Changes in water use will be driven by the combined effects of: changes in water availability, changes in water demand from land, as well as from other competing sectors including urban, and changes in water management.
2. Practices that increase the productivity of irrigation water use – defined as crop output per unit water use – may provide significant adaptation potential for all land production systems under future climate change. At the same time, improvements in irrigation efficiency are critical to ensure the availability of water both for food production and for competing human and environmental needs.
3. <u>Autonomous adaptation</u> actions are defined as responses that will be implemented by individual farmers, rural communities and/or farmers' organisations, depending on perceived or real climate change in the coming decades, and without intervention and/or co-ordination by regional and national governments and international agreements. To this end, maladaptation, e.g. pressure to cultivate marginal land, or to adopt unsustainable cultivation practices as yields drop, may increase land degradation and endanger the biodiversity of both wild and domestic species, possibly jeopardising future ability to respond to increasing climate risk later in the century.
4. <u>Planned adaptation</u>, therefore, including changes in policies, institutions and dedicated infrastructure, will be needed to facilitate and maximise long-term benefits of adaptation responses to climate change.

<u>Autonomous adaptation [Sec 4.2.4.1, page 63]</u>

1. Options for autonomous adaptation are largely extensions or intensifications of existing risk management and production enhancement activities, and are therefore already available to farmers and communities. These include, with respect to water:
    - heat shock and drought;
    - modification of irrigation techniques, including amount, timing or technology;
    - adoption of water-efficient technologies to 'harvest' water, conserve soil moisture (e.g. crop residue retention), and reduce siltation and saltwater intrusion;
    - improved water management to prevent waterlogging, erosion and leaching;
    - modification of crop calendars, i.e. timing or location of cropping activities;
    - implementation of seasonal climate forecasting.
2. Additional adaptation strategies may involve land-use changes that take advantage of modified agro-climatic conditions.
3. A few simulation studies show the importance of irrigation water as an adaptation technique to reduce climate change impacts. In general, however, projections suggest that the greatest relative benefit from adaptation is to be gained under conditions of low to moderate warming, and that adaptation practices that involve increased irrigation water use may in fact place additional stress on water and environmental resources as warming and evaporative demand increase.
4. Many adaptation strategies in key production sectors other than crop agriculture have also been explored, although, without a direct focus on water issues.
5. Adaptation strategies that may nonetheless affect water use include, for livestock systems, altered rotation of pastures, modification of times of grazing, alteration of forage and animal species/breeds, altered integration within mixed livestock/crop systems, including the use of adapted forage crops, care to ensure adequate water supplies, and the use of supplementary feeds and concentrates.
6. Adaptation strategies for forestry may include changes in management intensity, species mix, rotation periods, adjusting to altered wood size and quality, and adjusting fire management systems.
7. With respect to marine ecosystems, with the exception of aquaculture and some freshwater fisheries, the exploitation of natural fish populations precludes the kind of management adaptations to climate change suggested for the crop, livestock and forest sectors. Adaptation options thus centre on altering catch

size and effort. The scope for autonomous adaptation is increasingly restricted as new regulations governing the exploitation of fisheries and marine ecosystems come into force.

8. If widely adopted, adaptation strategies in production systems have substantial potential to offset negative climate change impacts and take advantage of positive ones. However, there has been little evaluation of how effective and widely adopted these adaptations may be, given the complex nature of decision making; the diversity of responses across regions; time lags in implementation; and possible economic, institutional and cultural barriers to change.
9. For example, the realisable adaptive capacity of poor subsistence farming/herding communities is generally considered to be very low. Likewise, large areas of forests receive minimal direct human management, limiting adaptation opportunities. Even in more intensively managed forests, where adaptation activities may be more feasible, long time lags between planting and harvesting may complicate the adoption of effective adaptation strategies.

Planned adaptation [Sec 4.2.4.2, page 65]

1. In addition to techniques already available to farmers and land managers today, new technical options need to be made available through dedicated research and development efforts, to be planned and implemented now, in order to augment overall capacity to respond to climate change in future decades.
2. Technological options for enhanced R&D include traditional breeding and biotechnology for improved resistance to climate stresses such as drought and flooding in crop, forage, livestock, forest and fisheries species.

Food security and vulnerability [Sec 4.2.4.3, page 65]

1. All four dimensions of food security: namely, food availability (production and trade), access to food, stability of food supplies, and food utilisation (the actual processes involved in the preparation and consumption of food), are likely to be affected by climate change.
2. Importantly, food security will depend not only on climate and socio-economic impacts on food production, but also (and critically so) on changes to trade flows, stocks, and food aid policy.
3. In particular, climate change will result in mixed and geographically varying impacts on food production and, thus, access to food. Tropical developing countries, many of which have poor land and water resources and already face serious food insecurity, may be particularly vulnerable to climate change.
4. Changes in the frequency and intensity of droughts and flooding will affect the stability of, and access to, critical food supplies. Rainfall deficits can

dramatically reduce both crop yields and livestock numbers in the semi-arid tropics. Food insecurity and loss of livelihood would be further exacerbated by the loss of both cultivated land and coastal fish nurseries as a result of inundation and coastal erosion in low-lying areas.

5. Climate change may also affect food utilisation through impacts on environmental resources, with important additional health consequences. For example, decreased water availability in already water-scarce regions, particularly in the subtropics, has direct negative implications for both food processing and consumption.
6. Conversely, the increased risk of flooding of human settlements in coastal areas from both rising sea levels and increased heavy precipitation may increase food contamination and disease, reducing consumption patterns.

<u>Water quality issues [Sec 4.2.4.4, page 66]</u>

1. In developing countries, the microbiological quality of water is poor because of the lack of sanitation, lack of proper treatment methods, and poor health conditions. Climate change may impose additional stresses on water quality, especially in developing countries. As yet there are no studies focusing on micro-organism life cycles relevant to developing countries under climate change, including a much-needed focus on the effects of poorly treated wastewater use for irrigation and its links to endemic outbreaks of helminthiasis.
2. About 10% of the world's population consumes crops irrigated with untreated or poorly treated wastewater, mostly in developing countries in Africa, Asia and Latin America. This number is projected to grow with population and food demand.
3. Increased use of properly treated wastewater for irrigation is therefore a strategy to combat both water scarcity and some related health problems.

<u>Rural communities, sustainable development and water conflicts [Sec 4.2.4.5, page 66]</u>

1. Transboundary water co-operation is recognised as an effective policy and management tool to improve water management across large regions sharing common resources.
2. Climate change and increased water demand in future decades will represent an added challenge to such framework agreements, increasing the potential for conflict at the local level. For instance, unilateral measures for adapting to climate-change-related water shortages can lead to increased competition for water resources.
3. Furthermore, shifts in land productivity may lead to a range of new or modified agricultural systems, necessary to maintain production, including

intensification practices. The latter, in turn, can lead to additional environmental pressures, resulting in loss of habitat and reduced biodiversity, siltation, soil erosion and soil degradation.

4. Impacts on trade, economic, and environmental development and land use may also be expected from measures implemented to substitute fossil fuels through biofuels, such as by the European Biomass Action Plan. Large-scale biofuel production raises questions on several issues including fertiliser and pesticide requirements, nutrient cycling, energy balance, biodiversity impacts, hydrology and erosion, conflicts with food production, and the level of financial subsidies required.
5. In fact, the emerging challenges of future decades include finding balance in the competition for land and raw materials for the food, forestry and energy sectors, e.g. devising solutions that ensure food and local rural development rights while maximising energy and climate mitigation needs.
6. Fish, an important source of food protein, is critical to food security in many countries of Asia, particularly among poor communities in coastal areas. Fish farming requires land and water, two resources that are already in short supply in many countries in Asia. Water diversion for shrimp ponds has lowered groundwater levels noticeably in coastal areas of Thailand.
7. At least 14 major international river watersheds exist in Asia. Watershed management is challenging in countries with high population density, which are often responsible for the use of even the most fragile and unsuitable areas in the watersheds for cultivation, residential, and other in Philippines, Indonesia and Vietnam, many watersheds suffer badly from deforestation, indiscriminate land conversion, excessive soil erosion and declining land productivity. In the absence of appropriate adaptation strategies, these watersheds are highly vulnerable to climate change.

Mitigation [Sec 4.2.4.6, page 67]

1. Adaptation responses and mitigation actions may occur simultaneously in the agricultural and forestry sector; their efficacy will depend on the patterns of realised climate change in the coming decades. The associated interactions between these factors (climate change, adaptation and mitigation) will frequently involve water resources.
2. Adaptation and mitigation strategies may either exhibit synergies, where both actions reinforce each other, or be mutually counter-productive. With respect to water, examples of adaptation strategies that reduce mitigation options largely involve irrigation, in relation to the energy costs of delivering water and the additional greenhouse gas emissions that may be associated with modified cultivation practices.
3. Using renewables for water extraction and delivery could, however, eliminate such conflict. Likewise, some mitigation strategies may have negative

adaptation consequences, such as increasing dependence on energy crops, which may compete for water resources, reduce biodiversity, and thus increase vulnerability to climatic extremes.

4. On the other hand, many carbon-sequestration practices involving reduced tillage, increased crop cover and use of improved rotation systems, in essence constitute – and were in fact originally developed as – 'good-practice' agro-forestry, leading to production systems that are more resilient to climate variability, thus providing good adaptation in the face of increased pressure on water and soil resources.

2.2.2 Stern Review: The Economics of Climate Change (2006) (Stern Review)

The following are the key observations and recommendations extracted from the Stern Review report that address this issue.

Agriculture & Irrigation Water Supply [Page 410]

2.1 In agriculture, adaptation responses could be even more diverse, ranging from low-cost farm-level actions – such as choice of crop variety, changes in the planting date, and local irrigation – to economy-wide adjustments – including availability of new cultivars, large-scale expansion of irrigation in areas previously only rain-fed, widespread fertiliser application, regional/national shifts in planting date.

2.2 Some studies suggest that relatively simple and low-cost adaptive measures, such as change in planting date and increased irrigation, could reduce yield losses by at least 30 - 60% compared with no adaptation.

2.3 But adaptation gains will be realised only by individuals or economies with the capacity to undertake such adjustments. The costs of implementing adaptation, particularly the transition and learning costs associated with changes in farming regime, have not been clearly evaluated.

2.2.3 The Economics of Climate Change in South East Asia: A Regional Review (2009) (ECC-SEA)

The following are the key observations and recommendations extracted from the ADB Review report that address this issue.

Figure A8.3 shows a table summarizing the key adaptations in the agriculture sector. [page 105]

Table 6.6. Summary of Key Adaptation Options in Agriculture Sector				
Practice	Scale	Reactive/Proactive	Planned/Autonomous	Example
Adjustment of cropping calendar and pattern	Local	Reactive	Autonomous	Widely used
Changes in management and farming techniques	Local	Reactive	Autonomous	Widely used
Use of heat-resistant varieties	Local/Sub-regional	Proactive	Autonomous	Widely used
Diversified farming, inter-cropping, crop rotation	Local	Proactive	Autonomous	Widely used
Utilization of SOI in designing cropping strategy	Local/Sub-regional	Proactive	Planned	Indonesia
Implementation of index-based insurance	Local/ Regional	Proactive	Planned	Thailand, Viet Nam
Development of early warning systems	Local/ Regional	Proactive	Planned	Philippines, Thailand, Viet Nam
Improvement of irrigation efficiency	Local	Reactive	Planned	Viet Nam

SOI = Southern Oscillation Index.
Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

Figure A8.3 Summary of key adaptations in the agriculture sector (ADB Review report).

3. Hydropower

3.1 *National Documents*

3.1.1 National Policy on Climate Change (2009) (NPCC) Extracts

The following are the Key Actions (KA) associated with the Strategic Thrusts (ST) in the NPCC related to the technical management of hydropower.

(a) **KA19 - ST5**: Promote RE and EE for power generation through:

- Burden sharing between government and power producers;
- Establishment of EE and RE targets/standards;
- Inclusion of RE in generation mix by power producers; and
- Promotion of RE generation by small and independent developers including local communities.

(b) **KA23 - ST5**: Empower local communities in basic Renewal Energy maintenance, especially in rural electrification including mini and micro hydroelectric schemes.

3.1.2 Tenth Malaysia Plan (2010-2014) (RMK10) Extracts

The following are the relevant extracts from RMK10 related to the technical management of hydropower.

(a) RMK10: Ensuring Effective Sourcing and Delivery of Energy [page 112]
Energy security will be enhanced through the development of alternative resources, particularly hydro as well as importation of coal and liquefied natural gas (LNG) by 2015.

(b) RMK10: Sarawak Corridor Renewable Energy [page 120]
The Sarawak Corridor Renewable Energy (SCORE) is located within the Central Region of Sarawak. The core of the Corridor is its energy resources, particularly hydropower, of 28,000 MW. This allows Sarawak to price its energy competitively and encourages investments in power generation and energy-intensive industries.

(c) RMK10: Increasing and Diversifying Generation Capacity [page 287]
The development of alternative sources of energy, particularly hydro as well as importation of coal and liquefied natural gas (LNG) by 2015 will improve security of supply.

3.1.3 National Physical Plan (2005) (NPP) Extracts

The following are the relevant extracts from the NPP related to the technical management of hydropower.

(a) Hydropower
The NPP2005 highlighted the need to reduce use of fossil fuels, and to utilise Renewable Energy (RE) solution and Energy Efficiency (EE). The target is to achieve use of RE from the present 0.5% to 5.0% of generation mix by 2005. As for EE the target is to improve use by about 10.0%, which will result in a savings of RM1.0 billion by 2005. Thus, the development of hydropower as a renewable energy resource has to be considered as part of the solution.

3.1.4 Second National Communications to UNFCCC (2010) (NC2) Extracts

The following are the relevant synthesized points extracted from the NC2 report related to the technical management of hydropower.

(a) Hydropower
Hydropower generation capacity will be impacted by reduced rainfall if there are insufficient amounts for generation. One of the adaptation measures proposed is medium term and long term catchment management programmes for hydropower stations. Another is to promote the national implementation of grid connected rooftop solar panels to reduce disruption risks and ease hydropower capacity requirements.

(b) Navigation

Changes in river flows due to more extreme rainfall patterns as well as increased frequency of extreme weather such as storms can affect the navigability of water bodies such as rivers and lakes. This can result in reduced navigability of water bodies which are used as primary modes of transportation both of people and for trade and communication purposes in some parts of the country, especially in East Malaysia. Cargo transportation such as timber can also be affected with sedimentation at river mouths.

3.2 *International Documents*

3.2.1 IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)

(a) IPCC-CC & Water Report — Executive Summary

The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

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Point 9 — Climate change affects the function and operation of existing water infrastructure – including hydropower, structural flood defences, drainage and irrigation systems – as well as water management practices.

1. Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation (very high confidence).
2. Globally, water demand will grow in the coming decades, primarily due to population growth and increasing affluence; regionally, large changes in irrigation water demand as a result of climate change are expected (high confidence).

Point 13 — Mitigation measures can reduce the magnitude of impacts of global warming on water resources, in turn reducing adaptation needs.

1. However, they can have considerable negative side effects, such as increased water requirements for afforestation/reforestation activities or bio-energy crops, if projects are not sustainably located, designed and managed.
2. On the other hand, water management policy measures, e.g. hydrodams, can influence greenhouse gas emissions. Hydrodams are a source of renewable energy. Nevertheless, they produce greenhouse gas emissions themselves. The magnitude of these emissions depends on specific circumstance and mode of operation.

(b) IPCC-CC & Water — Main Report
The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

4. River Navigation

4.1 *IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)*

(a) IPCC-CC & Water Report — Executive Summary
The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

(b) IPCC-CC & Water — Main Report
The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

5. Fisheries

5.1 *IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)*

(a) IPCC-CC & Water Report — Executive Summary
The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

(b) IPCC-CC & Water — Main Report
The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

6. Water Ecosystems

6.1 *National Documents*

6.1.1 National Policy on Climate Change (2009) (NPCC) Extracts

The following are the Key Actions (KA) associated with the Strategic Thrusts (ST) in the NPCC related to the technical management of water ecosystem.

(a) **KA15 - ST4**: Conserve and enrich carbon pools in natural ecosystems including plantations and promote rehabilitation of sensitive and degraded ecosystems through sound management practices and land use planning.

(b) **KA16 - ST4**: Identify and recognise the attribute and value of ecosystem services and integrate into the development planning process.
(c) **KA17 - ST4**: Develop national carbon accounting systems and baseline studies of forest ecosystems.

6.1.2 Tenth Malaysia Plan (2010-2014) (RMK10) Extracts

The following are the relevant extracts from RMK10 related to the technical management of water ecosystem.

(a) RMK10: Valuing the Nation's Environmental Endowments [page 297]
From our coastal areas and rivers, our islands and highlands, our forests and the air that we breathe, healthy ecosystems are a key determinant of our physical and economic well-being. Currently, Malaysia ranks 54 out of 163 countries under the Environmental Performance Index that measures and ranks the environmental performance of countries, as developed by Yale and Columbia University.

Moving forward, Malaysia's agenda will be one of protecting the environmental quality of life, caring for the planet, while harnessing economic value from the process. In achieving this, among others, the Government will be guided by sustainable production practices to decouple economic growth from environmental degradation. It will be guided by the view that environmental sustainability is not only about saving the planet, but also about developing business models to compete sustainably in the global economy and in building values in ways that help address some of the world's most profound social, economic and environmental challenges".

(b) RMK10: Conserving Forests [page 305]
Deforestation is considered as the second most important human-induced source of GHGs and is responsible for approximately 20% of total global emissions. At present, more than 55% of land area in Malaysia is covered with forests. Malaysia has long practiced sustainable forest management in utilising its resources, and at the same time, ensures these forests continue to function as carbon sinks.

During the Tenth Plan period, further initiatives will be undertaken to encourage States to gazette forests, especially the water catchment areas, as protected areas. In addition, the Government with the participation of the private sector, non-government organisations (NGOs) and the public at large will continue its efforts in planting more trees to green the country.

(c) RMK10: Enhancing Forest and Wildlife Conservation Efforts [page 306]
During the Plan period, efforts to protect biodiversity and habitats will be strengthened with the implementation of the Central Forest Spine of 4.32 million hectares in Peninsular Malaysia and the Heart of Borneo of 6.0 million hectares in Sabah and Sarawak. The establishment of ecological linkages within these areas will reconnect fragmented forest complexes to allow for the movement of wildlife and biological processes and reduce conflicts between humans and wildlife. These areas will also serve as biodiversity reservoirs and watershed areas, with potential to be developed for eco-tourism. These areas will be classified as Environmentally Sensitive Areas, where limited or no development will be permitted.

6.1.3 National Biodiversity Policy (1998) (NBP) Extracts

The following are the relevant extracts from the NBP related to the technical management of water ecosystem.

(a) Strategy 5 — Strengthen and Integrate Conservation Programmes
Increase efforts to strengthen and integrate conservation programmes.

(b) Strategy 6 — Integrate Biological Diversity Considerations into Sectoral Planning Strategies
Ensure that all major sectoral planning and development activities incorporate considerations of biological diversity management.

6.1.4 National Physical Plan (2005) (NPP) Extracts

The following are the relevant extracts from the NPP related to the technical management of water ecosystem.

(a) Environmentally Sensitive Areas
The NPP2005 has identified and categorised 3 types of Enviromentally Sensitive Areas (ESA) in Peninsular Malaysia. The ESA will be affected by climate change and thus there is a need to include them in any climate change adaptation plans. The 3 ESA categories are as follows and their locations are as shown in the map below:

- **ESA Rank 1** — No development, agriculture or logging shall be permitted except for low-impact nature tourism, research and education.
- **ESA Rank 2** — No development or agriculture. Sustainable logging and low impact nature tourism may be permitted subject to local constraints.
- **ESA Rank 3** — Controlled development where the type and intensity of the development shall be strictly controlled depending on the nature of the constraints.

6.1.5 New Economic Model for Malaysia (2009) (NEM) Extracts

The following are the relevant extracts from the NEM related to the technical management of water ecosystem.

(a) NEM Chapter 3 — What's happening around us?
In Chapter 3 on What's happening around us?, Section 3.3 entitled "Malaysia should lead the global green revolution" describes the abundance of natural resources we are endowed with giving us a strategic advantage. Although the economic advantage this provides is big, the greater benefit is articulated as follows:

"The major benefit of our green, high income, and inclusive strategy is that future generations of Malaysians (and world citizens) will continue to enjoy the clean air and water, and natural environment that they deserve and work so hard to preserve and enhance. Malaysians can feel proud that we are setting the pace in treasuring our heritage and delicate ecology for the mutual benefit of all mankind." [Chap 3, NEM, page 70]

6.1.6 Second National Communications to UNFCCC (2010) (NC2) Extracts

The following are the relevant synthesized points extracted from the NC2 report related to the technical management of water ecosystem.

(a) Fisheries
This component has not been considered in NC2 apart from the potential impacts on coastal aquaculture activities as mentioned above.

Studies should be undertaken to better understand the impact to fresh water fisheries resulting from climate change impacts to water bodies. At the same time, a holistic approach should be taken to ensure that climate change vulnerabilities are not further aggravated by other stressors such as over fishing and pollution.

6.2 *International Documents*

6.2.1 IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)

(a) IPCC-CC & Water Report — Executive Summary
The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

Point 6 — Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution

1. Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution – from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution, with <u>possible negative impacts on ecosystems</u>, human health, and water system reliability and operating costs (high confidence).
2. In addition, sea-level rise is projected to extend areas of salinisation of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and <u>ecosystems in coastal areas</u>.

(b) <u>IPCC-CC & Water — Main Report</u>
The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

<u>Ecosystems and biodiversity [Sec 4.1, Page 55]</u>

1. Temperature and moisture regimes are among the key variables that determine the distribution, growth and productivity, and reproduction of plants and animals.
2. Changes in hydrology can influence species in a variety of ways, but the most completely understood processes are those that link moisture availability with intrinsic thresholds that govern metabolic and reproductive processes.
3. The changes in climate that are anticipated in the coming decades will have diverse effects on moisture availability, ranging from alterations in the timing and volume of streamflow to the lowering of water levels in many wetlands, the expansion of thermokarst lakes in the Arctic, and a decline in mist water availability in tropical mountain forests.
   Impacts of changes in hydrology on major ecosystem types [Sec 4.1.3, page 55]
   Lakes and streams (Sec 4.1.3.1, page 55]
4. Impacts of global warming on lakes include an extended growing period at high latitudes, intensified stratification and nutrient loss from surface waters, decreased hypolimnetic oxygen (below the thermocline) in deep, stratified lakes, and expansion in range for many invasive aquatic weeds.
5. Water levels are expected to increase in lakes at high latitudes, where climate models indicate increased precipitation, while water levels at mid- and low latitudes are projected to decline.
6. Endorheic (terminal or closed) lakes are most vulnerable to a change in climate because of their sensitivity to changes in the balance of inflows and

evaporation. Changes in inflows to such lakes can have very substantial effects and, under some climatic conditions, they may disappear entirely.

7. A unit increase in temperature in tropical lakes causes a proportionately higher density differential as compared with colder temperate lakes. Thus, projected tropical temperatures will lead to strong thermal stratification, causing anoxia in deep layers of lakes and nutrient depletion in shallow lake waters. Reduced oxygen concentrations will generally reduce aquatic species diversity, especially in cases where water quality is impaired by eutrophication.
8. Effects of warming on riverine systems may be strongest in humid regions, where flows are less variable and biological interactions control the abundance of organisms. Drying of stream-beds and lakes for extended periods could reduce ecosystem productivity because of the restriction on aquatic habitat, combined with lowered water quality via increased oxygen deficits and pollutant concentrations.

Freshwater Wetlands [Sec 4.1.3.2, page 56]

1. Climate change will have its most pronounced effects on inland freshwater wetlands through altered precipitation and more frequent or intense disturbance events (droughts, storms, floods). Relatively small increases in precipitation variability can significantly affect wetland plants and animals at different stages of their life cycle.
2. Generally, climatic warming is expected to start a drying trend in wetland ecosystems. This largely indirect influence of climate change, leading to alterations in the water level, would be the main agent in wetland ecosystem change and would overshadow the impacts of rising temperature and longer growing seasons in boreal and sub-Arctic peatlands. Monsoonal areas are more likely to be affected by more intense rain events over shorter rainy seasons, exacerbating flooding and erosion in catchments and the wetlands themselves.
3. Most wetland processes are dependent on catchment-level hydrology, which can be altered by changes in land use as well as surface water resource management practices.
4. Recharge of local and regional groundwater systems, the position of the wetland relative to the local topography, and the gradient of larger regional groundwater systems are also critical factors in determining the variability and stability of moisture storage in wetlands in climatic zones where precipitation does not greatly exceed evaporation.
5. Changes in recharge external to the wetland may be as important to the fate of the wetland under changing climatic conditions, as are the changes in direct precipitation and evaporation on the wetland itself. Thus, it may be very difficult, if not impossible, to adapt to the consequences of projected changes in water availability.

6. Due, in part, to their limited capacity for adaptation, wetlands are considered to be among the ecosystems most vulnerable to climate change. Wetlands are often biodiversity hotspots. Many have world conservation status. Their loss could lead to significant extinctions, especially among amphibians and aquatic reptiles.
7. The seasonal migration patterns and routes of many wetland species will have to change; otherwise some species will be threatened with extinction. For key habitats, small-scale restoration may be possible, if sufficient water is available.

Coasts and Estuaries [Sec 4.1.3.3, page 57]

1. Changes in the timing and volume of freshwater runoff will affect salinity, sediment and nutrient availability, and moisture regimes in coastal ecosystems. Climate change can affect each of these variables by altering precipitation and locally driven runoff or, more importantly, runoff from watersheds that drain into the coastal zone.
2. Hydrology has a strong influence on the distribution of coastal wetland plant communities, which typically grade inland from salt, to brackish, to freshwater species.
3. The natural ecosystems within watersheds have been fragmented and the downstream flow of water, sediment and nutrients to the coast has been disrupted. Land-use change and hydrological modifications have had downstream impacts, in addition to localised influences, including human development on the coast.
4. If river discharge decreases, the salinity of coastal estuaries and wetlands is expected to increase and the amount of sediments and nutrients delivered to the coast to decrease. In coastal areas where streamflow decreases, salinity will tend to advance upstream, thereby altering the zonation of plant and animal species as well as the availability of freshwater for human use.
5. Deltaic coasts are particularly vulnerable to changes in runoff and sediment transport, which affect the ability of a delta to cope with the physical impacts of climatic change. In Asia, where human activities have led to increased sediment loads of major rivers in the past, the construction of upstream dams is now depleting the supply of sediments to many deltas, with increased coastal erosion becoming a widespread consequence.
6. Some of the greatest potential impacts of climate change on estuaries may result from changes in physical mixing characteristics caused by changes in freshwater runoff. Freshwater inflows into estuaries influence water residence time, nutrient delivery, vertical stratification, salinity, and control of phytoplankton growth rates.
7. Changes in river discharges into shallow near-shore marine environments will lead to changes in turbidity, salinity, stratification and nutrient availability.

Mountain Ecosystems [Sec 4.1.3.4, page 58]

1. The zonation of ecosystems along mountain gradients is mediated by temperature and soil moisture. Recent studies have shown the disproportionate risk of extinctions in mountain ecosystems and, in particular, among endemic species.
2. Many species of amphibians, small mammals, fish, birds and plants are highly vulnerable to the ongoing and projected changes in climate that alter their highly specialised mountain niche.

Forests, Savannas and Grasslands [Sec 4.1.3.5, page 58]

1. The availability of water is a key factor in the restructuring of forest and grassland systems as the climate warms. Climate change is known to alter the likelihood of increased wildfire size and frequency, while also inducing stress in trees, which indirectly exacerbates the effects of these disturbances. Many forest ecosystems in the tropics, high latitudes and high altitudes are becoming increasingly susceptible to drought and associated changes in fire, pests and diseases.
2. Effects of drought on forests include mortality due to disease, drought stress and pests; a reduction in resilience; and biotic feedbacks that vary from site to site. In some regions, forests are projected to replace other vegetation types, such as tundra and grasslands, and the availability of water can be just as important as temperature and CO2-enrichment effects on photosynthesis.

6.2.2 Stern Review: The Economics of Climate Change (2006) (Stern Review)

The following are the key observations and recommendations extracted from the Stern Review report that address this issue.

Water Ecosystem [page 422]

1. Protecting natural systems could prove particularly challenging. The impacts of climate change on species and biodiversity are expected to be harmful for most levels of warming, because of the limited ability of plants and animals to migrate fast enough to new areas with suitable climate.
2. In addition, the effects of urbanisation, barriers to migration paths, and fragmentation of the landscape also severely limit species' ability to move. For those species that can move rapidly in line with the changing climate, finding new food and suitable living conditions could prove challenging.
3. Climate change will require nature conservation efforts to extend out from the current approach of fixed protected areas. Conservation efforts will increasingly be required to operate at the landscape scale with larger contiguous tracts of land that

can better accommodate species movement. Policies for nature protection should be sufficiently flexible to allow for species' movement across the landscape, through a variety of measures to reduce the fragmentation of the landscape and make the intervening countryside more permeable to wildlife, for example use of wildlife corridors or "biodiversity islands".

Appendix 9 — Selected Extracts on "Water Management Issue" from key National and International documents.

This appendix presents a compilation of the relevant national actions that have been identified by our national policy makers and technical managers on the water management issue to address the potential climate change impacts on water and the adaptation measures that need to be taken. It also presents the international scenarios on the issue, and in particular, highlights the key recommendations from the IPCC Technical Paper VI on Climate Change on Water (2008), the Stern Review on the Economics of Climate Change (2006) and the report on "The Economics of Climate Change in Southeast Asia: A Regional Review" (2009) by ADB. Some selected examples of international best practices that have been taken to address the issue are also given.

The national actions that have been identified by our national policy makers and technical managers have been extracted from the following documents.

- National Policy on Climate Change (2009) – (NPCC)
- Tenth Malaysia Plan (2010-2014) – (RMK10)
- National Biodiversity Policy (1998) – (NBP)
- National Physical Plan (2005) – (NPP)
- New Economic Model for Malaysia (2009) – (NEM)
- Second National Communication Report to the UNFCCC project (2010) (NC2)

The extracts have been organized under the following water management issues:

- Floods
- Water Pollution
- Water Scarcity/Drought
- Human Health

1. Floods

1.1 *National Documents*

1.1.1 Tenth Malaysia Plan (2010-2014) (RMK10) Extracts

The following are the relevant extracts from RMK10 related to the technical management of floods.

(a) RMK10: Open Spaces and Green Corridors [page 257]
This section is relevant as the network of interconnected green spaces within the cities can be zoned as flood protection zones if they are located in low-lying areas.

Local Plans will incorporate open space strategies that move beyond just allocating land for open space activities, to understanding how cities can enhance and attract people to these public spaces. In order to encourage the development of public spaces, the Government will support local authorities in creating a seamless network of interconnected green spaces within the cities, connecting major activity hubs and housing sites, and be equipped with facilities such as amphitheatres, cycling and pedestrian pathways and other amenities. Companies will be encouraged to provide support in the establishment and maintenance of green spaces as part of their corporate social responsibility programmes".

(b) RMK10: Waterfront Rejuvenation [page 257]
Many of the world's iconic cities share an important characteristic: a vibrant waterfront. The Thames River in London, the Esplanade in Singapore, the Cheong Gye Cheon in Seoul, Republic of Korea, these cities all have well-preserved waterfronts that are vibrant public spaces. In recognition of this, the restoration of rivers and waterfronts in Malaysian cities will be a priority.

(c) RMK10: Developing a Long-Term Strategy for Water Resource Management to Achieve Water Security [page 282]
Other measures to be implemented during the Plan period include expanding the implementation of the Integrated Water Resources Management and Integrated River Basin Management approaches in planning, managing, protecting and rehabilitating water resources. The Government will provide RM5 billion for flood mitigation programmes. This includes the application of the Integrated Flood Management approach to manage the risks of flood damage through forecasting and warning facilities as well as the development of disaster preparedness and community awareness programmes and flood hazard maps. In addition, research and development efforts will be intensified in area of conservation of water resources to support efforts to develop a sustainable water sector for the national economy.

1.1.2 National Physical Plan (2005) (NPP) Extracts

The following are the relevant extracts from the NPP related to the technical management of floods.

(a) Flood Prone Areas
The NPP has identified the flood prone areas in Peninsular Malaysia and has recommended that the flood prone areas adjacent to the main drains, streams and rivers be designated as drainage or river reserves. The NPP2005 recommended measures to address the flood issues are as follows:

1. Studies should be undertaken to evaluate the impact of flood frequency of main drain and river systems on human and economic activities.

2. Structure Plans and Local Plans shall incorporate adequate reserves for all main drains and rivers.
3. The Urban Storm Water Management (USWM) manual proposals shall be applied in all urban areas.
4. For rural areas and areas not subject to USWM proposals but subject to flooding appropriate flood mitigation measures shall be adopted.
5. To enhance the quality of urban life, the USWM retention system and riverbank system shall be integrated to create continuous urban parkway networks.
6. In conjunction with the implementation of the USWM proposals, measures such as the reuse and recycling of rainwater shall be developed and applied.

(b) Drainage

Under the NPP development strategy, drainage and flood mitigation programmes for the period up to 2020 are to address flood problems for the main conurbation areas of Kuala Lumpur, George Town, Johor Bahru and Kuantan.

The NPP2005 Study recommended that traditional flood mitigation approaches shall be integrated with source control measures based on Manual Saliran Mesra Alam (MASMA). Flood risk maps for Peninsular Malaysia are to be prepared to ensure that adequate provision and consideration is given to this aspect for future physical and land use planning exercises. To this end, contemporary approaches in flood mitigation based on preventive measures which centre on avoidance of flood prone areas for development are to apply.

An exception can be allowed for agricultural activities, for which a suitable risk must be factored in for flooding. The principle is to curb intrusion of urban uses into wetlands and flood plain areas that serve as natural flood storage facilities. This environment friendly policy promotes conservation of wetlands and their flora and fauna as well as provides regional level recreation facilities for urban residents.

1.1.3 Second National Communications to UNFCCC (2010) (NC2) Extracts

The following are the relevant synthesized points extracted from the NC2 report related to the technical management of floods.

(a) Water Management

The components of water management relate to water excesses (floods, increased rainfall and extreme weather), water scarcity (droughts), pollution of water supply and water bodies, physical changes to water bodies and competing use of water resources.

(b) Water excesses

With regard to this component, floods, increased rainfall and extreme weather are expected to occur more frequently and with greater intensity. Floods may occur in historically flood free areas. Soil saturation and nutrient leaching can also occur.

Water control structures like dams, barrages and bunds are vulnerable as they are likely to fail under these conditions given if their design specifications do not account for climate change impacts. For example, the NC2 reported that the Timah Tasoh dam had been upgraded recently. However the November 2010 floods resulted in breaching the dam alert levels requiring six sluice gates to be opened. State Agriculture Committee chairman Sabry Ahmad said Perlis would request RM300 million from the Federal Government to upgrade the dam to prevent floods. *(nst.com.my, 05/11/2010 Situation improves in Perlis but not Kedah[5])*.

Rainfed agriculture is also vulnerable. In terms of rice for example, a 15% increase in rainfall in the early growth stages could result in an 80% decrease in yield. Apart from food security being vulnerable, economic security is also vulnerable as yields of important crops to the economy like oil palm, rubber and cocoa will also be affected. These impacts will reduce the number of rubber tapping days and increase fungal incidence in cocoa. Additionally, if these anticipated impacts are not properly managed, soil erosion will be accelerated causing soil degradation and cause scouring of drainage structures affecting their efficacy in flood mitigation and sedimentation into rivers and reservoirs. Frequent and severe landslides are anticipated as is an increase in tree mortality.

All the impacts and vulnerabilities described above will naturally affect economic activities resulting from damage of power generation equipment, transmission pylons, roads, rail lines, bridges and fuel delivery systems. Public health is also vulnerable to these impacts with a possibility of increased breeding ground for malaria and dengue vectors and spread of water borne diseases.

Adaptation measures proposed include non-structural approaches such as improved rainfall and flood forecasting, implementing an effective disaster warning system and flood hazard mapping and reviewing flood management plans as part of a coordinated disaster prevention and management plan.

Design standards for flood risk management in all new structures such as water control, transportation, electrical, water and waste amenities should be reviewed and existing under designed structures should be retrofitted/reinforced.

For agriculture, R&D should be enhanced for flood resistant varieties while drainage should be designed to efficiently regulate water tables and prevent floods. Specific measures like low intensity tapping system and rain gutters for the rubber industry should be used in a more widespread manner.

In terms of public health, mapping of the malaria vector areas using remote sensing, providing wider access to malaria drugs and aedes proofing buildings

[5]http://www.nst.com.my/nst/articles/12rece/Article#ixzz14nJ6wyOz

through the review of building standards and guidelines to prevent/minimise rain water collection have been proposed.

Gaps identified include improving crop modeling projections with better local data on the projected magnitude of climate change, crop parameters and soil properties. R&D and funding are also necessary to establish baseline data on the effects of rainfall patterns on agricultural activities especially to ensure food security. Worker skills should be enhanced to be able to apply newer technologies such as low impact tapping.

Recommendations proposed include paying special attention to projections regarding maximum monthly rainfall as they can reveal the potential severity of floods and influence policy decisions to enhance management of available water. Additionally, it is recommended that research into innovative rainwater management to reduce floods, drought and other climate risks be undertaken.

The water management paradigm should also be changed from draining rainwater to collecting rainwater with multiple benefits (source of water, prevention of urban flooding, control on non-point source pollution, restoration of hydrological cycle, alleviation of urban heat islands, supplementing flows of urban streams, recreation/tourism).

1.2 *International Documents*

1.2.1 <u>IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)</u>

(a) <u>IPCC-CC & Water Report — Executive Summary</u>
The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

Point 4 — Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas.

1. The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) will be very likely to increase over most areas during the 21st century, with consequences for the risk of rain-generated floods.
2. At the same time, the proportion of land surface in extreme drought at any one time is projected to increase (likely), in addition to a tendency for drying in continental interiors during summer, especially in the sub-tropics, low and mid-latitudes.

Point 9 — Climate change affects the function and operation of existing water infrastructure — including hydropower, structural flood defences, drainage and irrigation systems — as well as water management practices.

1. Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation (very high confidence).
2. Globally, water demand will grow in the coming decades, primarily due to population growth and increasing affluence; regionally, large changes in irrigation water demand as a result of climate change are expected (high confidence).

<u>Changes in Hydrological Cycle</u>

Point 1 — Observed warming over several decades has been linked to changes in the large-scale hydrological cycle

1. Observed warming over several decades has been linked to changes in the large-scale hydrological cycle such as: increasing atmospheric water vapour content; changing precipitation patterns, intensity and extremes; reduced snow cover and widespread melting of ice; and changes in soil moisture and runoff. Precipitation changes show substantial spatial and inter-decadal variability.
2. Over the 20th century, precipitation has mostly increased over land in high northern latitudes, while decreases have dominated from 10°S to 30°N since the 1970s. The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) has increased over most areas (likely).
3. Globally, the area of land classified as very dry has more than doubled since the 1970s (likely). There have been significant decreases in water storage in mountain glaciers and Northern Hemisphere snow cover. Shifts in the amplitude and timing of runoff in glacier- and snowmelt-fed rivers, and in ice-related phenomena in rivers and lakes, have been observed (high confidence).

Point 11 — Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions.

1. The consequences of climate change may alter the reliability of current water management systems and water-related infrastructure. While quantitative projections of changes in precipitation, river flows and water levels at the river-basin scale are uncertain, it is very likely that hydrological characteristics will change in the future.
2. Adaptation procedures and risk management practices that incorporate projected hydrological changes with related uncertainties are being developed in some countries and regions.

(b) <u>IPCC-CC & Water — Main Report</u>
The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

Floods [Section 3.2.1.2, Page 41]

Heavy precipitation events are projected to become more frequent over most regions throughout the 21st century. This would affect the risk of flash flooding and urban flooding.

Floods [Sec 3.2.1.3, Page 42]

It is likely that the area affected by drought will increase. There is a tendency for drying of mid-continental areas during summer, indicating a greater risk of droughts in these regions.

Impacts of climate change on costs and other socio-economic aspects of freshwater [Sec 3.2.6, Page 46]

1. Climate change-induced changes in both the seasonal runoff regime and inter-annual runoff variability can be as important for water availability as changes in the long-term average annual runoff.

2. Future flood damages will depend greatly on settlement patterns, land-use decisions, the quality of flood forecasting, warning and response systems, and the value of structures and other property located in vulnerable areas, as well as on climatic changes per se, such as changes in the frequency of tropical cyclones.

3. The impact of climate change on flood damages can be projected, based on modelled changes in the recurrence interval of current 20- or 100-year floods and in conjunction with flood damages from current events as determined from stage-discharge relations and detailed property data.

4. Increased flood periods in the future would disrupt navigation more often, and low flow conditions that restrict the loading of ships may increase.

5. Climate-change is likely to alter river discharge, resulting in important impacts on water availability for in-stream usage, particularly hydropower generation.

Disasters, including wind storms and floods [Sec 4.3.1.2, page 68]

1. Floods have a considerable impact on health both in terms of number of deaths and disease burden, and also in terms of damage to the health infrastructure. While the risk of infectious disease following flooding is generally low in high-income countries, populations with poor infrastructure and high burdens of infectious disease often experience increased rates of diarrhoeal diseases after flood events.

2. There is increasing evidence of the impact that climate-related disasters have on mental health, with people who have suffered the effects of floods experiencing long-term anxiety and depression.

3. Flooding and heavy rainfall may lead to contamination of water with chemicals, heavy metals or other hazardous substances, either from storage or from chemicals already in the environment (e.g. pesticides). Increases in both population density and industrial development in areas subject to natural disasters increase both the probability of future disasters and the potential for mass human exposure to hazardous materials during these events.

2. Water Pollution

2.1 *National Documents*

2.1.1 Tenth Malaysia Plan (2010–2014) (RMK10) Extracts

The following are the relevant extracts from RMK10 related to the technical management of water pollution.

(a) RMK10: Protecting Rivers from Pollution [page 285]
Major sources of pollution include improper discharge from sewerage treatment plants, agro based factories, livestock farming, land clearing activities and domestic sewage. During the Plan period, measures to improve pollution control targeting these sources will be implemented through:

- *Strengthening the enforcement on industrial effluents and sewage discharge in line with the revisions to the regulations under the Environmental Quality Act 1974;*
- *Assessing the Total Maximum Daily Load and carrying capacity of rivers to determine allowable discharge loads, for both point and non-point sources of pollution;*
- *Revising the current Water Quality Index to incorporate additional parameters, such as biological parameters, for more accurate river water classification;*
- *Developing the National Marine Water Quality Index to replace the current Marine Water Quality Criteria and Standard, which was developed in 2008; and*
- *Expanding outreach and awareness programmes targeting various segments of society, such as the Langkawi Award, Rakan Alam Sekitar, Malaysia Environment Week, Promotion of Cleaner Production to Industries and Environmental Debate amongst higher institutions.*

2.1.2 National Physical Plan (2005) (NPP) Extracts

The following are the relevant extracts from the NPP related to the technical management of water pollution.

(a) Sewerage
The NPP2005 highlighted that there is a need for a major commitment to sewerage treatment to create world class cities. It highlighted that 13 sewerage projects comprising ten sewerage treatment plants and three central sludge treatment facilities have been planned to increase the sewerage services to 14.4 million people.

2.1.3 Second National Communications to UNFCCC (2010) (NC2) Extracts

The following are the relevant synthesized points extracted from the NC2 report related to the technical management of water pollution.

(a) Quality of water supply and water bodies
Water supply quality will deteriorate with climate change impacts such as floods, droughts and extreme weather patterns. This in turn will adversely affect public health and cause diseases like cholera to spread easily. Improved sanitation and coverage of safe water supply is proposed to reduce this impact.

(b) Physical changes to water bodies
The NC2 briefly considers potential changes to sea water such as temperature rise, change in salinity and PH. However, no analysis is reported for changes to fresh water bodies.

2.2 *International Documents*

2.2.1 IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)

(a) IPCC-CC & Water Report — Executive Summary
The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

Point 6 — Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution.

1. Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution – from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution, with possible negative impacts on ecosystems, human health, and water system reliability and operating costs (high confidence).
2. In addition, sea-level rise is projected to extend areas of salinisation of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas.

(b) IPCC-CC & Water — Main Report

The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

Water Quality [Sec 3.2.1.4, Page 43]

1. Higher water temperatures, increased precipitation intensity, and longer periods of low flows are projected to exacerbate many forms of water pollution, including sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt and thermal pollution. This will promote algal blooms and increase the bacterial and fungal content. This will, in turn, impact ecosystems, human health, and the reliability and operating costs of water systems.

2. Rising temperatures are likely to lower water quality in lakes through increased thermal stability and altered mixing patterns, resulting in reduced oxygen concentrations and an increased release of phosphorus from the sediments.

3. More intense rainfall will lead to an increase in suspended solids (turbidity) in lakes and reservoirs due to soil fluvial erosion and pollutants will be introduced. The projected increase in precipitation intensity is expected to lead to a deterioration of water quality, as it results in the enhanced transport of pathogens and other dissolved pollutants (e.g. pesticides) to surface waters and groundwater; and in increased erosion, which in turn leads to the mobilisation of adsorbed pollutants such as phosphorus and heavy metals.

4. More frequent heavy rainfall events will overload the capacity of sewer systems and water and wastewater treatment plants more often.

5. An increased occurrence of low flows will lead to decreased contaminant dilution capacity, and thus higher pollutant concentrations, including pathogens. In areas with overall decreased runoff (e.g. in many semi-arid areas), water quality deterioration will be even worse.

6. In coastal areas, rising sea levels may have negative effects on storm-water drainage and sewage disposal and increase the potential for the intrusion of saline water into fresh groundwater in coastal aquifers, thus adversely affecting groundwater resources.

Water Erosion & Sedimentation [Sec 3.2.1.5, Page 43]

All studies on soil erosion show that the expected increase in rainfall intensity would lead to greater rates of erosion.

3. Water Scarcity/Drought

3.1 *IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)*

(a) IPCC-CC & Water Report — Executive Summary
The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

(b) IPCC-CC & Water — Main Report
The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

4. Human Health

4.1 *IPCC Technical Paper VI — Climate Change & Water (2008) (IPCC-CC & Water Report)*

(a) IPCC-CC & Water Report — Executive Summary
The following are the key observations and recommendations extracted from the 15 points Executive Summary of the IPCC-CC & Water Report that addresses this issue.

(b) IPCC-CC & Water — Main Report
The following are the key observations and recommendations extracted from the IPCC-CC & Water Main Report that addresses this issue.

Human Health [Sec 4.3, Page 67]

1. Human health, incorporating physical, social and psychological well-being, depends on an adequate supply of potable water and a safe environment. Human beings are exposed to climate change directly through weather patterns (more

intense and frequent extreme events), and indirectly through changes in water, air, food quality and quantity, ecosystems, agriculture, livelihoods and infrastructure.

2. Due to the very large number of people that may be affected, malnutrition and water scarcity may be the most important health consequences of climate change. Population health has improved remarkably over the last 50 years, but substantial inequalities in health persist within and between countries.

3. The Millennium Development Goal (MDG) of reducing the mortality rate in children aged under 5 years old by two-thirds by 2015 is unlikely to be reached in some developing countries. Poor health increases vulnerability and reduces the capacity of individuals and groups to adapt to climate change. Populations with high rates of disease and disability cope less successfully with stresses of all kinds, including those related to climate change.

4. The World Health Organization (WHO) and UNICEF Joint Monitoring Programme currently estimates that 1.1 billion people (17% of the global population) lack access to water resources, where access is defined as the availability of at least 20 litres of water per person per day from an improved water source within a distance of 1 km. An improved water source is one that provides 'safe' water, such as a household connection or a bore hole. Nearly two-thirds of the people without access are in Asia.

5. The WHO estimates that the total burden of disease due to inadequate water supply, and poor sanitation and hygiene, is 1.7 million deaths per year. Health outcomes related to water supply and sanitation are a focal point of concern for climate change in many countries. In vulnerable regions, the concentration of risks from both food and water insecurity can make the impact of any weather extreme (for example, flood and drought) particularly severe for the households affected.

6. Changes in climate extremes have the potential to cause severe impacts on human health. Flooding is expected to become more severe with climate change, and this will have implications for human health. Vulnerability to flooding is reduced when the infrastructure is in place to remove solid waste, manage waste water, and supply potable water.

7. Lack of water for hygiene is currently responsible for a significant burden of disease worldwide. A small and unquantified proportion of this burden can be attributed to climate variability or climate extremes. 'Water scarcity' is associated with multiple adverse health outcomes, including diseases associated with water contaminated with faecal and other hazardous substances (e.g. parasites).

8. Climate change is expected to increase water scarcity, but it is difficult to assess what this means at the household level for the availability of water, and therefore for health and hygiene. There is a lack of information linking large scale modelling of climate change to small-scale impacts at the population or household level. Furthermore, any assessments of future health impacts via changes in water availability need to take into account future improvements in access to 'safe' water.

<u>Implications for drinking-water quality [Sec 4.3.1.1, page 67]</u>

6. The relationship between rainfall, river flow and contamination of the water supply is highly complex, as discussed below both for piped water supplies and for direct contact with surface waters. If river flows are reduced as a consequence of less rainfall, then their ability to dilute effluent is also reduced – leading to increased pathogen or chemical loading. This could represent an increase in human exposures or, in places with piped water supplies, an increased challenge to water treatment plants.

7. Drainage and storm water management is important in low income urban communities, as blocked drains can cause flooding and increased transmission of vector-borne diseases. Cities with combined sewer overflows can experience increased sewage contamination during flood events.

   In high-income countries, rainfall and runoff events may increase the total microbial load in watercourses and drinking water reservoirs, although the linkage to cases of human disease is less certain because the concentration of contaminants is diluted.

8. A significant proportion of notified water-borne disease outbreaks are related to heavy precipitation events, often in conjunction with treatment failures.

9. Freshwater harmful algal blooms (HABs) produce toxins that can cause human diseases. The occurrence of such blooms in surface waters (rives and lakes) may increase due to higher temperatures. However, the threat to human health is very low, as direct contact with blooms is generally restricted. There is a low risk of contamination of water supplies with algal toxins but the implications for human health are uncertain.

10. In areas with poor water supply infrastructure, the transmission of enteric pathogens peaks during the rainy season. In addition, higher temperatures were found to be associated with increased episodes of diarrhoeal disease. The underlying incidence of these diseases is associated with poor hygiene and lack of access to safe water.

Disasters, including wind storms and floods [Sec 4.3.1.2, page 68]

4. Floods have a considerable impact on health both in terms of number of deaths and disease burden, and also in terms of damage to the health infrastructure. While the risk of infectious disease following flooding is generally low in high-income countries, populations with poor infrastructure and high burdens of infectious disease often experience increased rates of diarrhoeal diseases after flood events.

5. There is increasing evidence of the impact that climate-related disasters have on mental health, with people who have suffered the effects of floods experiencing long-term anxiety and depression.

6. Flooding and heavy rainfall may lead to contamination of water with chemicals, heavy metals or other hazardous substances, either from storage or from chemicals already in the environment (e.g. pesticides). Increases in both population density and industrial development in areas subject to natural disasters increase both the probability of future disasters and the potential for mass human exposure to hazardous materials during these events.

Drought and infectious disease [Sec 4.3.1.3, page 68]

For a few infectious diseases, there is an established rainfall association that is not related to the consumption of drinking water (quality or quantity) or arthropod vectors.

Dust storms [Sec 4.3.1.4, page 68]

Windblown dust originating in desert regions of Africa, the Arabian Peninsula, Mongolia, central Asia and China can affect air quality and population health in distant areas. When compared with non-dust weather conditions, dust can carry large concentrations of respirable particles; trace elements that can affect human health; fungal spores; and bacteria.

Vector-borne diseases [Sec 4.3.1.5, page 68]

1. Climate influences the spatial distribution, intensity of transmission, and seasonality of diseases transmitted by vectors (e.g. malaria) and diseases that have water snails as an intermediate host (e.g. schistosomiasis). During droughts, mosquito activity is reduced but, if transmission drops significantly, the population of non-immune individuals may increase. In the long term, the incidence of mosquito-borne diseases such as malaria decreases because mosquito abundance is reduced, although epidemics may still occur when suitable climate conditions occur.

2. The distribution of schistosomiasis, a water-related parasitic disease with aquatic snails as intermediate hosts, is influenced by climate factors in some locations. Irrigation schemes have also been shown to increase the incidence of schistosomiasis, when appropriate control measures are not implemented.

4.2 *The Economics of Climate Change in South East Asia: A Regional Review (2009) (ECC-SEA)*

The following are the key observations and recommendations extracted from the ADB Review report that address this issue.

(a) Health Sector
Figure A9.1 shows a table summarizing the key adaptations in the health sector. [page 117].

Table 6.10. Summary of Key Adaptation Options in Health Sector

Practice	Scale	Reactive/ Proactive	Planned/ Autonomous	Example
Coordination with other groups	Local/Sub-regional	Reactive	Autonomous	Widely used
Rebuilding and maintaining public health infrastructure	Local	Reactive	Planned/ Autonomous	Widely used
Establish green, clean, and beautiful areas	Local	Reactive	Autonomous	Widely used
Enhancing short-range and long-range forecasting and warning systems and improved surveillance (e.g., risk indicators, infectious disease outbreaks, etc.)	Local/Sub-regional	Proactive	Planned	Used in some countries in the region
Education and awareness (public information drive, capacity building)	Local/Sub-regional	Proactive	Planned	Widely used
Enhanced infectious disease control programs (vaccines, vector control, case detection and treatment)	Local/Sub-regional	Proactive	Planned	Widely used
Disaster preparedness (climate-proofed housing design; etc.)	Local/Sub-regional	Proactive	Planned	Used in some countries in the region

Sources: Boer and Dewi (2008), Cuong (2008), Ho (2008), Jesdapipat (2008), Perez (2008).

Figure A9.1 Summary of key adaptations in the health sector (ADB Review report).

Appendix 10 — Summary of Gaps and Recommendations for the Governance and Institutional, Climate Projections and R&D, Information Management and Stakeholder Participation and Awareness Issues.

1. Governance and Institutional Capacity

The institutional framework has evolved considerably and the highest decision making body, the Green Technology and Climate Change Council (GTCCC), is chaired by the Prime Minister. The National Water Council, chaired by the Deputy Prime Minister and comprised of all the State Chief Ministers is the appropriate avenue to discuss and determine water related issues nationwide including climate change water related measures.

A decision making framework however is still lacking. A framework to cope with the challenges of decision making relating to climate change and water issues should be formulated. Such a framework should be structured to include the following elements:

a) Scenario planning
b) Adopting a "resilient adaptation" approach.
c) SWOC/T analysis of proposed adaptation strategies;
d) Commoner's Four Laws of Ecology[6] in considering any adaptation strategy; and
e) Prioritising adaptation action to be implemented

Furthermore, another gap is the lack of coordination and cohesiveness in the implementation of the numerous national plans and policies that already exist that can be used as tools in addressing climate change. The following are recommended:

a) <u>To prepare a comprehensive checklist of relevant policies/plans summarizing key sections for quick reference by decision makers.</u>
b) <u>To formulate a process to ensure that this checklist is regularly updated with newer policies/plans.</u>

2. Climate Change Projections and R&D Capacity

Malaysia has successfully downscaled the outputs of several climate models for several emissions scenarios. While this is a commendable advancement, there are nevertheless gaps as noted below:

(b) inherent uncertainty in downscaled projections especially for Malaysia given the limited number of models used;
(c) a low understanding of uncertainties and limitations of climate change projections and scenarios for effective communication to decision makers and end users;

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[6]Taken from Commoner's book entitled *The Closing Circle* (1971)

(d) lack of procedures and risk management practices in incorporating projected climate and hydrological changes with related uncertainties from fine grid regional HCMs into sector analysis;
(e) lack of application of the projection results in sector vulnerability analysis; and
(f) Lack of data in various aspects.

The recommendations to address these gaps can be summarized as follows:

a) Reduce the uncertainties in climate projections for Malaysia by increasing the number of GCM models and realizations and river based models with finer scale and temporal resolutions.
b) Improve baseline data collection
c) Set-up Early Warning Systems and Improved Monitoring Set-up

R&D with regard to climate change and water that has been undertaken in the country include:

- A National Coastal Vulnerability Index (NCVI) study has been commenced with the pilot phase being completed.
- Forest CO_2 flux observations and the importance of rainfall patterns on gas exchanges in tropical rainforests.
- Technology development to harness renewable energy from biomass, micro/pico hydro and oceans amongst others
- Biofuels from palm oil
- Relationship between rainfall and dengue transmission
- Potential causes of coral bleaching
- Systematic observation through a network of climate and hydrological monitoring stations including 3 Global Atmospheric Watch stations.

In addition, a study on the Economics of Climate Change for Malaysia is underway as well as a Roadmap towards achieving the aspirational goal of reducing the emissions intensity by 40% of 2005 levels by 2020.

The gaps that have been identified are:

a) limited long term historical data for hydrology and water resources and also that the number and frequency of hydrological and river flow data are still low.
b) water studies are sector specific for example relating to consumption, irrigation, industrial, non-consumptive uses and not done in a holistic manner to consider availability to meet all these different needs.
c) limited experimental data on the impact of climatic factors such as temperature and rainfall variability on agriculture,

d) lack of long-term tidal records for good local models on sea level rise, climate impact research on coral bleaching and potential increase in brackish water ecosystems due to SLR and its impact on the spatial distribution of malaria.
e) lack of analysis using an integrated approach such as on an ecosystem basis.
f) lack of funding or other incentives to promote natural science research.
g) lack of focus on research areas that could provide alternatives to or reduce the uncertainties of relying on modeling projections of future climate change such as baseline studies, threshold change levels, monitoring of thresholds, analyzing past events.
h) lack of vulnerability mapping and resilience mapping to assist in formulating adaptation strategies.

Recommendations in this regard are as follows:

a) Address the research gaps, advance capacity, update the national water resources study regarding annual rainfall and its distribution in terms of surface runoff, evapotranspiration and groundwater recharge, develop an integrated programme to research priority areas to address interdisciplinary concerns and inter-related sectors and adopt a holistic vulnerability and adaptation approach such as the ecosystem approach as identified in the NC2.
b) More funding should also be made available for natural science research.
c) Water experts should be involved in providing inputs for studies like the Economics of Climate Change and the Roadmap to achieve the 40% emissions intensity reduction target.
d) Undertake research that can reduce the inherent uncertainties in future climate modeling projections, supplement the projections or serve as an alternative means of climate projections. These include research on climate change warning indicators and collating data to enable forecasting by analogy.
e) Develop the information gathered on climate change into procedures and risk management practices for climate change and Vulnerability and Resilience Mappings to formulate robust adaptation measures.

3. Information Management Capacity

There is some collection of environmental, biodiversity and socio-economic data in Malaysia. However, they are ad hoc and there are limited standards for the observation and archiving of such data. Activities to increase awareness of communities to climate variability and climate change issues are also likewise limited.

The existing gaps in information management are:

a) Comprehensive standards for the observation and archiving of climate change related events.

b) Historical climate, water, and weather-related impact information, even information about recent impacts, are often neglected, even though such information could often provide context and guidance for present and future planning.

Recommendations in this regard are:

a) To enhance our National Climate Service to strengthen the production, availability, delivery and application of science-based climate predictions and services as well as coordinate climate information for government and stakeholders and climate research.
b) Set-up Sector-specific Water and Climate Change Information Management Units (WCC-IMU) by each water related agency/department to systematically collect, compile and manage their relevant data related to climate change.
c) Set-up a National Global Climate Observation System (GCOS) Committee as a means to enhance coordination between the different parties involved in observing and collecting information relating to climate change.
d) Set-up a National Water and Climate Change Information Repository to store all studies and information relating to climate change and water for Malaysia as well as an archive of all water related incidents, their socio-economic impact, their frequency and any mitigatory measures that have averted more severe consequences.
e) Publicise and disseminate climate information using new and traditional media as well as through collaboration with the arts community.

4. **Stakeholder Awareness and Participation**

Anecdotal evidence shows an increase in general public awareness and understanding. However, affected populations are still insufficiently informed. At the institutional level, gaps in technical understanding between the different agencies result in a time lag in decision making

The gaps include:

a) Different levels of awareness and understanding within and between ministries
b) Identifying strategic partnerships in undertaking adaptation action
c) Means to overcoming on the ground resistance to adaptation measures

Recommendations in this regard are:

a) Increase awareness within and between ministries. One way to do so would be to encourage knowledge sharing through learning platforms.
b) Stakeholders involved in disaster relief and risk reduction work are natural partners for climate adaptation as they have ground level knowledge and it is in their interest

to reduce/avert disasters. They should therefore be engaged to be involved in the adaptation process.

c) Community-level engagement should also be fostered in developing and implementing adaptation measures best suited to issues on the ground. Establishing climate change awareness forums starting at the community-level, and then replicating them all the way up to district, state and national levels should be considered following the model of the late Tun Abdul Razak's Operations Room in addressing rural development in the 70s. Risk assessment maps can be effectively used as a good visual aid to communicate disaster risks as well as the difference with adaptation measures being undertaken.

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